OIL AND GAS FOR THE 21ST CENTURY

STRATEGY DOCUMENT

OG21 – Norway's oil and gas technology strategy for the 21st century

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INTRODUCTION

Elisabeth B. Kvalheim

OG21's vision is to have a competitive Norwegian petroleum sector. To achieve this we need to maximize resource utilization, improve industry productivity, reduce cost and reduce greenhouse gas emissions. This is a challenging task, where utilization of technology and innovation will be key to success. The new OG21 strategy sets the direction for prioritization of technology development and gives recommendations for how to accelerate technology development and use.

Scientists, engineers and technology leaders in oil companies, universities, research institutes, supplier companies and governmental bodies have over the last 1.5 years worked on the new OG21 strategy, and agreed to common challenges and an aligned strategy on how technology can lift our competitiveness. All OG21 stakeholders have been invited to actively contribute and follow the revision process. I am glad to see that the industry has taken ownership of the strategy and contributed with valuable efforts. But this is only the first step. Now the strategy needs to be taken into our everyday work to realize the full potential bottom line effects. Public funded research programs need to be updated to reflect the recommendations in the new strategy, and industry enterprises should take guidance from the strategy in their technology programs.

OG21 have identified ten technology needs:

- Three linked to the industry's responsibility to reduce emissions.
- Two related to improved recovery and subsurface understanding.
- Three linked to improved efficiency and reduced costs.
- And two cross disciplinary topics: digitalization and technologies for the High North.

The Norwegian Petroleum Directorate estimates that more than 50 percent of the resources on the Norwegian continental shelf are still to be produced, thus there is a considerable potential for further resource utilization and value creation from our industry. OG21 has carried out value estimates of developing and adopting the technologies recommended in the strategy, and the estimates are impressive: It shows that improved technology and expertise can provide as much as 14 billion extra barrels of oil equivalents from the Norwegian continental shelf over the next decades.

Cooperation between all parties in the Norwegian petroleum industry is one of our competitive advantages. My goal is that this strategy will be useful for the entire industry, to inspire and help efficient development and implementation of new promising technologies. But remember, a strategy is only as good as its execution and the reward of technology is only harvested if it's implemented!

Many thanks for all efforts and good reading,

Elisabeth B. Kvalheim
OG21 Board Chair

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Photo: Shutterstock

01

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

→

Vega field
Illustration: Statoil

The petroleum industry is Norway's most important industry in terms of income to the state, employment, export of petroleum products and export of services and equipment to the global petroleum industry. The successful development of the Norwegian petroleum industry is founded on a skilled and competent workforce and the implementation of advanced technologies. The Norwegian continental shelf is today one of the most technologically sophisticated petroleum provinces in the world, and Norway based suppliers have become global leaders within many offshore petroleum segments.

It is likely that petroleum will continue to dominate the global energy mix for decades to come. Less than 50 percent of petroleum resources on the Norwegian continental shelf have been produced, and Norway is in a good position to supply petroleum to the global market also in the future.

New technologies and competencies to develop and adopt technologies will continue to be a key success factor in the further development of the Norwegian continental shelf and the Norway based supplier industry. In response to this, OG21 (Oil and gas for the 21st century) has developed a national technology strategy for Norway that guides technology and research efforts of the authorities and the industry. OG21 brings government, business and research environments together to identify technology challenges and agree on strategies to address the challenges. OG21 was established by the Ministry of Petroleum and Energy in 2001. Since the first version of the strategy in 2001, the document has been revised every 5 years, and it has been due for a new revision in 2016.

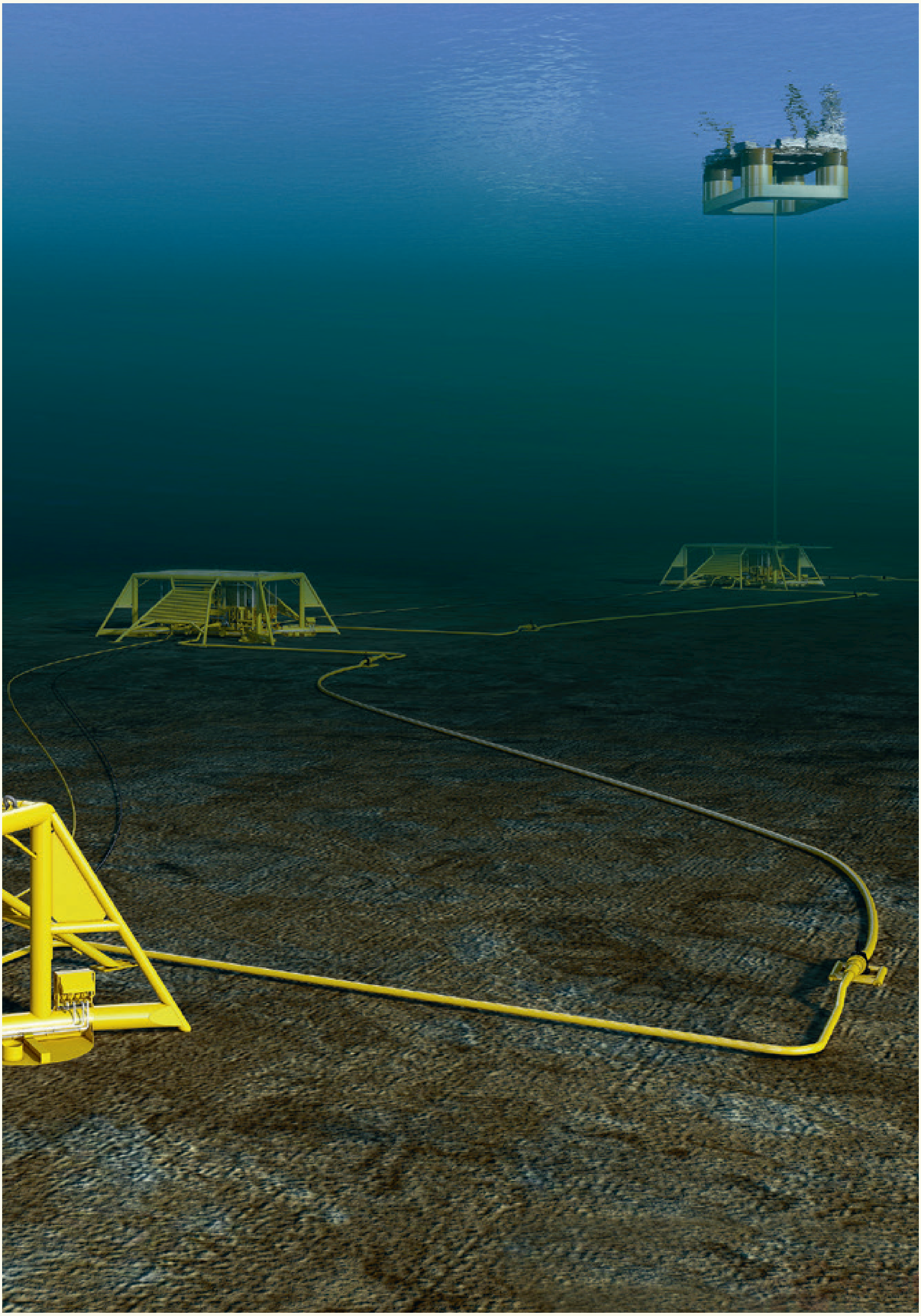
The OG21 strategy shall contribute to:

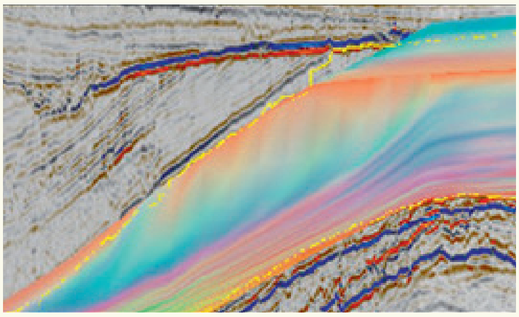
- Efficient and environmentally friendly value creation from the Norwegian continental shelf for several generations.
- Development of world class petroleum expertise and industry enterprises.

OG21'S VISION IS: TECHNOLOGIES AND INNOVATION FOR A COMPETITIVE NORWEGIAN PETROLEUM SECTOR.

The vision expresses a desire to secure the competitiveness of the Norwegian Continental Shelf and of the Norway based petroleum supplier industry by developing, implementing and adopting technologies. The vision is supported by five strategic objectives:

1. *Maximize resource utilization*
2. *Minimize environmental impact*
3. *Improve productivity and reduce costs*
4. *Develop innovative technologies*
5. *Attract, develop and retain the best talents*





Subsurface map generated with advanced seismic data interpretation software. Illustration: Schlumberger

The strategic objectives as well as related challenges and opportunities for the Norwegian petroleum sector, are outlined in Section 3 of the strategy document.

The main priorities of OG21 are reflected through the choice of Technology Target Areas (TTAs):

TTA1 Energy efficiency and environment
TTA2 Exploration and increased recovery
TTA3 Drilling, completions and intervention
TTA4 Production, processing and transport

Technology needs identified and prioritized through the TTAs are:

- Improved energy efficiency: Technologies contributing to more efficient energy production and less energy consumption.
- Zero carbon emissions: Technologies enabling renewable power supply to offshore facilities, electricity from shore, CO_2 storage, CO_2 use for enhanced recovery, and cost-efficient, de-carbonized hydrocarbon value chains.
- Protection of the external environment: Systems and technologies that reduce operational discharges and emissions, improve management of safety barriers and minimize impacts of accidental spills.
- Subsurface understanding: Technologies for better understanding of geology and reservoirs.
- Drilling efficiency and P&A: Technologies that reduce the overall work effort for well construction and well plugging, thereby lowering the costs of exploration and production wells as well as of plugging and abandonment (P&A).
- Production optimization: Processing, downhole and intervention technologies that increase the regularity, availability and productivity of wells and installations.
- Improved subsea and unmanned systems: Technologies that reduce development costs and increase the capabilities of subsea and unmanned production systems.
- Enhanced oil recovery: Offshore technologies that increase production of mobile oils and enable production of immobile oils.
- Digitalization: Enabling automation, autonomy and ICT-technologies for all petroleum industry disciplines. The technology needs reach across data acquisition, data management, data quality, data integration, decision support and data security.
- High North: Technologies that address particular challenges of the currently opened areas in the Norwegian parts of the Barents Sea, including shallow reservoirs, carbonates, long distances and logistics and protection of the environment.

A further detailing and prioritization of technology needs is provided in the strategy document under each Technology Target Area in Section 4.

The value of technologies is realized when technologies are applied or commercialized. Section 5 of this strategy document therefore includes discussions of drivers and barriers to technology development, adoption and implementation.

RECOMMENDATIONS ON ADDRESSING PRIORITIZED TECHNOLOGY NEEDS:
OG21 is of the opinion that the current organization and structure of the public funded innovation system works well for the petroleum industry, and should be continued. Public funded petroleum research programs should now be updated to reflect the prioritized technology needs and the recommendations of the revised OG21 strategy.

OG21 calls for a strengthening of public funding of petroleum research. Public funding of petroleum research offers high return to the society and is becoming increasingly more important as a result of more complex technology challenges on the Norwegian continental shelf. The Petromaks2 budget should be increased considerably over the 2017–2021 period, whereas the Demo2000 budget, which increased substantially from 2015 to 2016, should be maintained at the 2016 nominal level over the 2017–2021 period.

Petro Centers address topics of high strategic importance, and a new center on low emission petroleum technologies should be considered.

Petroleum industry enterprises, universities and research institutes should update their R&D and technology strategies to reflect the guidance in the revised OG21 strategy.

RECOMMENDATIONS ON HOW THE APPLICATION OF VALUE-ADDING TECHNOLOGIES COULD BE STIMULATED:
Barriers to technology adoption and implementation should be reduced. Authorities should look at incentives mechanisms to encourage the implementation of new technologies with high societal value.

The industry should continue its efforts on standardization to simplify implementation of new technologies and reduce unit costs.

Cross-disciplinary research that includes social sciences could be important to further understand drivers and barriers to technology development, adoption and implementation, and should be integrated in public funded petroleum research programs.

Cap X. Illustration: Statoil

Åsgard subsea gas compression. Photo: Aker Solutions

RECOMMENDATIONS ON ADDRESSING COMPETENCE NEEDS:
Learning from other industries and adopting solutions from other regions of the world would be an efficient approach to address many of the prioritized technology needs, and should be reflected in public and industry R&D and technology strategies and programs.

The petroleum industry has lost competence during the activity downturn in 2014–2016. A competence and organizational capability shortage could hit the petroleum industry when activities rebound. The industry needs to maintain core competencies and capacity throughout activity cycles.

The activity downturn has also reduced the industry's attractiveness to students and professionals. OG21 and industry organizations need to put special efforts into increasing students' interest for petroleum core subjects, and to attract professionals with digitalization, automation and ICT competencies.

Section 6 of the strategy document contains further details on the recommendations.

OG21 strategy implementation:

OG21 will communicate the strategy to its stakeholders through conferences, seminars and meetings. OG21 has well established connections with most stakeholder groups. These connections will be maintained. OG21 needs to strengthen its engagement with the supplier industry, and will leverage established industry clusters' networks to achieve this.

Implementation status is evaluated annually by the OG21 board. Topics that need further follow-up through deep dive studies or stakeholder engagement are included in the annual OG21 activity plans.

OG21 strategic recommendations and results from deep dive studies are presented and discussed at the annual OG21-forum, open to all interested stakeholders.

SUMMARIZED OVERVIEW OF THE OG21 STRATEGY:

VISION: TECHNOLOGIES AND INNOVATION FOR A COMPETITIVE NORWEGIAN PETROLEUM SECTOR

STRATEGIC OBJECTIVES:

- Maximize resource utilization
- Minimize environmental impact
- Improve productivity and reduce costs
- Develop innovative technologies
- Attract, develop and retain the best talents

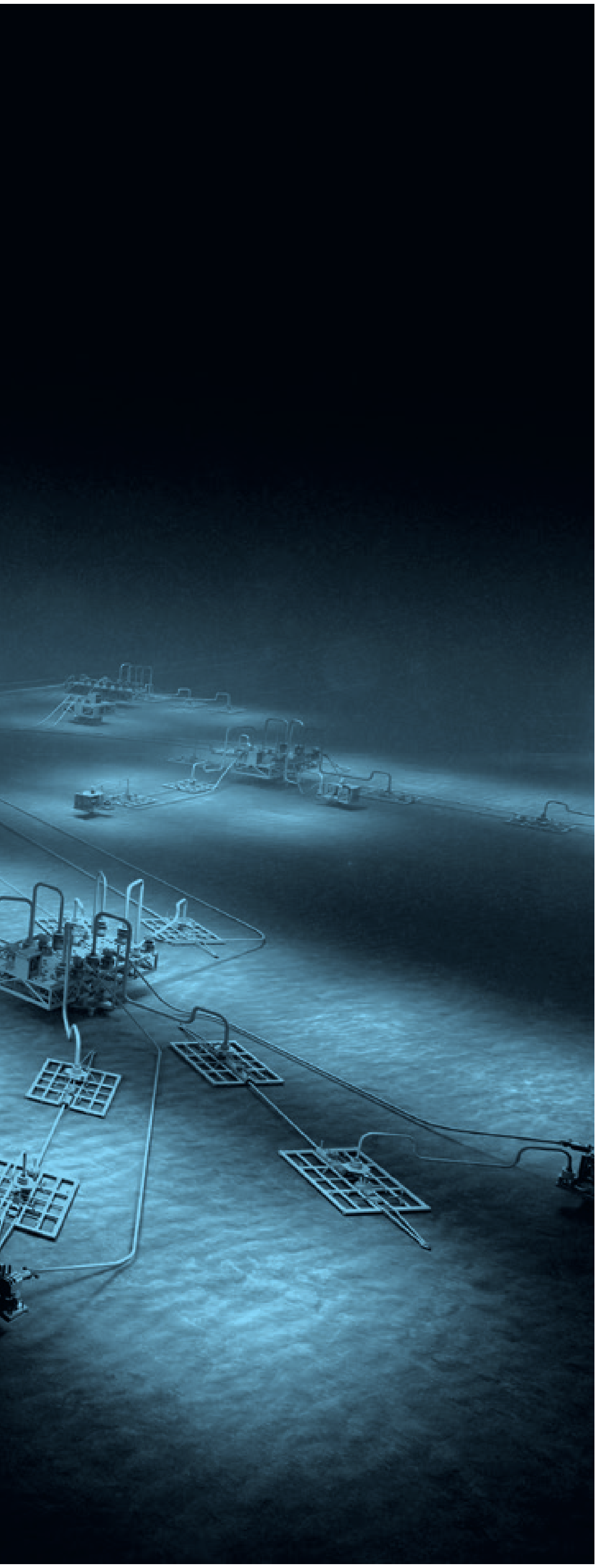
TECHNOLOGY NEEDS (DETAILS IN SECTION 4)

Improved energy efficiency	Zero carbon emissions	Protection of the external environment	Subsurface understanding	Drilling efficiency and P&A
Production optimization	Improved subsea and unmanned systems	Enhanced oil recovery	Digitalization	High North technologies

STRATEGIC RECOMMENDATIONS (DETAILS IN SECTION 6)

Address prioritized technology needs	Stimulate application of value-adding technologies	Address competence needs

02



Subsea factory. Illustration: Aker Solutions

02

PURPOSE AND SCOPE

PURPOSE AND SCOPE

Åsgard subsea compression. Photo: Elin A. Isaksen / Statoil

2.1 About OG21

OG21 has its mandate from the Norwegian Ministry of Petroleum and Energy (MPE). The purpose of OG21 is to *"contribute to efficient and environmentally friendly value creation from the Norwegian oil and gas resources through a coordinated engagement of the Norwegian petroleum cluster within education, research, development, demonstration and commercialization. OG21 will inspire the development and use of better skills and technology"*.

OG21 brings together oil companies, universities, research institutes, suppliers, regulators and public bodies to develop a national petroleum technology strategy for Norway.

Technology opportunities and challenges have been identified, described and prioritized by Technology Target Area groups (TTAs):

TTA1 Energy efficiency and environment
TTA2 Exploration and increased recovery
TTA3 Drilling, completions and intervention
TTA4 Production, processing and transport

The TTAs have members from oil companies, universities, research institutes, suppliers, regulators and public bodies.

Appendix A provides further details on OG21 and its organization.

Johan Sverdrup. Illustration: Statoil

2.2 Purpose of this strategy revision

The first OG21 strategy document was developed in 2001. The strategy document has been revised every 5 years. It was last revised in 2011 and it is due for a new revision in 2016.

The OG21 strategy provides recommendations to the Norwegian petroleum sector on research and development (R&D) and technology prioritizations. It addresses the full R&D value chain from ideas to technology implementation.

Technology needs have been prioritized based on the degree of alignment with OG21's strategic objectives. In addition, technologies will need to have a potential application on the Norwegian continental shelf to become prioritized by OG21.

Since the OG21 strategy was last revised in 2011, several influencing factors have emerged or changed, for example:

- Cost inflation on equipment and services in the petroleum industry.
- Oil price decline and uncertain future price development.
- An increased attention to greenhouse gas (GHG) emissions and new pledges to reduce emissions through the COP21 agreement.
- Delimitation agreement between Russia and Norway in the Barents Sea, and acreage awards in the South-East Barents Sea in the 23rd licensing round.
- Increased international competition in the offshore petroleum service markets.
- Reduced activities and uncertainties about the future activity level, resulting in restructuring of companies and redundancies.
- An increasing pace of digitalization and automation in all industries.

2.3 New elements in this strategy revision

New elements as compared to the previous revision of the strategy document, are:

- Energy efficiency and reduction of GHG emissions have been evaluated across all Technology Target Areas.
- Digitalization and automation discussed into detail across all Technology Target Areas.
- Specific technology needs for High North (i.e. within currently opened areas including South East Barents Sea) identified across all Technology Target Areas.
- Barriers to technology implementation and adoption, and measures to reduce barriers, have been identified.
- A need for social science research to further understand drivers and barriers for technology application, has been identified.

2.4 Interfaces with other strategy documents

OG21 has important interfaces to other strategy processes. See figure 1.

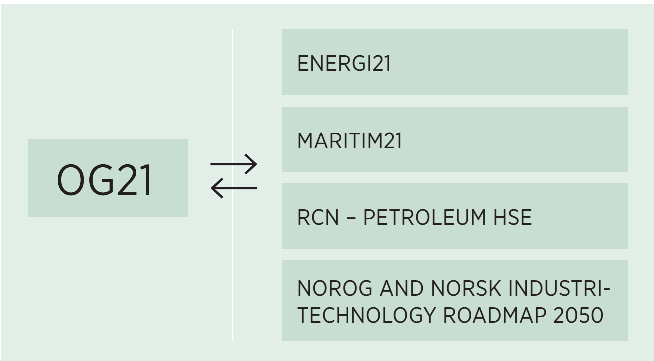
Energi21 is the national technology strategy for renewable energy. OG21 has interfaces with Energi21 on Carbon capture and storage (CCS), power transmission and use of renewables for power supply.

Maritim21 is the national technology strategy for the maritime industry. Interfaces with OG21 include: marine operations, mobile drilling units, gas transport, emergency preparedness technologies and automation and autonomy. Maritim21 revises its strategy in 2016.

The Research Council of Norway develops a new Petroleum health, safety and working environment (HSE) strategy (knowledge basis) document in 2016. It includes HSE elements such as working environment, occupational safety and major accident risks. OG21 covers technical integrity, reliability and maintenance, environmental risks and environmental preparedness technologies.

The Norwegian Oil and Gas Association and the Federation of Norwegian Industries has issued a technology roadmap towards 2050 that describes at a generic level, the need for technologies within the petroleum sector to improve energy efficiency and reduce climate gas emissions.

FIGURE 1
Interfaces between OG21 and other strategy processes



2.5 Abbreviations

AICV	Autonomous inflow control valve
bbl	Barrels
BCG	Boston Consulting Group
bcm	Billion cubic meters
boe	Barrels oil equivalent
BOP	Blowout preventer
CCS	Carbon capture and storage
COE	Center of excellence
COP21	Conference of the parties (2015 United Nations Climate Change Conference)
CRI	Center for research based innovation
EU	The European Union
EOR	Enhanced oil recovery
IEA	The International Energy Agency
GCE	Global centre of excellence
GHG	Greenhouse gases
G&G	Geology and geophysics
ICT	Information and communication technology
IN	Innovation Norway
IOR	Improved oil recovery
IP	Intellectual property
IPCC	International panel on climate change
LTP	Langtidsplan for forskning og høyere utdanning
MLT	Multi-lateral technology
MPE	The Ministry of Petroleum and Energy
NCE	National centre of excellence
NCS	Norwegian continental shelf
NIFU	Nordisk institutt for studier av innovasjon, forskning og utdanning
NOU	Norsk offentlig utredning
nmVOC	Non-methane volatile organic compound
NPD	The Norwegian Petroleum Directorate
NVCA	The Norwegian Venture Capital & Private Equity Association
OG21	Oil and gas for the 21st century
opex	Operational expenditures
P&A	Plugging and abandonment
PDO	Plan for development and operation
PSA	The Petroleum Safety Authority
SIVA	Selskaper for industrivekst
STEM	Science, technology, engineering and mathematics
R&D&I	Research and development and innovation
RCN	The Research Council of Norway
RLWI	Riserless light well intervention
SSB	Statistisk Sentralbyrå
TCM	Technology Center Mongstad
TTA	Technology Target Area
UiS	University of Stavanger
UiT	University of Tromsø
450S	450 parts CO_2 per million, scenario from IEA corresponding to IPCC's 2 degrees scenario

Photo: Shutterstock

03

OG21'S VISION AND STRATEGIC OBJECTIVES

OG21'S VISION AND STRATEGIC OBJECTIVES

OG21's vision and strategic objectives are shown in Figure 2.

OG21's vision *"Technologies and innovation for a competitive Norwegian petroleum sector"*, expresses a desire to make the Norwegian continental shelf highly competitive with other petroleum provinces in the world through the application of safe, efficient, and productivity enhancing technologies. It includes an ambition of further strengthening Norwegian competence and technology providers to become successful in the international market for offshore petroleum equipment and services.

The vision is supported by five strategic objectives. Table 1 shows the strategic objectives and a summary of opportunities and challenges related to each. Opportunities and challenges are described in more detail in Appendix B.

The strategic objectives have formed the basis for the identification and prioritization of technology and competence needs described in section 4.

FIGURE 2
OG21's vision and strategic objectives

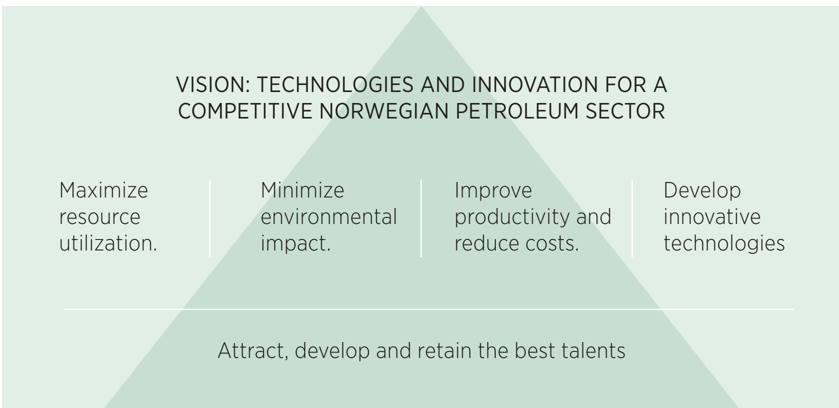


TABLE 1 OG21 strategic objectives, and summary of opportunities and challenges related to each

STRATEGIC OBJECTIVE	OPPORTUNITIES AND CHALLENGES
Maximize resource utilization	× Optimize production from existing fields – About two thirds of the NCS production in 2030 is expected to come from existing fields (i.e. with approved PDO), of which a large portion from legacy fields. Need to maintain mechanical integrity, keeping opex/bbl low and have cost-efficient wells. × Mature portfolio of discoveries to become sanctioned projects – approximately 68 out of 88 existing discoveries (in 2016) are likely to be subsea developments w/ tie-back to existing infrastructure. This calls for life extension of hubs, de-bottlenecking and cost-efficient subsea solutions. × Exploration efforts over the next years vital to replace production after 2030. × Production and reserves forecasts are dependent upon cost levels. Keeping costs down is essential. × Develop High North discoveries with low carbon footprint. Particular challenges include shallow reservoirs, karstified carbonates, long-distances, and concerns for potential environmental impact.
Minimize environmental impact	× Improve energy efficiency of existing infrastructure – The petroleum production represented 28% of Norway's CO_2-emissions in 2015. × Develop low-carbon solutions for new fields – New large fields could produce for decades to come. × Reduce environmental risk from continuous discharges –Norway has a global leading position on low emissions and discharges, and the position should be maintained. × Reduce risk for accidental releases – Low risk acceptance, especially High North, calls for continued efforts to improve mechanical integrity, monitoring and oil spill preparedness.
Improve productivity and reduce costs	× NCS needs to stay competitive compared to onshore and offshore petroleum provinces elsewhere. × Develop and implement technologies that enable faster and higher production with less effort and with improved safety. Need for remote control, automation and autonomy. × Reduce opex for mature fields – Currently competitive opex/bbl on the NCS, but increase in opex/bbl expected unless productivity is improved.
Develop innovative technologies	× Strengthen Norwegian technology and competence suppliers' global competitive position – Strong growth 2001–2014, drop in 2015–2016, a possible rebound within few years, if able to adapt products and services to new market realities. × Respond to growing international competition in important market segments – Market shares have dropped in subsea and drilling equipment segments. × Maintain the Norwegian Continental Shelf as a province for testing and early use of value-adding technologies.
Attract, develop and retain the best talents	× Turn young people's perception of the petroleum industry – Norway's petroleum industry delivers energy to the world's growing population, and does so with the lowest carbon footprint of the global petroleum provinces. × The industry needs access to qualified people and sufficient capacity for the future activity level.


HUGIN

Hugin. Photo: Kongsberg Maritime

04

PRIORITIZED TECHNOLOGY NEEDS

PRIORITIZED TECHNOLOGY NEEDS

Åsgård subsea compression system. Illustration: Aker Solutions

The Goliat field
Photo: Eni Norge

Technology needs have been prioritized based on the degree of alignment with strategic objectives and the potential business and societal values. Furthermore, technologies will need to have a potential application on the Norwegian continental shelf to become prioritized.

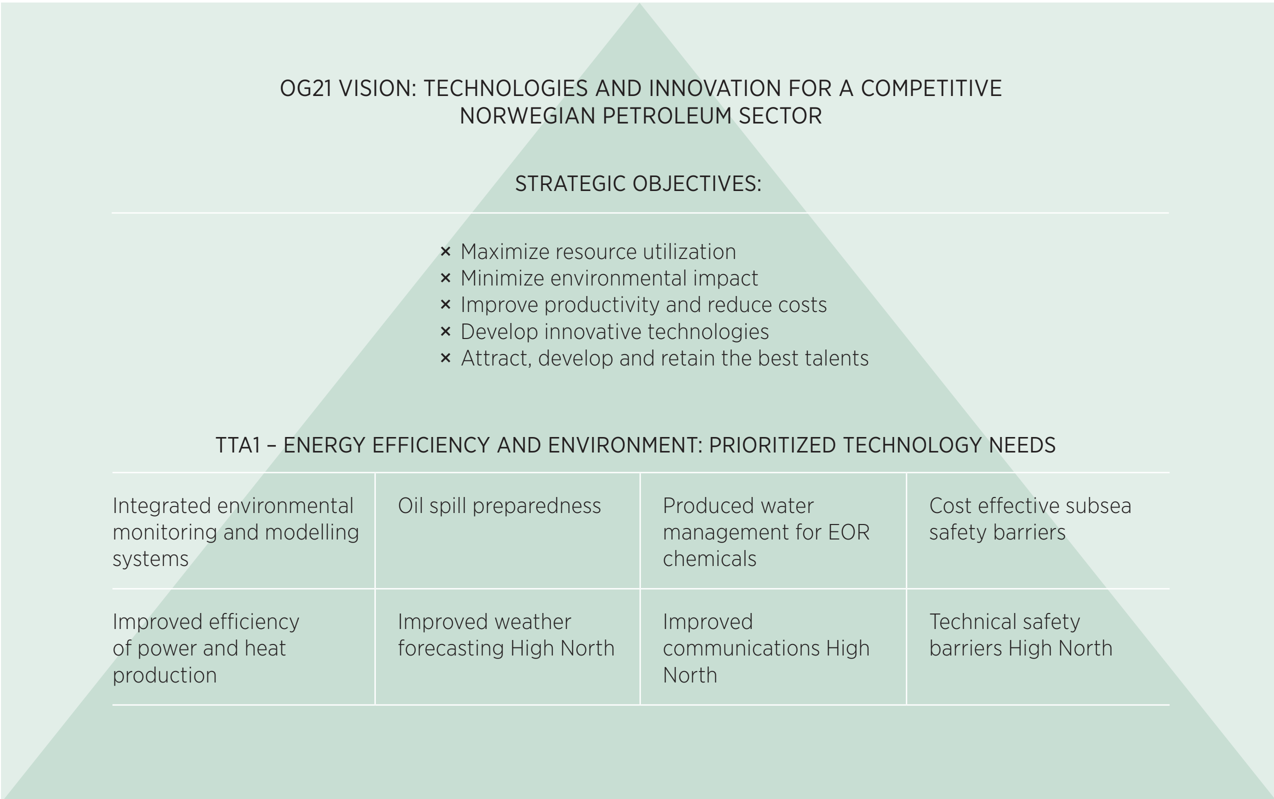
On a high level, the detailed technology needs prioritized by the TTAs fall under the categories:

- Improved energy efficiency: Technologies contributing to more efficient energy production and less energy consumption.
- Zero carbon emissions: Technologies enabling renewable power supply to offshore facilities, electricity from shore, CO_2 storage, CO_2 use for enhanced recovery, and cost-efficient, de-carbonized hydrocarbon value chains.
- Protection of the external environment: Systems and technologies that reduce operational discharges and emissions, improve management of safety barriers and minimize impacts of accidental spills.
- Subsurface understanding: Technologies for better understanding of geology and reservoirs.
- Drilling efficiency and P&A: Technologies that reduce the overall work effort for well construction and well plugging, thereby lowering the costs of exploration and production wells as well as of plugging and abandonment (P&A).
- Production optimization: Processing, downhole and intervention technologies that increase the regularity, availability and productivity of wells and installations.
- Improved subsea and unmanned systems: Technologies that reduce development costs and increase the capabilities of subsea and unmanned production systems.
- Enhanced oil recovery: Offshore technologies that increase production of mobile oils and enable production of immobile oils.
- Digitalization: Enabling automation, autonomy and ICT-technologies for all petroleum industry disciplines. The technology needs reach across data acquisition, data management, data quality, data integration, decision support and data security.
- High North: Technologies that address particular challenges of the currently opened areas in the Norwegian parts of the Barents Sea, including shallow reservoirs, carbonates, long distances and logistics and protection of the environment.

4.1 TTA1 – prioritized technology needs

The prioritized technology needs of *TTA1 – Energy efficiency and environment* are summarized in Figure 3. A detailed list of the TTA1 prioritized technology needs is provided in Appendix C

FIGURE 3
Technology needs prioritized by TTA1 – Energy efficiency and environment



4.2 TTA2 – prioritized technology needs

The prioritized technology needs by *TTA2 – Exploration and increased* recovery are summarized in Figure 4. A detailed list of the TTA2 prioritized technology needs is provided in Appendix C.

FIGURE 4
Technology needs prioritized by TTA2 – Exploration and increased recovery

OG21 VISION: TECHNOLOGIES AND INNOVATION FOR A COMPETITIVE NORWEGIAN PETROLEUM SECTOR

STRATEGIC OBJECTIVES:

- Maximize resource utilization
- Minimize environmental impact
- Improve productivity and reduce costs
- Develop innovative technologies
- Attract, develop and retain the best talents

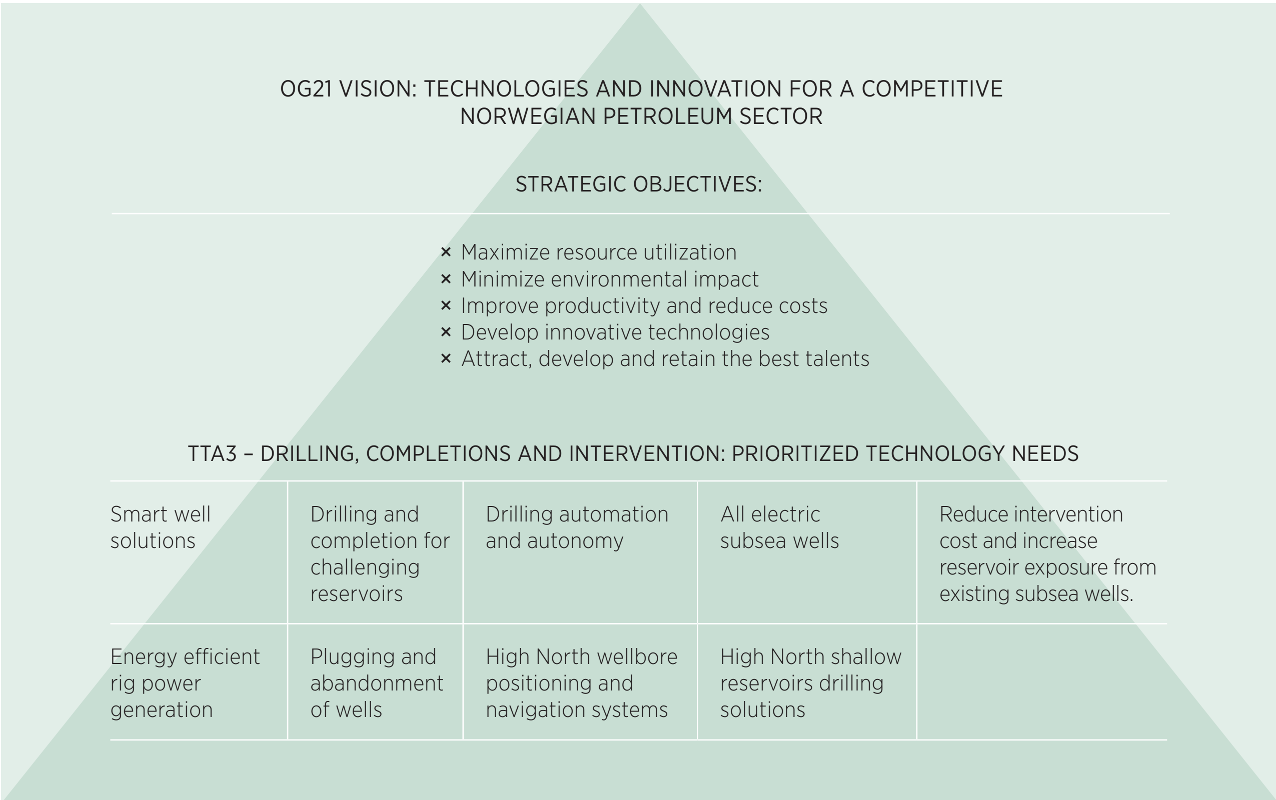
TTA2 – EXPLORATION AND INCREASED RECOVERY: PRIORITIZED TECHNOLOGY NEEDS

CO_2 for EOR and storage	Improved reservoir understanding and management	Understand and maintain well productivity, and smart well solutions
Improved HC-prospect identification	Water diversion and radical new EOR methods	Improved exploration technologies

4.3 TTA3 – prioritized technology needs

The prioritized technology needs by *TTA3 – Drilling, completions and intervention* are summarized in Figure 5. A detailed list of the TTA3 prioritized technology needs is provided in Appendix C.

FIGURE 5
Technology needs prioritized by TTA3 – Drilling, completions and intervention



4.4 TTA4 – prioritized technology needs

The prioritized technology needs by *TTA4 – Production, processing and transport* are summarized in Figure 6. A detailed list of the TTA4 prioritized technology needs is provided in Appendix C.

FIGURE 6
Technology needs prioritized by TTA4 – Production, processing and transport

OG21 VISION: TECHNOLOGIES AND INNOVATION FOR A COMPETITIVE NORWEGIAN PETROLEUM SECTOR

STRATEGIC OBJECTIVES:

- Maximize resource utilization
- Minimize environmental impact
- Improve productivity and reduce costs
- Develop innovative technologies
- Attract, develop and retain the best talents

TTA4 – PRODUCTION, PROCESSING AND TRANSPORT: PRIORITIZED TECHNOLOGY NEEDS

Life extension of fields	Produced water handling	Unmanned operations	Efficient marine operations	Integrated monitoring
Lean stand-alone field development concepts	Flexible field development concepts	Cost-efficient utilization of host platform by subsea developments	Autonomous components, systems and decision support	Energy generation and management
Process simulation and optimization	High North flow assurance	High North shallow reservoirs, subsea facilities incl. subsea compression		


WeST
WeST Group

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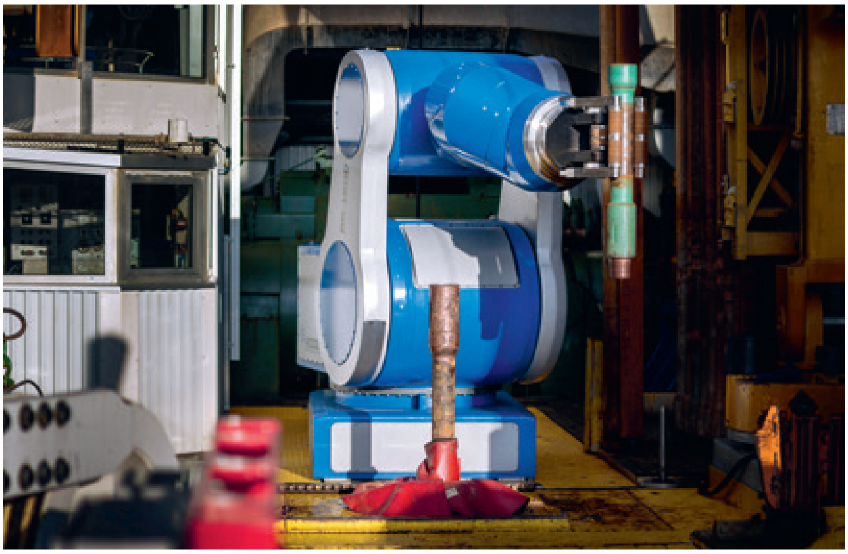
Continuous Motion Rig.
Photo: West Group



RDS drill floor robot.
Photo: Robotic Drilling System.

4.5 Addressing technology needs

According to a study conducted by Rystad Energy (2016), development and application of technologies addressing the OG21 priorities offer huge rewards to businesses and society. The main findings of the study are presented in Appendix D.

OG21's ambition is that the high estimated value of new technology will encourage industry enterprises to develop and implement technologies addressing the prioritized technology needs. OG21 recommends that stakeholders such as industry enterprises, universities and research institutes, consider the OG21 priorities when updating their R&D / technology strategies.

It is the industry's responsibility and also in their own best interest, to develop, implement and adopt technologies. However, as described in Section 5.1, many barriers exist for efficient development and application of new technologies. A typical example is that new technologies and competencies often become available in the market within short time after development. Combined with the deployment risks and potential costs associated with new technologies, the incentives for conducting R&D and testing out new technologies may be too weak.

Public support of petroleum research therefore continues to be important to stimulate technology development, and public funded petroleum R&D programs should now be updated to reflect the OG21 priorities.


HEEREMA
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Installation of Nini East. Photo: DEA Deutsche Erdoel AG

05

INCENTIVES AND BARRIERS TO TECHNOLOGY DEVELOPMENT AND APPLICATION

INCENTIVES AND BARRIERS TO TECHNOLOGY DEVELOPMENT AND APPLICATION

5.1 Barriers to technology development and application

OG21 have identified barriers to technology development and implementation. An overview is shown in Figure 7, and more details are given in Table 2.

FIGURE 7
Types of barriers to technology development and implementation

5.2 Strategies to reduce or remove barriers

OG21 works to reduce barriers for technology development and application in three ways:

1. Address what OG21 can directly influence.
2. Recommend R&D to reduce barriers.
3. Engage stakeholders that can reduce barriers.

Elements that OG21 can directly influence are mainly related to public R&D priorities, covered in section 5.4 in this report. Further R&D to reduce barriers is discussed in Section 5.8.

But the responsibility and opportunity to reduce or remove most barriers lay with OG21's stakeholders. OG21 therefore needs to engage its stakeholders to take ownership of actions:

- The industry should work to enhance the use of novel, value-adding technologies through measures such as:
  - Contract strategies in projects that encourage the use of new value-adding technology.
  - Commercialization strategies with robust partnerships and convincing business cases.
- The industry should continue its standardization efforts to simplify deployment of new technology and reduce unit costs. Examples include standard material specifications, standard technical specifications, as well as standard interfaces and communication protocols to enable component interchangeability.

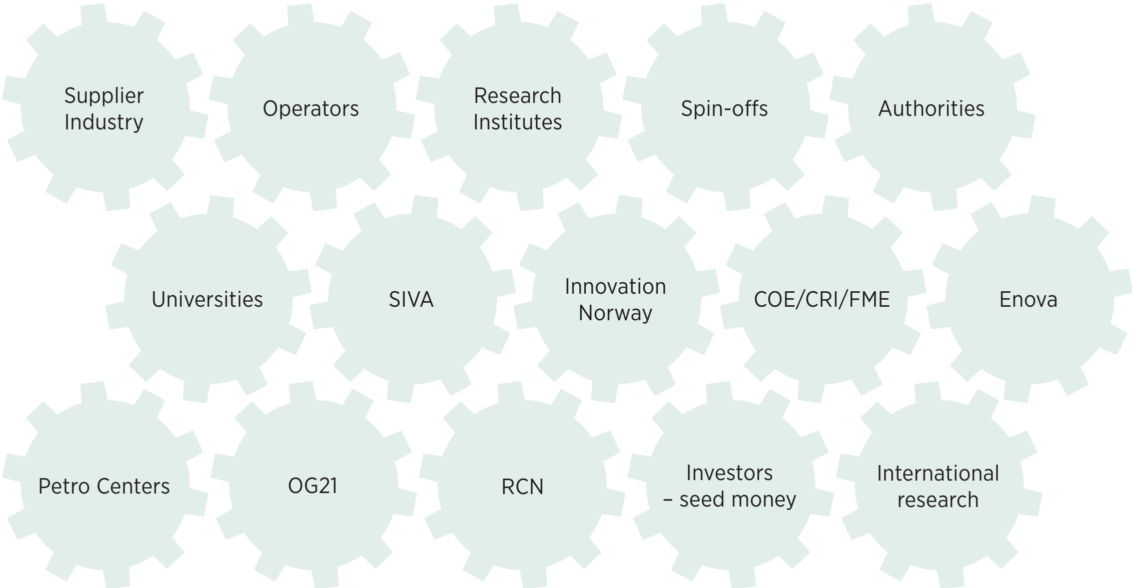
Furthermore, the authorities could contribute to reducing barriers by:

- The authorities should evaluate whether sufficient incentives are in place to encourage the application of new technologies with high societal value.
- Authorities should actively use established instruments to encourage implementation of value-improving technologies.
- The effects of the voting rules in NCS licenses on technology uptake should be further investigated.

TABLE 2 Barriers to technology development and implementation

BARRIERS	DESCRIPTION
Technologies full potential not harvested	× Component potential not utilized due to inferior system compatibility, lack of integration or system bottlenecks. × Effects dependent upon other new or legacy systems/technologies (brownfield). × Insufficient access to input resources, e.g. power, CO_2, data and information. × Operational envelope not fully utilized due to lack of trust in new technology. × Lack of a functioning CCS value chain.
High perceived risks	× Some technologies are intrusive - affect cash flow if problems. × Risk perception, aversion and conservatism. × Perceived or real HSE risks.
Contractual barriers	× Lack of contract incentives that encourage the use of new, value-adding technologies. × Unclear IP-rights.
High societal value, but lower business value	× Required rate of return higher in oil companies than for the state. × Capital constraints - capital intensive technologies are not favored. × Market too small for technologies addressing too specific needs.
Piloting and first use challenges	× Lack of access to real conditions for some types of technologies, e.g. oil spill technologies, intrusive technologies. × Logistical challenges - Lack of field infrastructure, remoteness, environmental concerns, quantities of equipment or chemicals. × High costs. × Uncertainty of effects, e.g. for EOR -long time until effects materialize. × Reliability/integrity of new technologies improve over time – first mover disadvantage. × Weaknesses in partnership. × Lack of long-term commitment from oil companies.
NCS structural challenges	× Smaller fields/licenses have lower capacity to carry technology development. × NCS portfolio effects not considered – optimization on project level. × Wide spread in focus among operators from integrated oil&gas companies with technology focus to financial entities with little intention of technology development and implementation. × License voting rules blocking technology implementation. × Lack of competition among suppliers. × Lack of infrastructure in frontier areas.
Competence and organizational capability	× Lack of organizational capability to understand and address technology needs. × Lack of competence to develop and implement technologies.
Lack of standardization/ standards	× Lack of standard interfaces and communication protocols that enable component interchangeability. × Lack of standard technical specifications and materials specifications
Leadership and commitment	× Strategic decisions of being “fast followers” or “market proven”-procurement only. × Lack of steering signals or ambiguous steering signals on importance of innovation, risk acceptance and need for change.

FIGURE 8
Illustration of the Norwegian innovation system, based on collaboration and interaction



5.3 The Norwegian innovation system and competence needs

The Norwegian innovation system is characterized by collaboration and close connections between industry enterprises, research institutes and universities, public bodies and financial investors and funds, as illustrated in Figure 8.

OG21, with its 100+ people network, contributes with a focused technology strategy aligning stakeholders around common goals and technology needs. The OG21 strategy is operationalized through public R&D programmes and support instruments and engagement of industry enterprises. OG21 is one important cog in an efficient innovation system that has resulted in global leading petroleum clusters.

Public support of R&D&I is channelled through the institutions: the Research Council of Norway, Innovation Norway (IN), ENOVA, Gassnova and SIVA. The main support mechanisms and programmes offered by RCN, IN, ENOVA and Gassnova, relevant for petroleum related enterprises, are shown in Figure 9.

SIVA has an important role for the commercialization of technologies at higher education institutions as it provides infrastructure for industry, startups and research environments. SIVA's incubator program is of particular importance (NIFU, 2015).

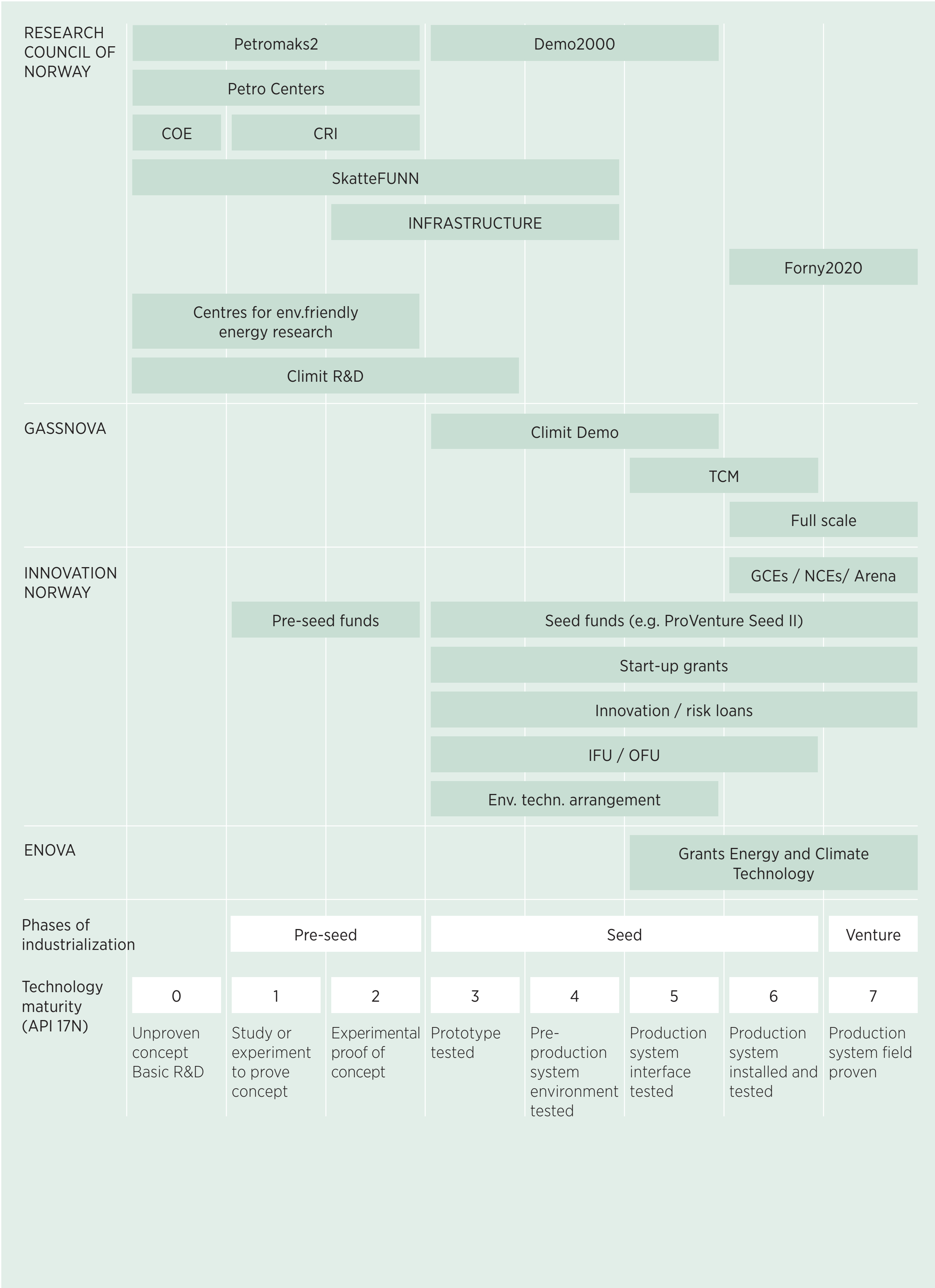
OG21 is of the opinion that the public R&D&I financing instruments serve the petroleum industry well, and that it has contributed to creating world leading petroleum clusters. The instruments include:

- Sector specific R&D programs such as Petromaks2 and Demo2000.
- Petro Centers (IOR-senter at UiS and ARCEx at UiTromsø)
- Open R&D arenas where petroleum sector enterprises compete with other industries, e.g. Centers of Excellence, Centers for research based innovations, and Infrastructure.
- SkatteFUNN.
- Industry Innovation Norway supported cluster programs such as GCE Node, GCE Subsea, GCE Blue Maritime and Subsea Valley.

ENOVA funding of energy efficiency and climate technology projects is a new and important opportunity for the petroleum sector. It addresses a strategic challenge for the industry, and it covers a phase when access to capital is scarce. In addition to support of demonstration and first use of new technologies, ENOVA also provides financial support for implementation of proven technologies resulting in improved energy efficiency and reduced CO_2-emissions.

Carbon Capture and Storage (CCS) is an important strategic element for EU in its plans for reductions of greenhouse gas emissions, and for Norway both in terms of being an integral part of the EU greenhouse gas emission system and for strengthening the future market position for natural gas. Climit is an R&D program managed by Gassnova and the Research Council of Norway, which supports technology development within CO_2 capture, transport, injection and storage. Gassnova manages the CO_2 capture demonstration project at Technology Center Mongstad (TCM), and is also responsible for the planning of full scale projects with the aim of demonstrating the full CCS chain from capture to storage.

FIGURE 9
R&D&I financing instruments managed by the RCN, Innovation Norway and ENOVA



⟵

Technology Center Mongstad.
Photo: TCM

A major obstacle to CCS within EU is access to suitable storage locations. NPD has developed CO_2 storage atlases demonstrating that the NCS, and especially the North Sea, is well suited for storage of large quantities of CO_2. CO_2 is in many cases also efficient as an injection fluid for enhanced oil recovery, but access to sufficient quantities of CO_2 has historically been a limitation on the NCS.

To make CCS attractive, costs need to be reduced and a well-functioning value chain needs to be established. The public funded Climit, TCM and full-scale demonstration programs organized through RCN and Gassnova and co-funded by industry partners, are important stepping stones to achieve this.

OG21's technology priorities are operationalized, among others, through research programs administered by the RCN, see Figure 10. OG21 believes that the established R&D programs' structure and organization support the close collaboration philosophy. The petroleum programs' boards have a broad industry representation, and their project evaluation processes and criteria reflect industry needs. The competition for funding and the project selection process results in high quality R&D projects.

A successful implementation of the OG21 strategy in public funded R&D projects is reflected in the RCN project portfolio. The implementation is being monitored through two steps as shown in Figure 11: OG21 reviews the program plans, and RCN monitors that the project portfolios reflect the program plans through portfolio evaluations.

The challenge of harvesting the full potential of new technologies was identified as a barrier in Section 5.1. OG21 therefore recommends: **To better understand the value of new technologies and how technologies depend on system integration, petroleum research programs should encourage holistic R&D approaches, including system perspectives.**

FIGURE 10
OG21 influences public petroleum R&D funding and priorities

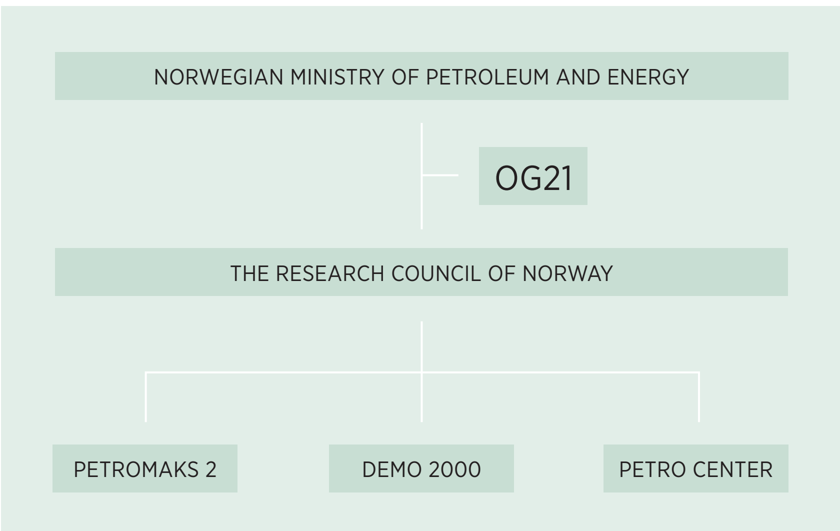


FIGURE 11
Implementation of the OG21 strategy through RCN petroleum R&D programs

Sand screen test lab.
Photo: Hung Ngo / Iris

OG21 advocates close collaboration between industry and universities/ research institutes. Within technology disciplines, close industry involvement is associated with high quality research (Perkmann et al, 2011). Collaboration results in high industry relevance of R&D, and it provides the industry access to new ideas and solutions. A NIFU report suggests that Norwegian universities are industry oriented and that they conduct more applied technology research than the average of universities in 13 other countries (2011). The report refers to other studies that suggest that a Norwegian engineering and technology research culture has evolved over time that prioritizes industry relevance over academic publishing.

Likewise, close connections between industry and academia in the design of study programs is important for the continual development of industry relevant competencies. OG21 therefore supports the recommendation in the Governmental white paper on research and higher education (Langtidsplan for forskning og høyere utdanning – LTP) on the need for such collaboration (St. meld. nr. 7, 2014–2015).

LTP describes a need for more Ph.D's within technology, mathematics and natural science. The public petroleum research funding through the Research Council of Norway is an important contributor to Ph.D.-education in Norway with 122-136 Ph.D. positions during the years 2013–2015 (RCN, 2016). Petromaks2 is the dominant source of petroleum Ph.D. funding, but with important contributions also through other programs such as the Petro Centers, the Industry Ph.D.-arrangement, and various COEs/CRIs.

Collaboration across disciplines such as engineering, physics and social science spur innovation (St.meld. nr. 7, 2014–2015). OG21 encourages cross-discipline R&D collaboration when relevant. The petroleum industry is complex and technologically challenging. It needs professionals from many disciplines such as economics, law, mathematics, natural science and engineering and technology. A general high educational level is important for developing and maintaining world leading industry clusters.

For addressing the OG21's scope, the natural science, technology, engineering and mathematics (STEM) subjects are considered the most important. According to a NIFU study, STEM subjects increased significantly in popularity among students at Norwegian institutions for higher education during the period 2003–2013 (NIFU, 2014). The same study did however not find a corresponding increase neither in direct research funding nor academic personnel for the STEM subjects. The modest increase in research funding is entirely linked to external sources, such as through the RCN.

A GENERAL HIGH EDUCATIONAL LEVEL IS IMPORTANT FOR DEVELOPING AND MAINTAINING WORLD LEADING INDUSTRY CLUSTERS.

Despite the increase in STEM students, a study carried out for OG21 reveals that the petroleum industry could experience challenges in attracting highly qualified candidates within petroleum core disciplines such as geology, geophysics, and reservoir engineering (Rystad Energy, 2016). **This is a concern to OG21, and OG21 needs to work with the petroleum industry to improve the attractiveness of the industry to students.**

The LTP describes a need for more people with advanced ICT-education. Professionals with advanced ICT degrees are becoming increasingly more important to a petroleum industry going through a digitalization transition to become more automated. OG21 supports the view of the LTP that R&D on «enabling technologies» such as ICT, bio-technology, nano-technology and advanced production systems, should be strengthened.

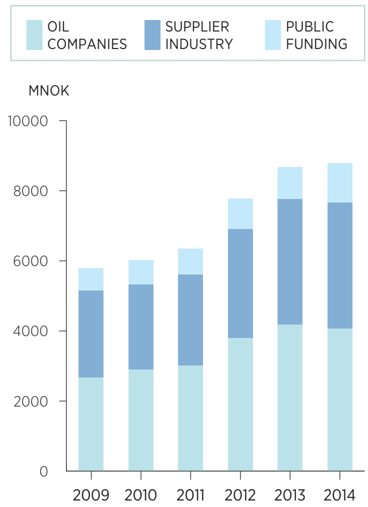
International collaboration is important, and especially for smaller countries like Norway. Much of the competence and technology development take place internationally, and improvements to productivity is dependent upon the competence to apply and adopt technologies developed internationally (NOU 2015:1). A study comparing universities in 14 countries, concludes that Norwegian universities are significantly more internationally oriented than the average among the countries examined (NIFU, 2011).

Petroleum research is not prioritized within EU's research program Horizon2020. However, technologies with their origin in the petroleum industry could be developed and adopted for use in other industries, and such technologies are within the scope of the EU program (RCN, 2015).

Since research on technologies for use in the petroleum industry is not prioritized in the EU research programs, national petroleum research as well as bilateral research collaboration become particularly important for the petroleum industry (St.meld. nr. 7, 2014–2015).

Norway currently has bilateral agreements on petroleum research, technology development and higher education with among others the USA and Brazil, and further collaboration agreements should be evaluated based on strategic needs for the Norwegian petroleum industry, e.g. for the High North.

FIGURE 12
Petroleum R&D investments (Menon, 2015)



5.4 Petroleum R&D funding and prioritizations

Figure 12 illustrates the total petroleum R&D investments by oil companies, petroleum-related supplier industry and public R&D-funding. It shows that oil companies and the supplier industry account for almost 90 percent of total petroleum-related R&D investments.

Even though the public funding of petroleum R&D represents only around 10 percent of the total R&D investments, the public funding is important for several reasons:

- It addresses technology needs that are otherwise not addressed due to market imperfections.
- It covers basic research and early phases - phases for which industry R&D funding is challenging.
- It stimulates development of technologies which could have high rewards, but which fall short due to high development costs or risks.
- It addresses technologies which offer high societal rewards, but which are less attractive to private enterprises due to factors such as different return requirements and/or license/project portfolio limitations and challenges.

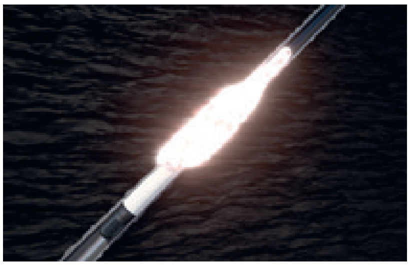
Moving forward, public petroleum R&D funding in Norway is becoming increasingly important:

- The NCS is maturing and the average field size is decreasing. This reduces the financial capability of licenses to carry R&D investments.
- Improved oil recovery is important for a maturing NCS, but often such projects are marginal and new IOR/EOR technologies could struggle in the competition for funding internally in oil companies.
- The NCS attracts new types of oil companies, often smaller with a strategy of applying market proven, low risk technologies, and with little appetite for applying, let alone developing new technologies.
- Petroleum from the NCS is competing with supplies from other regions in the world. Staying competitive requires improved productivity and lower cost solutions.
- The global competition for attracting technology development investments is increasing.

Petroleum R&D offers vast returns. Appendix D summarizes the value potential of addressing the technology needs described in this OG21 strategy document. For the period 2016-2050, the potential adds up to additional 4 billion boe in discovered resources, additional 14 billion boe in production, and additional sanctioned and developed fields equivalent to 8 billion boe.

Public petroleum R&D funding contributes to realizing such values through development of competence and solutions in academia and research institutes and by stimulating industry R&D and innovation. Figure 13 illustrates that many more high quality R&D projects could have been started if more public funding had been available. The graph shows the accumulated Petromaks2 grants split on evaluation scores where 7 is the highest. If all high quality projects

Thermal plug.
Illustration: Interwell



(grade 5 or higher) should have received funding, the allocations would have had to increase almost three-fold.

OG21 therefore recommends that public funding through Petromaks2 is increased. Historic data suggest that there is sufficient research capacity and high quality R&D project ideas to accommodate a significant increase of the annual Petromaks2 budgets.

The Demo2000 program co-funds demonstration and piloting projects in the industry. For many years its budget has been around 50 million NOK per year. In 2016 the budget was increased considerably as part of a Governmental stimulation package to the petroleum industry. The industry responded positively to the increased funding opportunities, as illustrated in Figure 14. Even with a tri-fold increase in the budget, the competition for funding was so extensive that many high quality projects (grade 5 or higher) did not receive funding.

Financing the late technology development phases, i.e. demonstration, piloting and market introduction, is a challenge OG21 has discussed in previous studies, (Menon, 2014) and (Rystad Energy, 2013). There is little private seed capital available, and public co-funding is important for risk relieve. The significant industry response to the recent Demo2000 engagement efforts has demonstrated the high availability of quality projects relevant for the NCS.

OG21 therefore recommends that the public funding level of Demo2000 in 2016, where the increase from 2015 was intended as a counter-cyclical effort, is continued for the 2017-2021 period.

Two petroleum centers receive earmarked funding through the RCN: The IOR-center at the University of Stavanger, and the ARCEx center at the University of Tromsø. Both were established in 2013 to reflect particular needs for the petroleum industry described in a Governmental White Paper on the future of the petroleum industry in Norway (St.meld. 28, 2010-2011). The IOR-center addresses competence and technology needs related to improved recovery from the NCS, whereas ARCEx addresses the needs related to exploration and environmental risk management in the High North of the NCS. Improved recovery, exploration in the High North and environmental risk management are still priorities of OG21, continued from previous strategy document revisions.

Technologies for improved energy efficiency and reduced GHG emissions on the NCS have emerged as a new area of particular, strategic importance in the light of the COP21-agreement in Paris. **Petroleum centers address topics of high strategic importance, and a new center on low emission petroleum technologies and solutions should be considered.**

FIGURE 13
Petromaks2 allocations split on evaluation grade (RCN data)

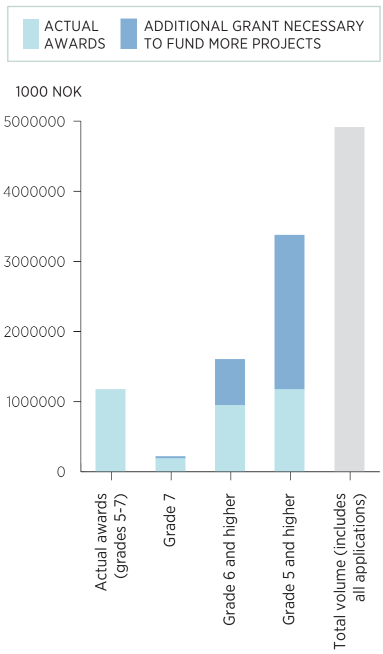
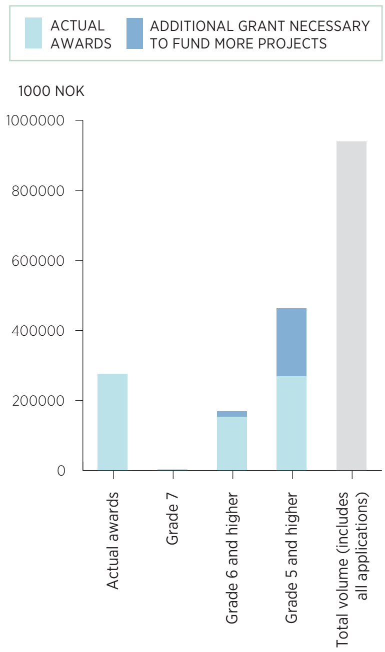


FIGURE 14
Demo2000 allocations fall 2015 – spring 2016



Wireless gass detector. Photo: GasSecure AS

5.5 Private equity investments in technology development

Enterprises in the petroleum sector in Norway in 2014 attracted 2 508 million NOK in private equity investments (NVCA, 2015). The majority of this, 2 441 million NOK, was invested in enterprises in the "buy-out" phase, a phase relatively late in the technology development. In the earlier "seed" and "venture" phases when the technology is still being developed and little revenue is made, 2014 investments were 22 million NOK and 117 million NOK, respectively.

FIGURE 15
Seed and venture investments in petroleum related enterprises 2007-2014 (Menon, 2015)

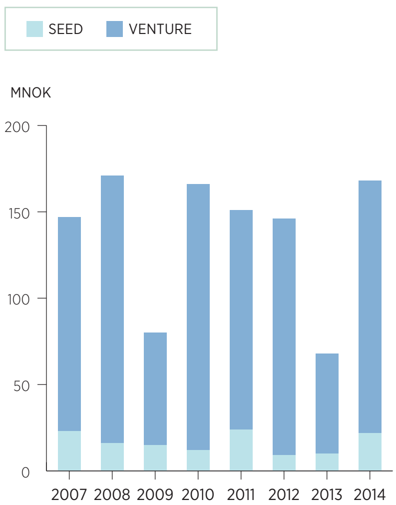


Figure 15 shows the development in the seed and venture phases between 2007 and 2014. Especially in the early seed phase, when large scale demonstration and piloting of technologies takes place, but generally before any sales are made, access to private equity is a challenge. Seed investments in petroleum related enterprises in Norway were around 20 million NOK per year in the period 2007-14, which is much less than public funding through the Research Council of Norway and Innovation Norway. The new 500 million NOK seed fund ProVenture Seed II, aimed at the petroleum industry and funded equally between Innovation Norway and private investors, addresses the lack of early seed investments. By April 2016 it had invested in three enterprises, but with the lion's share of capital still available for new investments.

Investinor provides an overview of possible funding sources for enterprises at their home page: www.investinor.no.

"Angel money" is an important source of capital in many countries, but in Norway the volume has traditionally been low and the number of angel investors few. A new initiative has recently been launched to organize angel investors, which could be of importance to entrepreneurs with solutions for the petroleum industry, see www.norban.no.

5.6 Technology and competence transfer between industries

The government appointed Productivity Commission described in its first report that productivity growth not only relates to a country's ability to move the technology frontier through technology development and implementation, but also to its ability to adopt new technology developed abroad (NOU, 2015:1). Furthermore, a country's ability to exploit technology developed abroad is determined in large extent of the overall knowledge capital, which in turn is influenced by the educational and research system.

Applying this to the Norwegian petroleum sector, productivity growth is a result of:

- Technology development and innovation within the Norwegian petroleum industry.
- Technology transfer from other industries and geographies.
- Competence and capacity to develop new technologies, adopt technologies and implement technologies.

The petroleum industry in Norway is to a large extent built on competence and experience from other industries and geographies. For example foreign competence and technologies brought in by international oil companies was essential during the build-up of the industry in the 70-ies, and particular offshore challenges were being solved by applying Norwegian maritime competence. A global leading Norwegian petroleum industry emerged as a result.

The Norwegian petroleum industry still benefits from competence and technology influx from the petroleum industry abroad. International oil companies and oil service providers invest massively in R&D&I to solve global technology challenges, and their Norwegian affiliates bring the competence and solutions to the NCS. **Attracting international technology leaders within the petroleum industry to the NCS through access to acreage as well as attractive and predictable frame conditions, should therefore still be a high priority.**

Technology adoption for new challenges in the Norwegian parts of the Barents Sea is a particular area of importance. Operations in the eastern and northern most acreage awarded in the 23rd licencing round, would need to be designed to handle seasonal ice, icebergs, marine icing and dense fog and snow. A DNV GL study carried out in cooperation with OG21 showed that such conditions, by and large, have been dealt with successfully in other regions in the world, for instance at the Great Banks outside New Foundland, Canada (OG21, 2015). **Experience and solutions from Canada and other arctic regions, should therefore be leveraged when developing new acreage in the Barents Sea.**

The opportunity to learn from other maritime industries continues. In a study on the technology transfer opportunities between the "blue industries" marine, maritime and offshore petroleum, Marintek suggests that the scope for competence and technology transfer is large (Marintek, 2016). The study indicates that the larger potential is for other blue industries to learn from the petroleum industry, but it does list some areas for competence and technology transfer to the petroleum industry that could be important, e.g. energy efficiency and hybrid battery technologies from the maritime sector, and wind turbines for power supply from the renewables sector.

There is a general desire across industries to digitalize manufacturing and operations. It includes extended automation by efficient use of big data, the internet of things and cyber physical systems. It is often referred to as Industry 4.0, and it is by many considered the 4th industrial revolution (Sintef, 2016). According to the Sintef-presentation, the European industry is predicted to invest €140 billion annually in Industry 4.0 solutions in the years towards 2020. Industries that invest heavily in new solutions include manufacturing and engineering, the car industry, the process industry, electronics and electrical systems and information and communications.

Results from a Boston Consulting Group study (2015) underlines that the petroleum industry could benefit from technology and competence transfer from other industries. Among the 50 most innovative companies identified by BCG, there are none from the petroleum industry, but several from the manufacturing and engineering industry, the car industry, the process industry, the electronics industry and the information and communications industry.

OG21 has identified several digitalization technology needs across the TTAs. **Considering the huge innovation efforts in other industries, a large extent of adoption/modifications of solutions from other industries would benefit the petroleum industry when addressing prioritized technology needs.**

Learning from other industries includes also elements around ICT vulnerability and security, including data theft, data manipulation and sabotage. Challenges and risks are discussed in a governmental assessment report (NOU 2015:13).

NEW BUSINESS MODELS COULD BE A SOLUTION TO HARVEST THE POTENTIAL REWARDS OF NEW TECHNOLOGIES OR BE A DRIVER FOR DEVELOPING NEW TECHNOLOGIES.

5.7 New business models

New business models could be a solution to harvest the potential rewards of new technologies or be a driver for developing new technologies. One example is business models where all parties gain on higher availability and efficiency offered by new, value-adding technologies.

OG21 recommends that new business models that could enhance technology adoption and application, are investigated as part of the social science research in petroleum R&D programs.

Control room, Gassco Karmøy.
Photo: Gassco / Øyvind Sætre

5.8 Social science and cross-disciplinary research

As discussed in Section 5.1, market imperfections and other barriers may cause sub-optimal solutions and lost value and opportunities.

OG21 therefore recommends cross-disciplinary R&D, including social sciences, to be included in public funded R&D programs. Social science research should contribute to understand, reduce and remove barriers to technology development and application.

Social sciences contributions could include elements such as:

1. Identify measures and strategies for reducing or removing barriers to development and implementation of technologies with high value creation potential on the NCS.
2. Understand challenges associated with traditional business models in the petroleum industry, including but not limited to organisation of competence and technologies contract incentives and practices and work processes. Identify opportunities for business model innovations.
3. Understand cross-market opportunities and mechanisms for competence and technology transfer between the petroleum industries and other established or emerging industries, societal challenges or disciplines, and identify improvement opportunities for stimulating such.

The objective is that such research will contribute to development and implementation of technologies needed to meet OG21's strategic objectives, presented in Section 3.

06

Oseberg B. Photo: Harald Pettersen / Statoil

06

OG21 RECOMMENDATIONS

OG21 RECOMMENDATIONS

Recommendations made throughout the strategy document are summarized in the following sections. Recommendations are split into three categories:

1. Technology development to address prioritized technology needs.
2. Stimulation of technology application.
3. Competence to develop, adopt and apply new technologies

6.1 Recommendations on technology development

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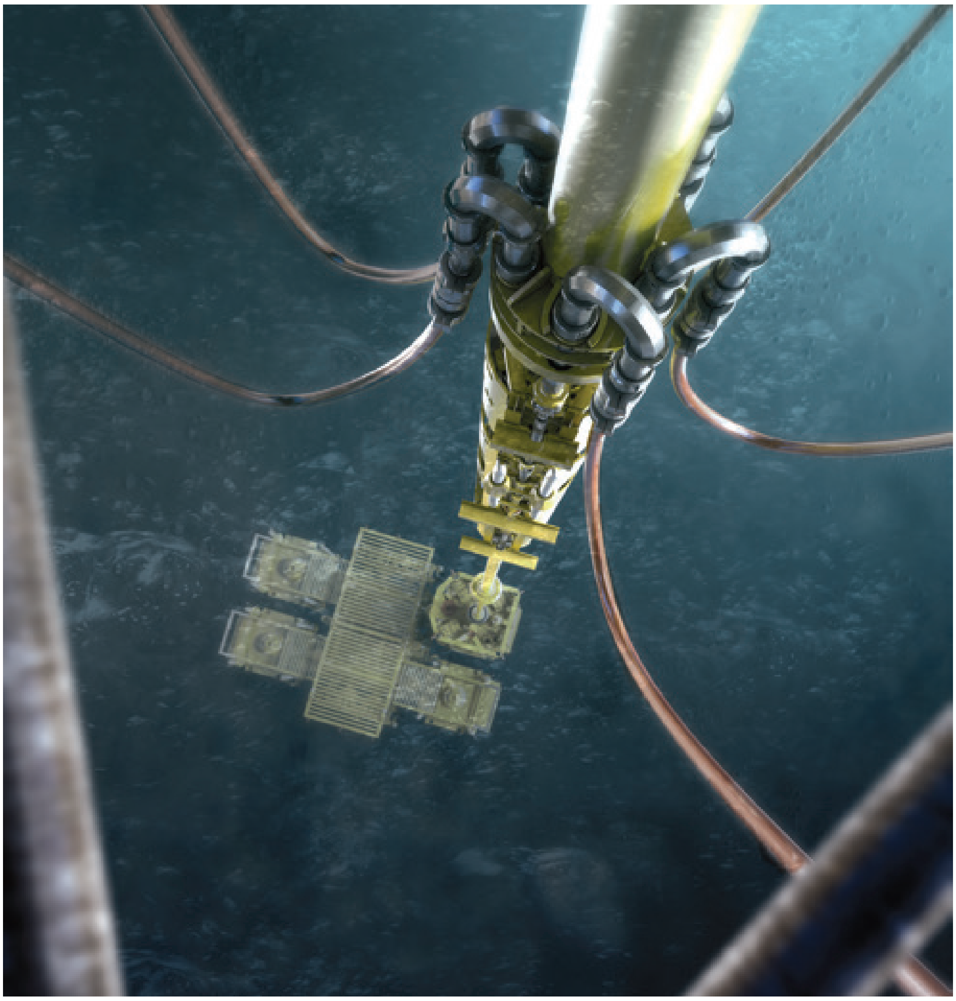


Flex Joint.
Illustration: FMC Technologies

TABLE 3 Recommendations on technology development

ID.	RECOMMENDATION	RELEVANT STAKEHOLDER	OG21 ACTION
TD1	The current design of the innovation system has resulted in world leading petroleum competence, and should be continued.	RCN, IN, Enova, Gassnova	Communication
TD2	Public funded petroleum R&D programs should be updated to reflect the OG21 priorities.	RCN	Communication
TD3	Public funding of Petromaks2 should be increased significantly over the 2017-2021 period. Historic data suggest that there is sufficient research capacity and high quality R&D project ideas to accommodate a significant increase of the annual Petromaks2 budgets.	MPE, RCN	Communication
TD4	The public funding level of Demo2000 in 2016, with a significant counter-cyclical effort increase from 2015, should be continued for the 2017-2021 period.	MPE, RCN	Communication
TD5	OG21 stakeholders such as industry enterprises, universities and research institutes, should consider OG21 priorities when updating their R&D/ technology strategies.	Oil companies, suppliers, research institutes, universities	Communication
TD6	Considering the huge digitalization innovation efforts in other industries, a large extent of adoption/modifications of solutions from other industries would benefit the petroleum industry when addressing prioritized digitalization technology needs.	RCN, oil companies, suppliers, research institutes, universities	Communication
TD7	Petroleum centers address topics of high strategic importance, and a new center on low emission petroleum technologies and solutions should be considered.	MPE	Communication
TD8	Competence to adopt technologies and learn from other industries is increasingly important, and should be encouraged in R&D programs.	RCN	Communication
TD9	Cross-disciplinary R&D, including social sciences, should be included in public funded R&D programs. Social science research should contribute to understand, reduce and remove barriers to technology development and application.	RCN	Communication
TD10	To better understand the value of new technologies and how technologies depend on system integration, petroleum research programs should encourage holistic R&D approaches, including system perspectives.	RCN, oil companies, suppliers, research institutes, universities	Communication
TD11	International collaboration should be encouraged in R&D programs when relevant.	RCN	Communication

6.2 Recommendations on stimulation of technology application

TABLE 4 Recommendations on stimulation of technology application

ID.	RECOMMENDATION	RELEVANT STAKEHOLDER	OG21 ACTION
TA1	New business models to enhance technology adoption and application, should be investigated as part of the social science research in petroleum R&D programs.	RCN	Communication
TA2	The industry should work to enhance the use of novel, value-adding technologies through measures such as: × Contract strategies in projects that encourage the use of new value-adding technology. × Commercialization strategies with robust partnerships and convincing business cases.	Oil companies, suppliers	Communication
TA3	The authorities should evaluate whether sufficient incentives are in place to encourage the application of new technologies with high societal value.	MPE	Communication
TA4	Authorities should actively use established instruments to encourage implementation of value-improving technologies.	MPE	Communication
TA5	The effects of the voting rules in NCS licenses on technology uptake should be further investigated.	MPE	Communication
TA6	The industry should continue its standardization efforts to simplify deployment of new technology and reduce unit costs. Examples include standard material specifications, standard technical specifications, as well as standard interfaces and communication protocols to enable component interchangeability.	Industry organizations	Communication

6.3 Recommendations on competence

TABLE 5 Recommendations on competence

ID.	RECOMMENDATION	RELEVANT OWNER	OG21 ACTION
C1	A competence and organizational capability shortage could hit the petroleum industry when activities rebound: × The industry needs to maintain core competencies and capacity through activity cycles. × OG21 should work w/ industry organizations to improve the reputation of the industry, increase the interest for petroleum core subjects and attract professionals with digitalization, automation and ICT competencies.	Oil companies, suppliers, industry organizations	Engagement
C2	Industry clusters are important for innovation. OG21 should strengthen its links and collaboration with petroleum relevant GCEs, NCEs and Arena programs.	OG21	Engagement
C3	Attracting international technology leaders within the petroleum industry to the NCS through access to acreage as well as attractive and predictable frame conditions, should still be a high priority.	MPE	Communication
C4	Experience and solutions from Canada and other arctic regions, should be leveraged when developing new acreage in the Barents Sea.	Oil companies	Communication
C5	Norway currently has bilateral agreements on petroleum research, technology development and higher education with among others the USA and Brazil. Further collaboration agreements should be evaluated based on strategic needs for the Norwegian petroleum industry, e.g. for the High North.	MPE	Communication

Fishbones.
Illustration: Fishbones AS

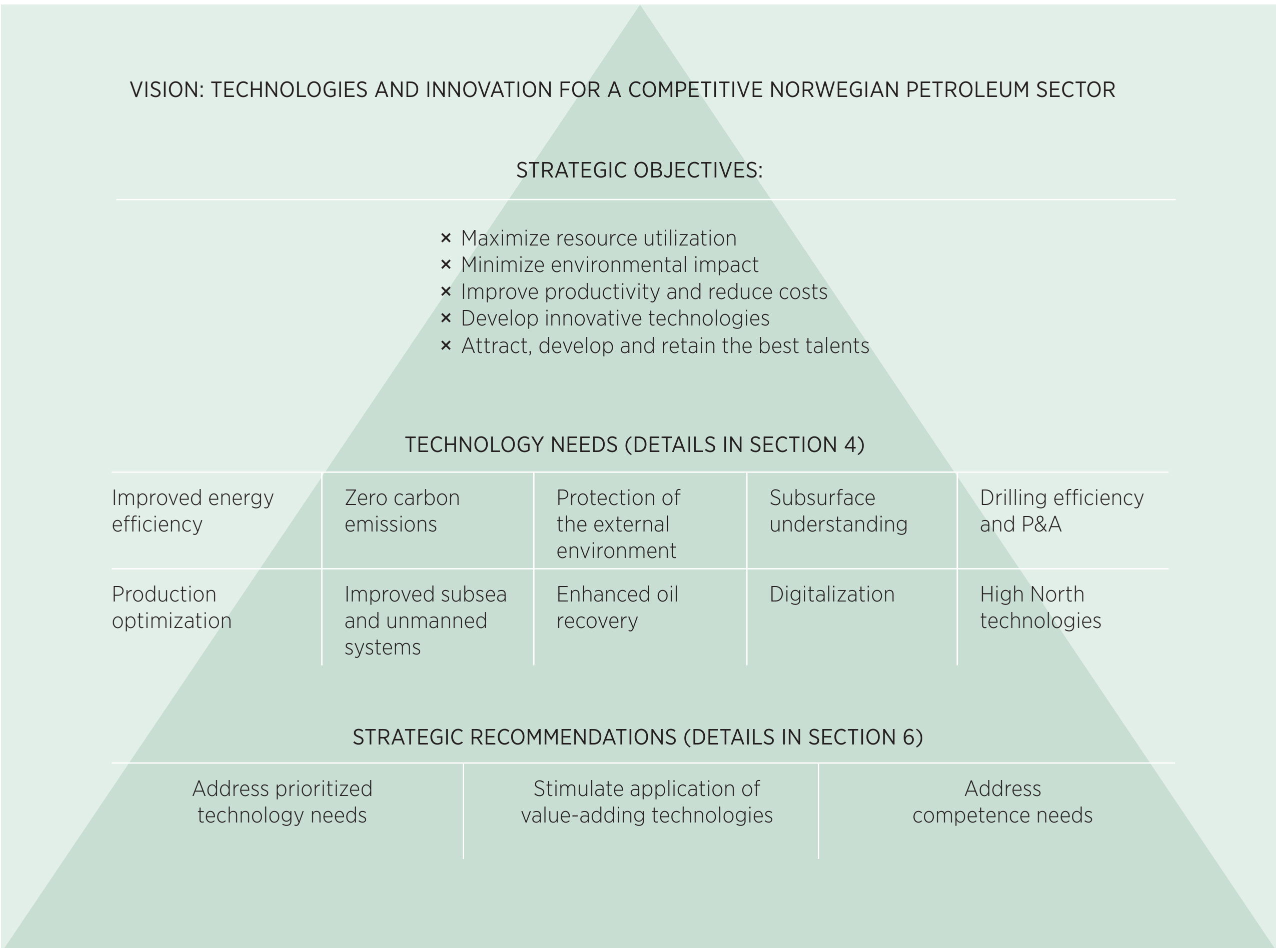
→

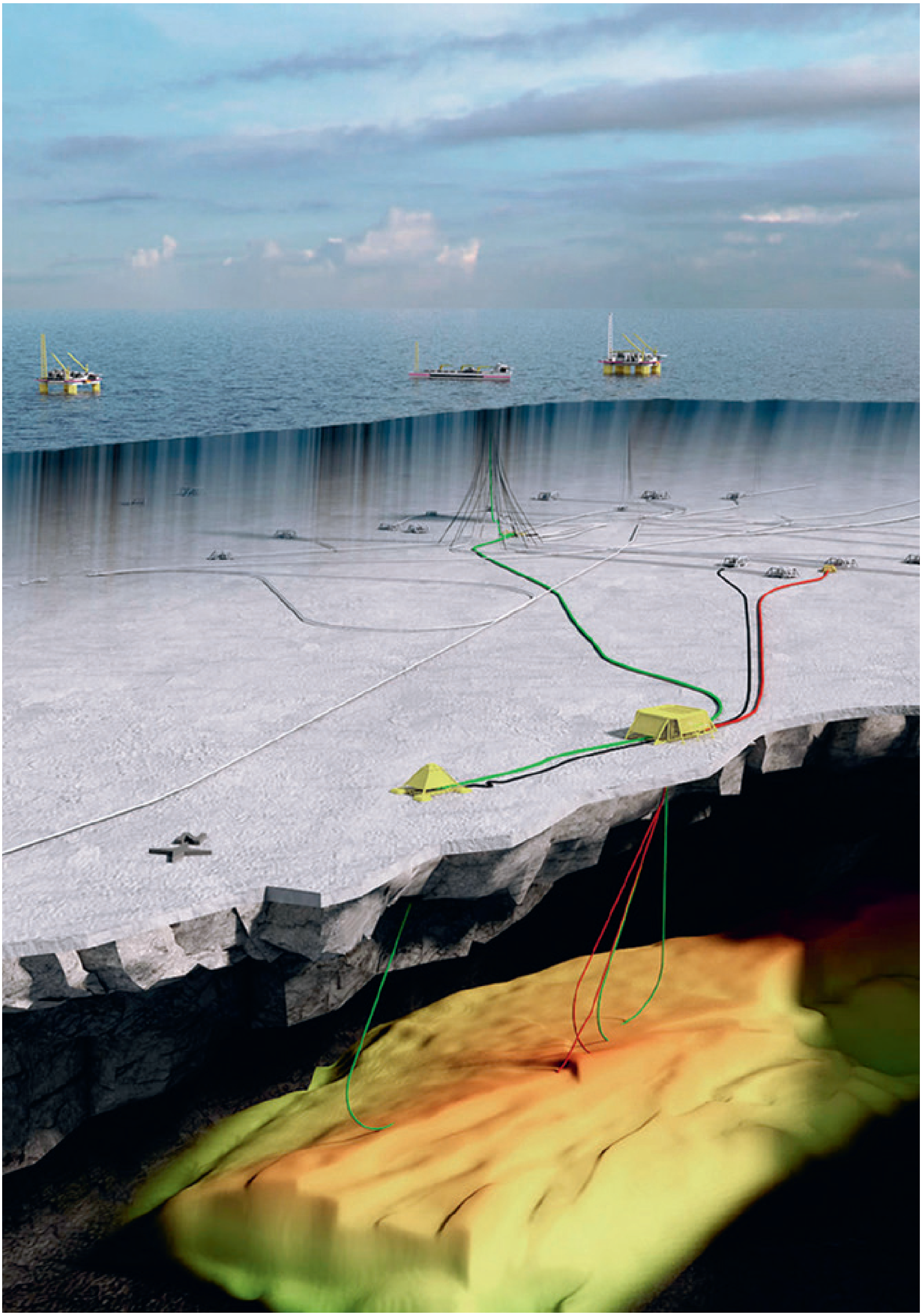
Trestakk reservoir.
Illustration: Statoil

6.4 Summarized overview of the OG21 strategy

A summarized overview of the OG21 strategy is shown in Figure 16.

FIGURE 16
OG21 strategy – summarized overview



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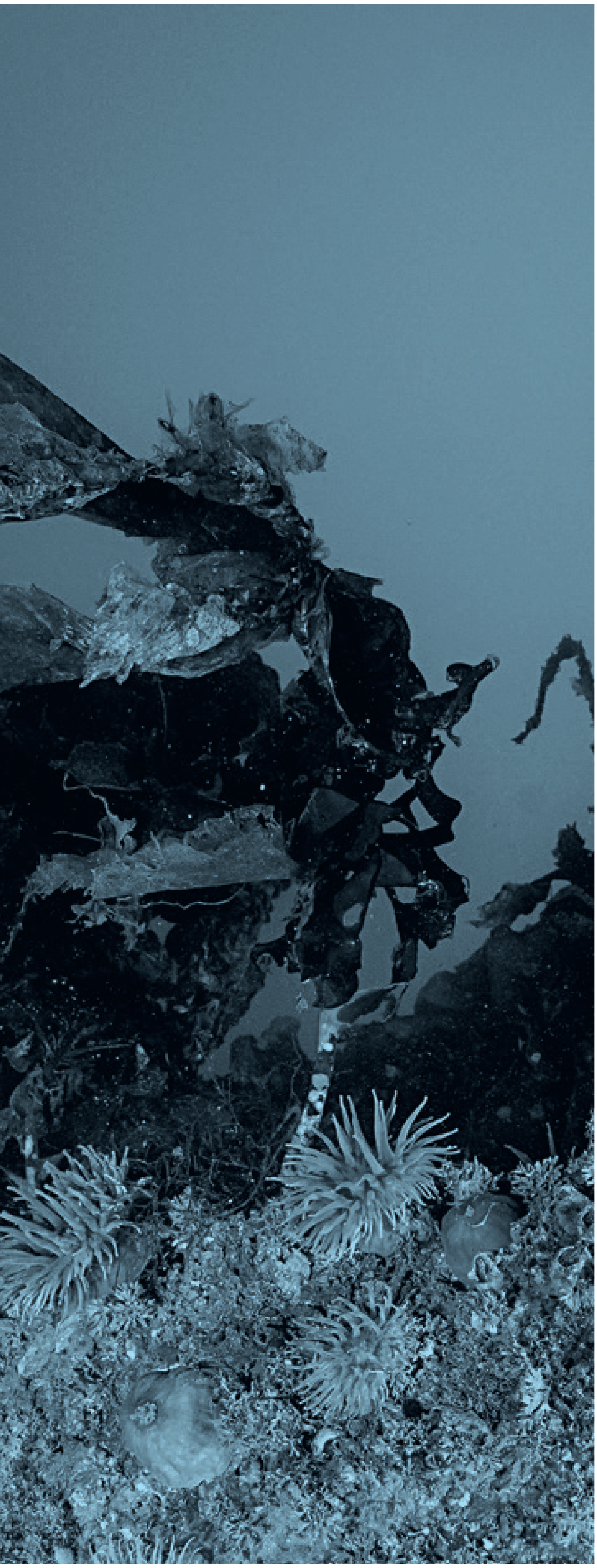
Photo: Shutterstock

07

STRATEGY IMPLEMENTATION

STRATEGY IMPLEMENTATION

→

Maersk Interceptor
Photo: Aker BP

The implementation of the OG21 strategy is dependent upon efficient communication and engagement of stakeholders. It is OG21's responsibility to communicate to its stakeholders the recommendations listed in Sections 6.1 through 6.3.

OG21 wants to highlight the following important actions to strengthen stakeholder involvement and engagement:

- Provide well documented guidance on petroleum R&D to the MPE.
- Continue the TTAs also during the periods between strategy document revisions.
- Maintain the good relationships with Konkraft, Intsok, Norsk Industri and the Norwegian Oil and Gas Association, and provide relevant information to these industry organisations.
- Strengthen the relationship with relevant technology cluster organizations.
- Enter into an "expert role" on petroleum technology in the public domain.

The OG21 board will monitor the implementation of the strategy on a continual basis, and evaluate whether the following success criteria are met:

- The OG21-strategy continues to be the basis for public investments in petroleum R&D.
- The OG21-strategy is well known by decision makers in oil companies, supplier companies, research institutes and academia.
- The OG21-strategy influences technology and business investments of oil companies, supplier companies, research institutes and academia.

Further details on strategy implementation are provided in Appendix E.

Photo: Shutterstock

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APPENDICES

APPENDIX A – ABOUT OG21

APPENDIX B – OPPORTUNITIES FOR THE NORWEGIAN PETROLEUM SECTOR

APPENDIX C – DETAILS ON PRIORITIZED TECHNOLOGY NEEDS

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APPENDIX A.

ABOUT OG21

A.1. Organization

OG21 has its mandate from the Norwegian Ministry of Petroleum and Energy (MPE). The purpose of OG21 is to *"contribute to efficient and environmentally friendly value creation from the Norwegian oil and gas resources through a coordinated engagement of the Norwegian petroleum cluster within education, research, development, demonstration and commercialization. OG21 will inspire the development and use of better skills and technology".*

OG21 brings together oil companies, universities, research institutes, suppliers, regulators and public bodies, to develop a national petroleum technology strategy for Norway.

The MPE appoints the OG21 board, which has members from oil companies, universities, research institutes, suppliers, regulators and public bodies.

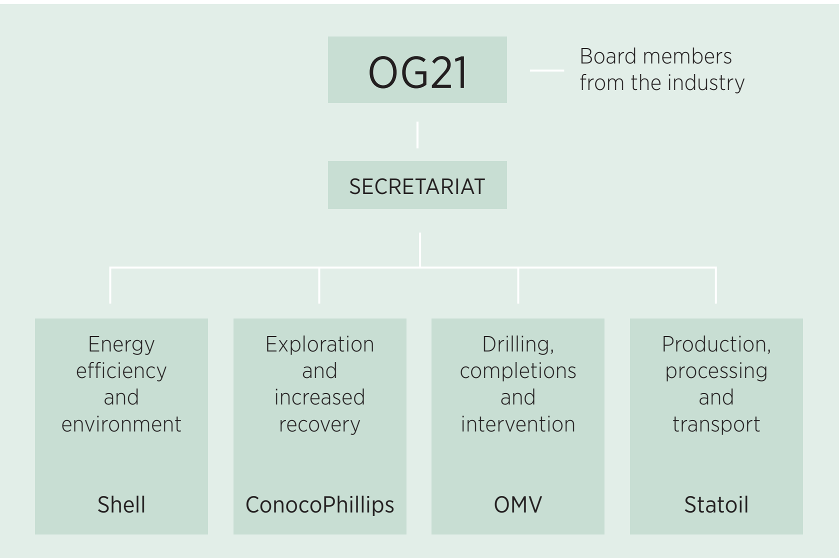
The OG21 organization is shown in Figure 17. The administration of the daily OG21 work is managed by the secretariat, hosted at the Research Council of Norway (RCN).

Technology opportunities and challenges are identified, described and prioritized by Technology Target Area groups (TTAs). For the new OG21 strategy document, the OG21 board decided to continue the four TTAs that were established for the previous version:

- *TTA1 Energy efficiency and environment*
- *TTA2 Exploration and increased recovery*
- *TTA3 Drilling, completions and intervention*
- *TTA4 Production, processing and transport*

The TTA teams have representatives from the same type of stakeholder groups as the board, i.e. oil companies, universities, research institutes, suppliers, regulators and public bodies.

FIGURE 17
The OG21 organization



The Ramford Vanguard.
Photo: Ole Jørgen Bratland / Statoil

A.2. Mandate (in Norwegian)

FORMÅL MED OG21

Formålet med OG21 er å sikre en effektiv og miljøvennlig verdiskaping fra norske olje- og gassressurser gjennom et samordnet engasjement i petroleumsklyngen innenfor utdanning, forskning, utvikling, demonstrasjon og kommersialisering. OG21 skal inspirere til utvikling og bruk av bedre kompetanse og teknologi.

HOVEDOPPGAVE FOR STYRET

OG21-styret skal utarbeide en nasjonal teknologistrategi[1] som skal være retningsgivende for næringen og myndighetenes samlede teknologi- og forskningsinnsats.

Strategien skal bidra til:

- effektiv og miljøvennlig verdiskaping på norsk sokkel i flere generasjoner
- kompetanse og industri i verdensklasse innenfor petroleum

Strategien skal skape en helhetlig tenkning rundt satsingen på mer effektiv petroleums-teknologi- og kunnskapsutvikling gjennom å koble myndigheter, næringsliv og forskningsmiljøer nærmere sammen.

Det er også et mål å bidra til økt nasjonal satsing på FoU for å kunne utvikle internasjonalt konkurransedyktig kompetanse og næringsliv innenfor petroleumssektoren.

STYRETS OPPGAVER FOR ØVRIG:

- beskrive framtidens muligheter og utfordringer på norsk sokkel fra et økonomisk, miljømessig og samfunnsmessig perspektiv
- definere hvilke teknologiutfordringer og teknologi-gap norsk kontinentalsokkel står overfor
- identifisere virkemidler for å lukke teknologi-gapene og øke eksportverdien
- etablere arbeidsgrupper på de prioriterte innsatsområdene og følge opp at disse konkretiserer, spisser og handlingsretter strategien, herunder utvikler delmål innenfor innsatsområdet
- kommunisere og forankre strategien hos relevante aktører og stimulere til samhandling i petroleumsklyngen
- bidra til operasjonalisering av strategien gjennom samarbeid med utførende organer som Norsk olje og gass, Norsk Industri, Innovasjon Norge, INTSOK og Forskningsrådet
- gi råd til OED i henhold til OG21-strategien og delstrategiene og peke på områder hvor offentlig finansiering er avgjørende
- profilere Norge som et internasjonalt senter for olje- og gassteknologi
- arrangere et seminar hvert annet år for å formidle OG21-strategien og de prioriterte innsatsområdene (OG21 Forum)
- revidere strategien hver 2-3 år og i den sammenheng evaluere oppnådde resultater i strategiarbeidet
- samarbeide med E21, bl.a. om en helhetlig strategi innen CO_2 fangst og lagring.

[1] Innenfor OG21's mandat ligger oppstrøm-, midtstrømaktiviteter - inklusive CO_2-transport og – lagring. Energieffektiviseringstiltak for disse verdikjedene ligger også innenfor mandatet til OG21. Alternativ energi slik som vind-, bølge-, tidevann, geotermisk-, biomasse-, saltvann og hydro-kraft ligger ikke innenfor mandatet til OG21.

A.3. The OG21 strategy contributors

TABLE 6 OG21 resources

NAME	COMPANY	GROUP
Anne-Mette Hilmen	Shell	OG21 board
Arne Holhjem	NPD	OG21 board
Christina Johansen	FMC	OG21 board
Elisabeth B. Kvalheim	Statoil	OG21 board
Gunn Mangerud	UiB	OG21 board
Kjartan Pedersen	AkerSolutions	OG21 board
Lars Høier	Statoil	OG21 board
Lars Sørum	Sintef	OG21 board
Roy Ruså	Petoro	OG21 board
Siri Helle Fridemann	RCN	OG21 board
Torjer Halle	Schlumberger	OG21 board
Gunnar Lille	OG21	OG21 secretariat
Roger Strøm	OG21	OG21 secretariat
Alfred Hansen	UiT	TTA1
Are Børjesson	Lloyd's	TTA1
Eilen Arctander Vik	Aquateam	TTA1
Eirik Sønneland	IOS Intermoor	TTA1
Espen Hoel	Proactima	TTA1
Gunnhild Bækken	Shell	TTA1
Hanne Greiff Johnsen	Statoil	TTA1
Ivar Singsaas	Sintef	TTA1
Trond Sagerup	AkerSolutions	TTA1
Odd Raustein	NPD	TTA1
Ove Tobias Gudmestad	UiS	TTA1
Tor-Petter Johnsen	NIVA	TTA1
Ane Lothe	Sintef	TTA2
Cathrine Ringstad	SINTEF	TTA2
Eirik Møgedal	Senergi	TTA2
Gorm Liland	Halliburton	TTA2
Lars Jensen	NPD	TTA2
Lars Sønneland	Schlumberger	TTA2
Mariann Dalland	NPD	TTA2
Ole Eeg	ConocoPhillips	TTA2
Tor Langeland	CMR	TTA2
Ying Guo	IRIS	TTA2
Øivind Fevang	Statoil	TTA2
Cecilie Drange	Weatherford	TTA3
Dag Helge Breivik	OMV	TTA3
Etienne Bourdelet	Total	TTA3
Hans Magnus Bjørneli	Schlumberger	TTA3
Inge Asgeir Alme	Lloyd's	TTA3
Jan Butler Wang	NPD	TTA3
Kent Allan Dahle	Halliburton	TTA3
Rik DeBruijn	Shell	TTA3
Sigmund Stokka	IRIS	TTA3
Stein Børre Torp	Statoil	TTA3
Anne Minne Torkildsen	NPD	TTA4
Anngjerd Pleym	Siemens	TTA4
Bjørn Søgård	DNV GL	TTA4
Charlotte Skourup	ABB	TTA4
Christian Pauchon	Total	TTA4
Dag Eirik Nordgård	Sintef	TTA4
Jo Jernsletten	Shell	TTA4
Joar Dalheim	Lloyd's	TTA4
Jon Harald Kaspersen	Sintef	TTA4
Kjetil Skaugset	Statoil	TTA4
Kristian J. Sveen	IFE	TTA4
Linda Fløttum	AkerSolutions	TTA4
Marie Holstad	CMR	TTA4
Marit Storvik	FMC	TTA4

TABLE 7 Additional resources

NAME	COMPANY	GROUP
Anders Steensen	RCN	Demo2000
Øyvind Salvesen	RCN	Demo2000
Andreas Quamme Nielsen	RCN	Petromaks2
Ingrid Anne Munz	RCN	Petromaks2
Kimberly C. Mayes	RCN	Petromaks2
Tarjei Nødtvedt Malme	RCN	Petromaks2
Roald Johansen	Total	Resource
Trygve Nilsson	Det Norske	Resource

APPENDIX B. OPPORTUNITIES FOR THE NORWEGIAN PETROLEUM SECTOR

FIGURE 18
IEA forecasts on world primary energy demand by fuel and scenario (IEA WEO, 2015)

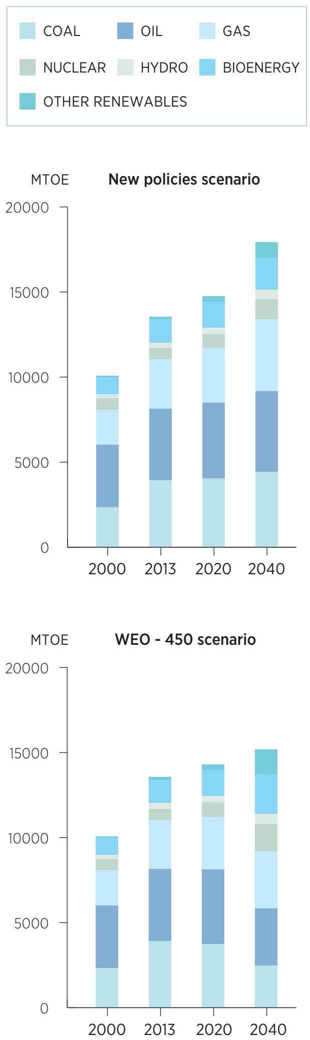
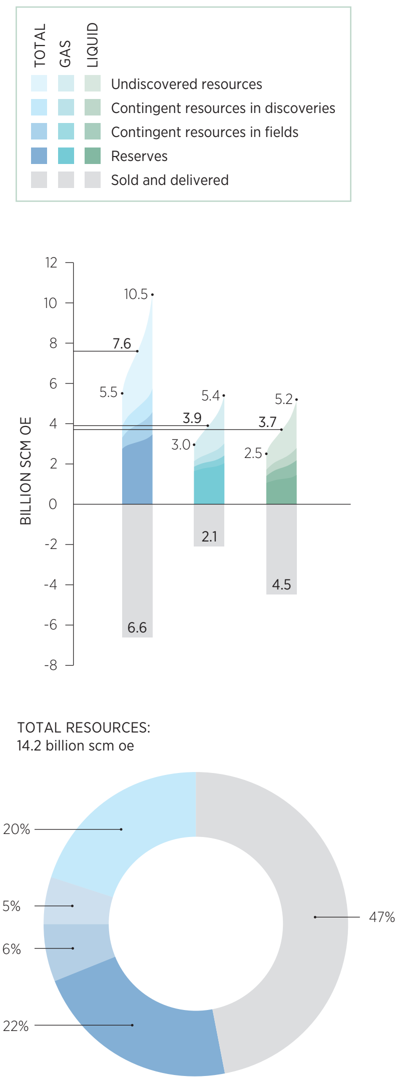


FIGURE 19
Resources on the NCS (NPD, 2016)



B.1. Petroleum in the global energy mix

The global primary energy demand forecasts by the IEA are presented in Figure 18 (IEA WEO, 2015).

The new policies scenario (NPS) includes relevant policies and measures that had been adopted mid-2015, including energy related pledges submitted by national governments by October 1, 2015, to the COP21 meeting in Paris. The 450 scenario (450S) assumes a set of policies that would result in a trajectory of greenhouse gas emissions consistent with the 2^{0}C goal.

In the NPS, the share of fossil fuels would be reduced from 81 percent in 2013 to 75 percent in 2040. In the 450S scenario, the share of fossil fuels in 2040 would still be 60 percent of the total energy demand. Concerning the global oil demand in the 450S scenario, it would in 2040 still be 79 percent of the global oil demand in 2013.

The forecasts show that oil and gas are likely to still play an important role in the global energy mix for decades to come, even if stringent greenhouse gas curbing policies are introduced.

According to IEA, existing oil fields today will be capable of producing less than 40 percent of the global demand in 2040. Compared with the forecasts from IEA presented above, new fields need to be brought on stream from now and until 2040 to meet global oil demand, also in the low-carbon 450S scenario. Large investments in exploration and field development are required to meet global oil demand.

Natural gas plays an important role in the shift to a low-carbon energy mix. A shift from coal to natural gas reduces emissions of CO_2 by approximately 50 percent in the power sector, and is therefore an important measure to reduce greenhouse gas emissions. In the longer term, further reductions are required to meet the 2⁰C goal or the 1.5⁰C ambition. Development of a functioning CCS value chain could strengthen Norwegian gas supplies in the long term.

B.2. Maximize resource utilization on the NCS

Norway is an important producer of petroleum to the global market. In 2015, Norway was the 8th largest crude oil exporter and the 3rd largest natural gas exporter in the world (www.norskpetroleum.no). The Norwegian Continental Shelf still offers large opportunities, as only 47 percent of the estimated resources has been produced (NPD, 2016). See figure 19.

A production forecast for the Norwegian continental shelf is shown in Figure 20 (NPD, 2016). The forecast indicates:

- Production from existing fields producing today will be a significant contributor to the overall production in 2030. Approximately two thirds of the production is likely to come from these fields, of which a large portion would be from legacy fields.
- Fields under development today will contribute to maintaining today's production level until approximately 2020-25.
- Discoveries that need to be sanctioned over the next few years, would contribute to maintaining the production level until 2030.

Continued exploration efforts and new discoveries are needed to maintain production after 2030.

FIGURE 20
Historical and expected production from the NCS (NPD, 2016)

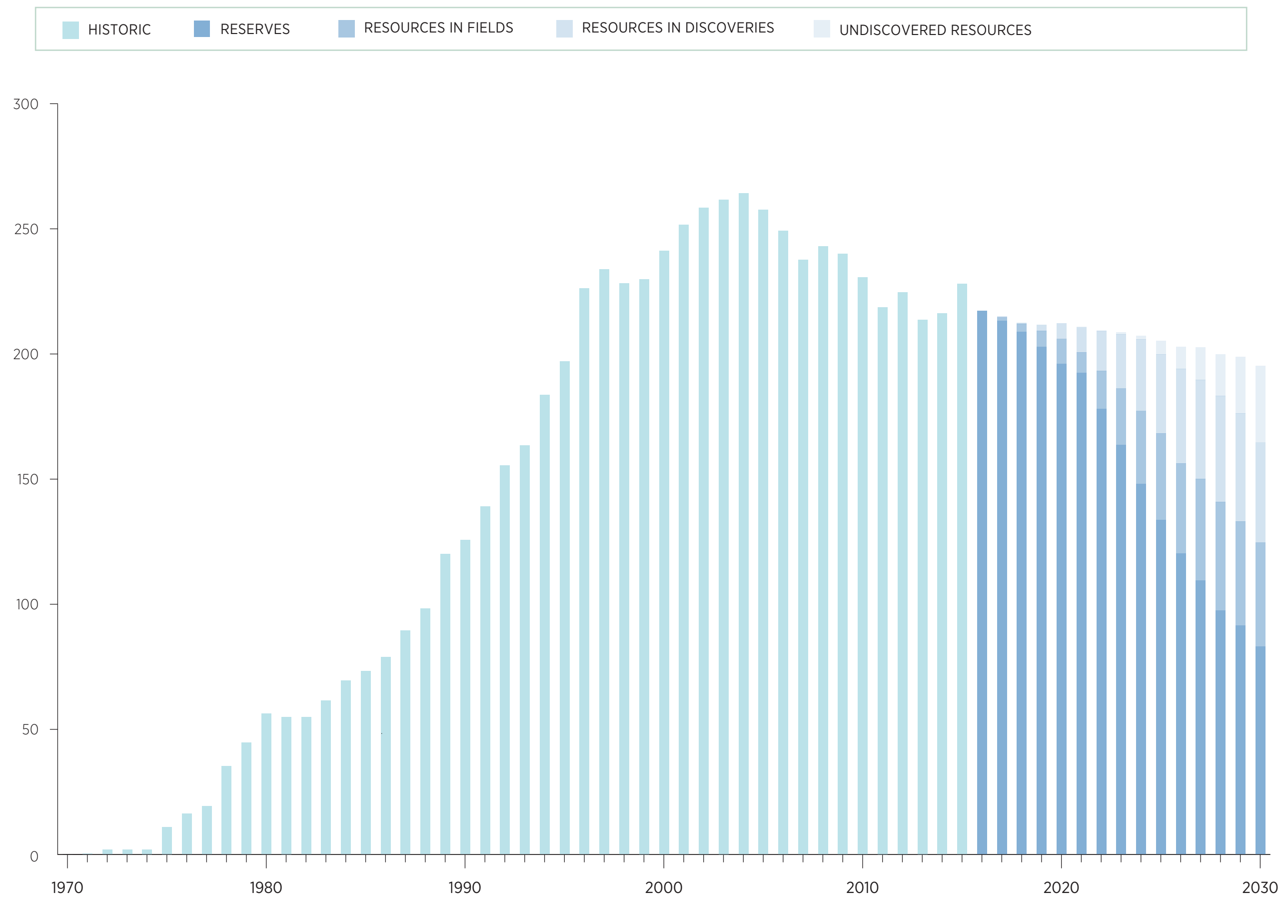


FIGURE 21
Expected development solutions for current discoveries on the NCS (NPD, 2015)

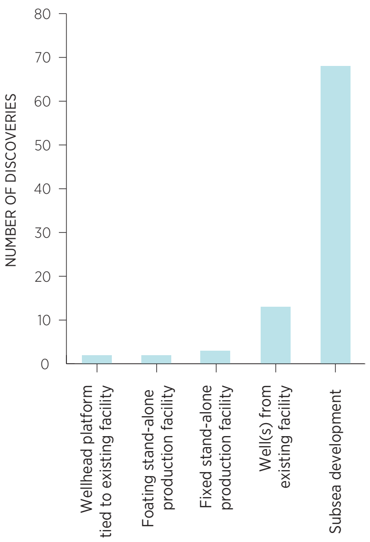
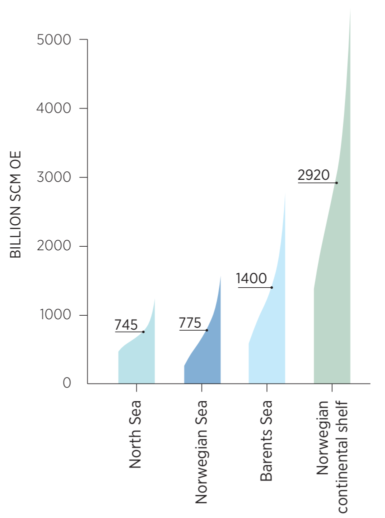


FIGURE 22
Estimates for NCS undiscovered recoverable resources with uncertainty ranges (NPD, 2016)



The relative importance of gas has been increasing on the NCS (NPD, 2015). In 2015, Norway produced equal amounts of gas and oil measured in Sm^3 oil equivalents. It is expected that the relative share of oil will recover for a period as a result of some large oil field developments (e.g. Johan Sverdrup phase 2, Johan Castberg and others), (Rystad Energy, 2016).

The current discovery portfolio on the NCS is dominated by many small development projects. Many discoveries are located close to existing infrastructure. Excluding the Johan Sverdrup and Johan Castberg fields, about 80 per cent of resources in the discoveries lie within a distance of roughly 40 kilometers from existing infrastructure. Utilizing existing infrastructure to realize the resources in small fields is therefore attractive. This underpins the importance of life extension of existing infrastructure to enable new production.

Figure 21 shows likely development solutions for the 88 discoveries in the 2015 portfolio of discoveries on the NCS (NPD, 2015). Subsea facilities tied back to existing installations could represent the most relevant solution for 68 of the 88 discoveries. Wells drilled from existing facilities are also a common development solution for small discoveries close to infrastructure with spare capacity. In not to deep waters, such as the North Sea, simple wellhead installations can be a relevant development solution instead of subsea facilities. For deeper waters, unmanned floating facilities could also be an alternative to subsea solutions. Discoveries which require long tie-backs to infrastructure with spare capacity, and which cannot justify a stand-alone development on their own, could be developed through coordinated area developments.

To maintain production from the NCS after 2030, new fields would have to be discovered and developed. Figure 22 shows NPD's estimates on undiscovered, recoverable resources on the NCS (NPD, 2014). While the North Sea and the Norwegian Sea still offer great opportunities, the highest expectations are for the Barents Sea.

B.3. Minimize environmental impact

Reducing GHG emissions
The petroleum industry in Norway contributed in 2015 with 28 percent of Norway's total greenhouse gas emissions, and the relative contribution trend is increasing (Rystad Energy, 2016).
CO_2-emissions from the final combustion of petroleum products (end-user) and from the downstream processing of products from the NCS, are higher than the emissions from the Norwegian oil and gas production. The emissions from the production contribute with 3 percent of the total CO_2-emissions when looking at the entire value chain (Rystad Energy, 2016).

Natural gas is to a large extent used for power generation where it, when substituting coal, reduces CO_2-emissions by approximately 50 percent. CCS is an opportunity and strategic element for Norway for further strengthening of the future market position for natural gas.

The COP21 meeting in Paris adopted ambitious climate targets. The aim is to keep the increase in global average temperature to well below 2 °C compared to pre-industrial levels, and strive to limit the temperature increase to 1.5 °C.

Norway has committed to reduce the greenhouse gas emissions from within its borders by 40 percent between 1990 and 2030, and to further reduce emissions after that to become carbon-neutral by 2050. The intention is to achieve the targets in collaboration with EU. EU's target is to reduce its own emissions with 40 percent without purchasing international quotas. To achieve its goal, EU wants the emissions from industries defined within the EU quota system to be reduced by 43 percent in 2030 as compared to 2005. The emission reduction will be achieved by cutting down the number of quotas year by year.

The Norwegian oil and gas sector is part of the EU CO_2-emissions quota system. In addition to paying for emission quotas, emitters on the NCS are paying a national CO_2-tax.

Platforms already installed will continue to dominate the petroleum production on the NCS towards 2030. Reducing greenhouse emissions from existing platforms is hence an important element of a climate gas reduction strategy for the NCS. Figure 23, showing a break-down of the greenhouse gas emission from the Norwegian petroleum production, draws the attention to combustion machinery for power production as a main target for reducing emissions. There are also some opportunities related to mobile drilling units and flaring, although the reduction potential for these two elements is considerably lower than for power generation machinery. In addition there are opportunities within energy efficient operations, such as energy management and logistics and supply.

After 2030, the NCS production will more and more be dominated by new fields already in the discovery portfolio of 2016 or discovered after 2016. For mature areas of the NCS, the majority of new discoveries are likely to be small, and resource realization would be dependent upon tie-back to and utilization of already established infrastructure. In addition to energy efficiency measures on the existing infrastructure, there are also opportunities for innovative power supply and/or distribution to the new satellites that could save energy and reduce emissions.

Larger discoveries could still be made in mature areas of the NCS, and maybe more likely, in the Barents Sea. New stand-alone developments offer opportunities for developing innovative and flexible energy supply solutions.

FIGURE 23
Breakdown of 2014 lifecycle CO_2 emissions originating from Norwegian oil and gas (Rystad Energy, 2016)

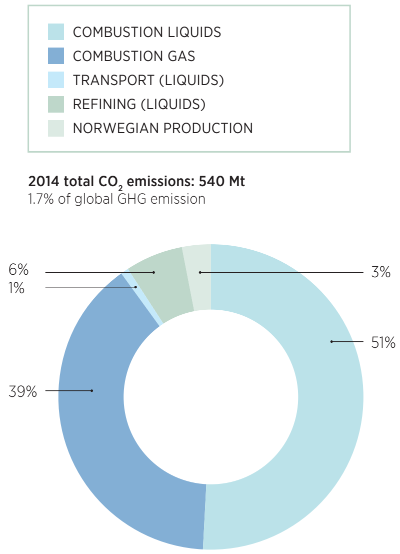
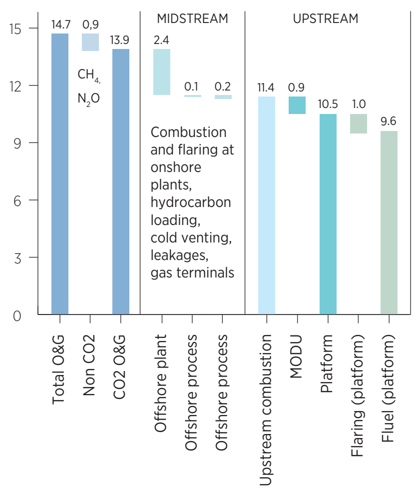
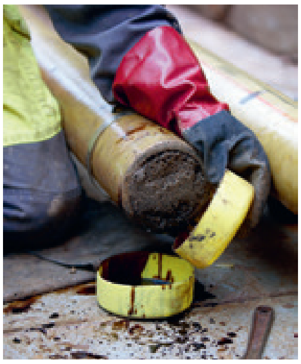


FIGURE 24
2014 GHG emissions from Norwegian petroleum production, million tons CO_2 equivalents (Rystad Energy, 2016)





Transocean Leader at the Aldous field - core sample.
Photo: Anette Westgård / Statoil

Minimizing environmental risks from planned operations
The Norwegian petroleum production is among the cleanest globally. Keeping emissions and discharges as low as practically possible is important to keep environmental risks low and to maintain the industry's acceptance in the society. Some data on discharges and emissions are provided below. A comprehensive disclosure of NCS discharges and emissions is provided by the Norwegian Oil and Gas Association (2015).

The water cut increases as the NCS matures, and as a consequence the amounts of produced water increases, Figure 25. Produced water is either treated to well below acceptable limits and discharged to sea, or injected into reservoirs. Small amounts of oil and dissolved chemicals are released with the discharged water.

In addition to oil and chemicals discharged with produced water, chemicals are discharged also from other parts of the production. Figure 26 presents the percent-age breakdown of chemical discharges on the NCS split on the colour categories green, yellow, red and black, where green chemicals have the least environmental impacts and black the most potential impact. Chemicals are assessed on the basis of their environmental properties, including persistence, bioaccumulative ability and toxicity (PBT).

There are still opportunities related to further reducing emissions and discharges, monitoring and modelling discharges and impacts, and to assess and understand environmental risks.

Minimizing risk of acute spills
The number of acute oil spills has decreased on the NCS over the 2004-2014 period, see Figure 27, whereas there has been an increasing trend for the number of acute chemical spills, see Figure 28.

Unplanned spills of oil and chemicals are a concern. Spills have environmental impacts and possibly unacceptable environmental consequences, they cause operational disruptions and they are costly to manage. Avoiding accidental spills altogether and reducing environmental impacts should they occur, are priorities for the industry.

FIGURE 25
Produced water on the NCS, million cubic meters
(Norwegian oil and gas association, 2015)

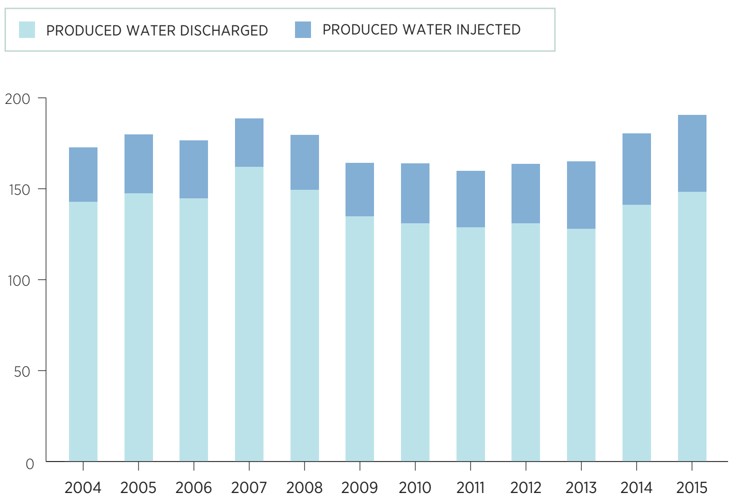


Illustration: Aker Solutions

FIGURE 26
Chemical discharges on the NCS broken down by NEA's color codes
(Norwegian oil and gas association, 2015)

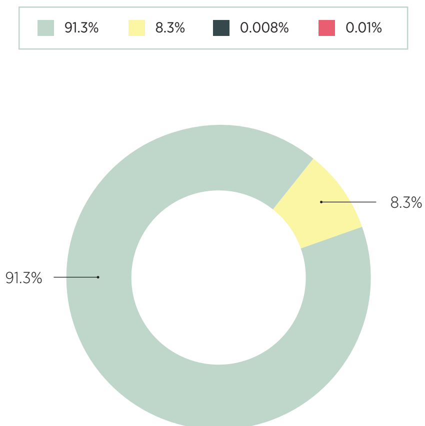
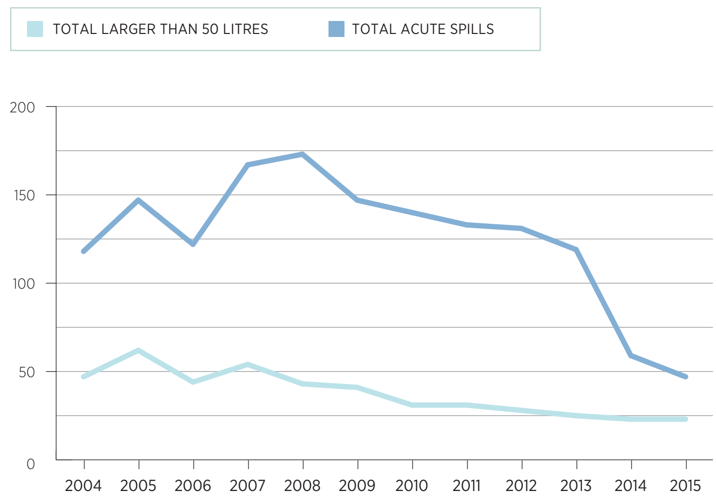
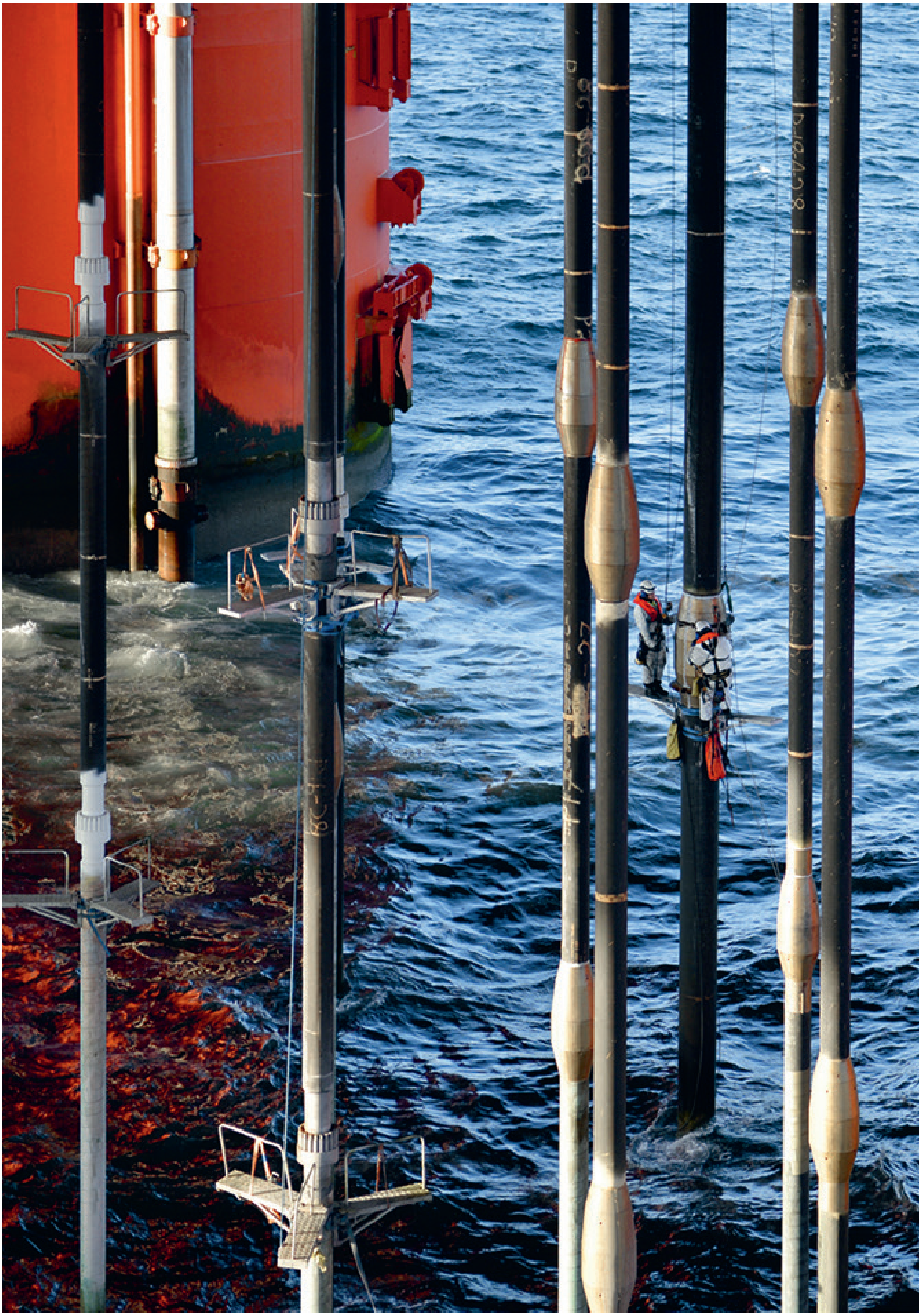


FIGURE 27
Number of acute oil spills on the NCS
(Norwegian oil and gas association, 2015)





←

Risers on Snorre A.
Photo: Harald Pettersen / Statoil

B.4. Improve productivity and reduce costs

The future of the NCS is dependent upon being competitive with other oil and gas supplier regions in the world. According to Rystad Energy, break-even prices for Norwegian prospects are fairly competitive in the international picture, but important competition like shale oil and oil sands, which currently appear to be more costly than Norwegian petroleum, are experiencing strong productivity gains with reduced break-even prices as a result.

The average opex per barrel for current producing oil fields on the NCS was approximately 80 NOK per barrel in 2015. This was very competitive compared to most other oil producing regions in the world, except the Middle East countries (Rystad Energy, 2016). However, as fields are maturing, the opex increases considerably as shown in Figure 29. The production forecast, see Figure 20, shows that fields producing today, will continue to be a main contributor to the production in 2030, and also be important to enable production from smaller fields.

Hence, to stay competitive, the Norwegian continental shelf will have to improve its productivity, i.e. to produce more with less effort and input. Much can be achieved by more stringent cost control, improved contracts and cultural changes, but fundamental shifts through implementation of new technologies and changed work processes, would be key to obtain the necessary productivity improvements.

FIGURE 28
Number of acute chemical spills on the NCS (Norwegian oil and gas association, 2015)

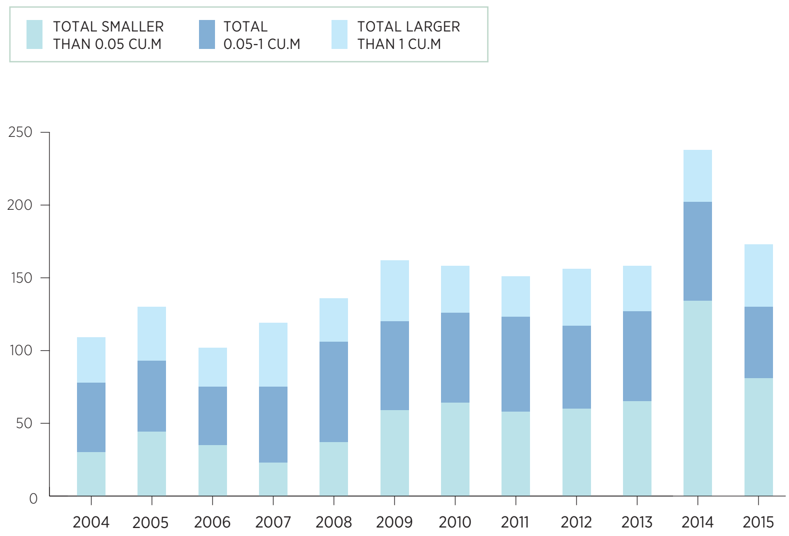
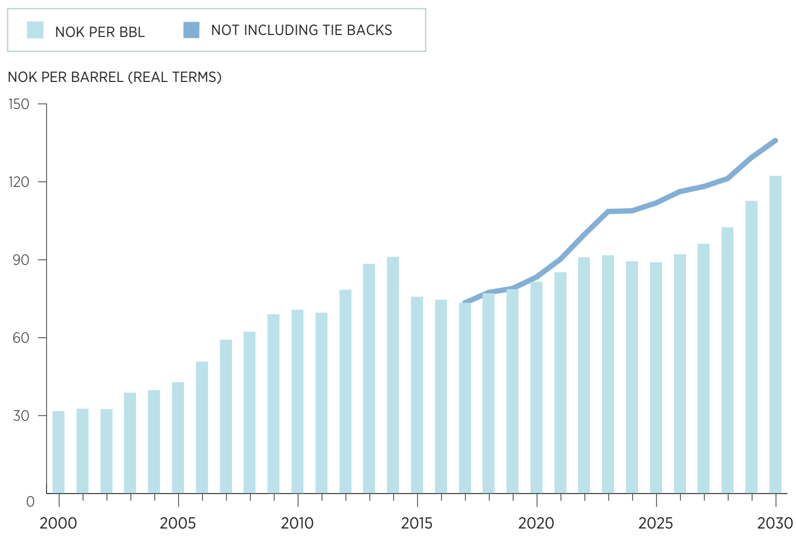


FIGURE 29
Operating expenditures per barrel on current producing oil fields on NCS, (Rystad Energy, 2016)



B.5. Develop innovative technologies

The Norwegian supplier industry provides services and solutions with high technology and competence content to the global petroleum equipment and services markets. Norwegian suppliers have a strong position in the international markets, and the international part of their revenue was 195 billion NOK in 2014, see Figure 30. It was shrinking in 2015 and is expected to do so also in 2016, but the supplier industry is still Norway's 2nd largest export industry only surpassed by the export of petroleum products.

Norwegian suppliers grew strong on developing solutions to the NCS. Now they are facing increased competition from suppliers globally, and they are experiencing a significant drop in activity both on the NCS and internationally due to lower oil prices. Figure 31 shows that especially within drilling equipment (main part of "topside and processing equipment" category) and subsea equipment and services, Norwegian suppliers have lost market shares over the 2013-2014 period.

Maintaining a competitive supplier industry is important for creation of jobs as well as value creation for the Norwegian society.

B.6. Attract, develop and retain the best talents

The petroleum activities on the NCS are technologically challenging and access to talent and competence is fundamental to be able to realize the petroleum resources. Likewise, the success of the Norwegian suppliers is based on high competence contents of services, products and solutions.

The number of employees in Norway working in the oil and gas industry grew from around 100 000 in 2000 to almost 170 000 in 2013, Figure 32. Lay-offs during the low activity period starting in 2014, had by mid-2016 reduced the workforce with 20-30 thousand employees, (Rystad Energy, 2016).

The staff reductions are concerning with respect to the industry's capability of responding to an activity rebound. Figure 33 shows how a demographic gap within the Norwegian petroleum industry evolved after year 2000, probably as a result of the activity reduction around year 2000 (IRIS, 2016).

The share of employees with a university degree in the Norwegian petroleum industry was 40 percent in 2014, up from 34 percent in 2010 and 32 percent in 2003.

The public petroleum research funding through the Research Council of Norway is an important contributor to Ph.D.-education in Norway with 122-136 Ph.D. positions during the years 2013-2015 (RCN, 2016). Petromaks2 is the dominant source of petroleum Ph.D. funding, but other programs such as the Petro Centers, the Industry Ph.D.-arrangement, and various COEs/CRIs. are also important.

Attracting and retaining competence can be positively influenced by maintaining or increasing R&D activities in academia, research institutes, supplier companies and oil companies. There are lots of technology challenges for the industry near-term and long-term, and counter-cyclical measures would therefore produce valuable knowledge and solutions in addition to maintaining the industry's competence base.

FIGURE 30
International revenue from Norwegian suppliers, NOK Billion
Source: Rystad Energy report to MPE, October 2015.

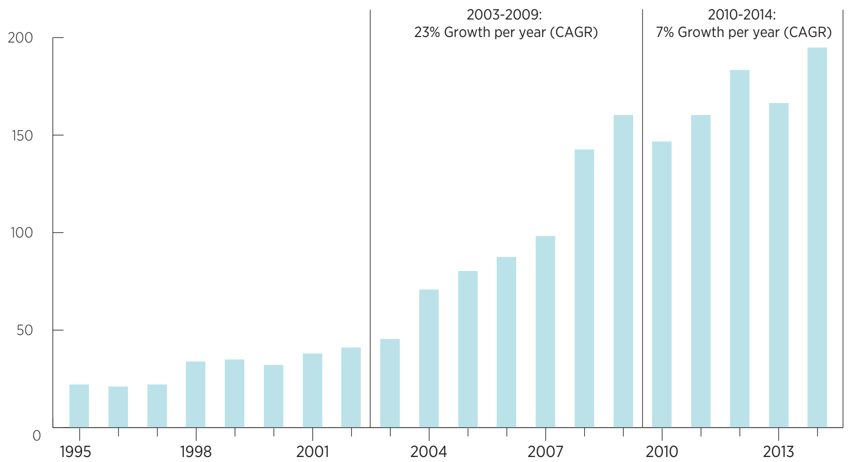


FIGURE 31
Market share and growth potential of international revenue, main export segments (Rystad Energy, 2016)

	INTERNATIONAL REVENUE	MARKET SHARE	MARKET SHARE GROWTH 2013-2014	Y-Y MARKED GROWTH 2015-2030
Topside and Processing Equipment	67	20%	-13% ↓	0% →
Subsea Equipment and Installation	31	9%	-8% ↓	7% ↑
Transportation and Logistics	29	14%	5% ↑	4% ↑
Operational and professional services	24	7%	15% ↑	3% ↑
Seismic and G&G	14	17%	0% →	2% ↑
Procurement, Construction and Installation	12	4%	26% ↑	0% →

Overall offshore 3% ↑

FIGURE 32
Staff in oil and gas related companies in Norway, thousand employees.
(Rystad Energy, 2016)

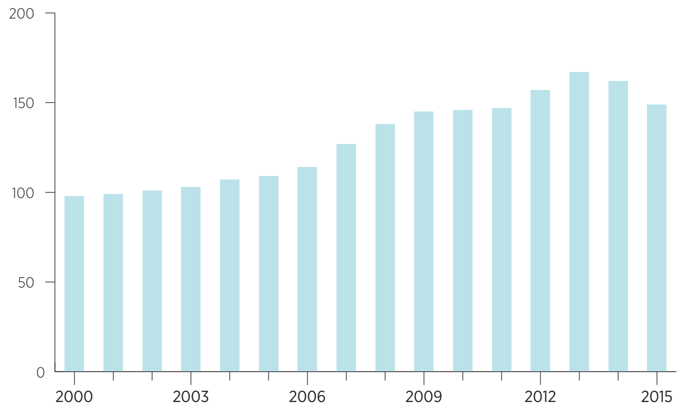
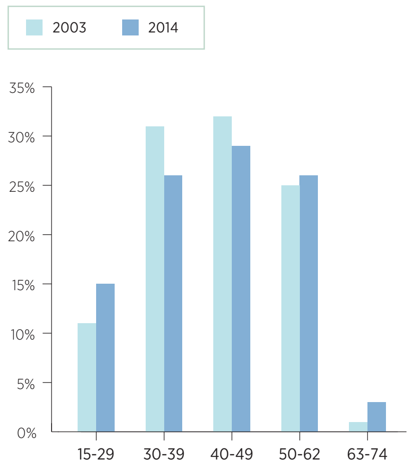


FIGURE 33
Age distribution of workforce in oil companies, pipe transport, oil service, petroleum onshore bases and yards, 2003 and 2014.
Based on SSB data. (IRIS, 2016)




MAERSK INTEGRATOR

←

Gina Krog. Photo: Øyvind Torjusen / Statoil

APPENDIX C.

DETAILS ON PRIORITIZED TECHNOLOGY NEEDS

Gina Krog by night.
Photo: Øyvind Torjusen / Statoil

C.1. Prioritized technology needs for each TTA

OG21s vision and strategic objectives have guided the identification and prioritization of technology needs, as illustrated in Figure 34.

Prioritized technology needs for the four TTAs are presented in Table 8 through Table 11. An overview map is presented in Table 13.

FIGURE 34
Technology needs derived from strategic objectives

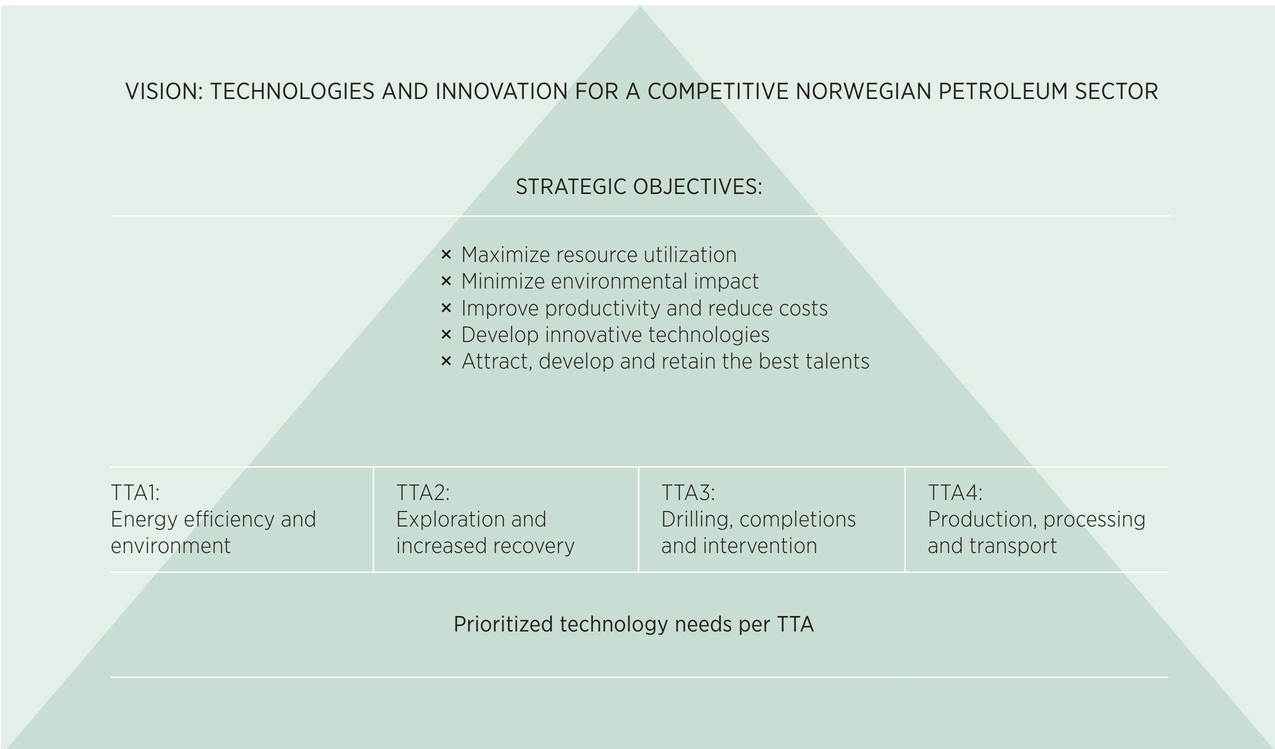


TABLE 8 TTA1 – prioritized technology needs

TTA1 PRIORITIZED TECHNOLOGY NEEDS	TECHNOLOGY NEED DESCRIPTION AND EXAMPLES
Integrated environmental monitoring and modelling systems	× Improved decisions through data gathering, systemizing, and analysis. × Real-time coupling environmental data to process/production data. × Includes human interfaces and use. × Improved predictive and decision models. × Systems to integrate data and models between fields and operators, e.g. ecological resources distribution and variation. × Integration between leak detection sensor systems and models for real-time monitoring. × Better understanding of leakages and their characteristics through analyses and modelling. × Vulnerability and security of components and systems.
Technical safety barriers High North	× Safety barriers management and solutions for operations in ice, e.g.: – Optimization between designing for loads and disconnecting systems. – Alternatives to relief wells. – Alternatives to capping and containment. × Cultural/organizational/management issues on decision support and actions.
Oil spill preparedness	× High North: Oil drifting into ice infested waters, e.g. weathered oil. × High North: Winterization of response equipment. × Response technologies in high waves. × Subsea injection of dispersants. × Subsea leak detection systems.
Produced water management for EOR chemicals	Find environmentally friendly: × EOR chemicals - polymers, etc. × Produced water treatment of EOR chemicals, × Produced water re-injection suitable for EOR chemicals.
Cost effective subsea safety barriers	× Improved interaction between operational, organizational and technical accident barriers and of the relationship between risk management and managing barriers × Proactive, model-based decision support systems. × Collaborative technology and collaboration surfaces providing global access to real time information and integration of multiple expertise across disciplines, organizations and geographical locations. × Use of data for decision support (high need LoVeSe and High North).
Improved efficiency of power and heat production	× Improve gas turbine thermal efficiency. × Use produced fluids as heat source. × Hybrid power supply systems: – Fuel cells. – Battery technologies. × Improved availability and more cost-efficient electricity from onshore grid. × Offshore geothermal energy for use in petroleum operations (e.g. from Hotspot in the Barents Sea): Produce heat and power from reservoir also after depletion..Conversion to power either direct conversion thermal/electricity or via heat exchanger.
Improved weather forecasting High North	× Forecasting, simulation and monitoring of ice and icing. × Knowledge of polar lows and troughs and implications to design and operational philosophy.
Improved communications High North	× Poor reception from geostationary satellites -cross-industry need for polar satellites/HEO satellites. × Enable telemedicine prior to fiber installation.

TABLE 9 TTA2 – prioritized technology needs

TTA2 PRIORITIZED TECHNOLOGY NEEDS	TECHNOLOGY NEED DESCRIPTION AND EXAMPLES
CO_2 for EOR and storage	× Reservoir monitoring. × In addition, the same details apply as for technology need “Water diversion and radical new EOR methods.
Improved reservoir understanding and management	× Tight reservoirs: «converting» log response (WL and MWD) to physical properties (permeability, porosity and water saturation). × Integrate all data types (ex. Geophysical data, well-logs, production/pressure data, tracer data) using data assisted interpretation methods for generation and conditioning reservoir models. × Collect sufficient data, share and make use of data. × Combined use of geophysical reservoir management (GRM), production data and tracer data for real time management. × Reduce environmental impacts from seismic data acquisition. × Vulnerability and security of components and systems.
Understand and maintain well productivity, and smart well solutions.	× Linked to reservoir understanding and also aging infrastructure. Link to TTA3
Improved HC-prospect identification	× Basin modeling, source rock & migration prediction: concepts, tools and capabilities to predict source rock, HC generation & migration. × EM-data for shallow reservoirs (High North) × Prospect screening based on integration of geological and geophysical understanding, seismic data interpretation using advanced computer technology (including big data and cognitive computing) × Vulnerability and security of components and systems.
Water Diversion and radical new EOR methods	× Increase sweep efficiency. × Increase oil mobilization. × Improved understanding of mechanisms for diversion and oil mobilization. × Improved tools for testing, upscaling (lab to field), modelling and simulation.
Improved exploration technologies	× Trap prediction: Enhanced understanding of different trap types and their seal pressure capacity. × Seismic interpretation: Integrated processing, imaging and interpretation, using all available data and concepts/models. × Seismic acquisition: New source types for enhanced resolution with minimal impact on the environment. × Vulnerability and security of components and systems.

TABLE 10 TTA3 – prioritized technology needs

TTA3 PRIORITIZED TECHNOLOGY NEEDS	TECHNOLOGY NEED DESCRIPTION AND EXAMPLES
Smart well solutions	× Solutions to improve production from tight chalk and heterogeneous sandstones × Water shut-off: – Autonomous inflow control AICVs. – Patch-thru-patch. – Expandable pipe to seal off watered-out perfos – installable through existing patches (not only bottom's up). × Reliable intelligent well system. × Multi-lateral technologies / hydraulic fracs,
Cost-efficient drilling and completion technologies for challenging reservoirs (depleted, tight margins, faulted, karstified carbonates)	× Managed pressure drilling. × Dual gradient drilling. × Mud cap drilling. × Seismic while drilling. × Liner drilling. × Drilling and completion solutions for high dogleg well designs.
Drilling automation and autonomy	× Drilling optimization and well control: – Downhole models. × Drillfloor automation and autonomy, e.g. pipe-handler / iron roughneck / elevators. × Full electric and autonomy. × Vulnerability and security of components and systems.
High North shallow reservoirs drilling solutions – high reservoir exposure	× New well standard for shallow low pressure, low temperature reservoirs: – Simplified casing program. – Drilling without BOP to top of reservoir. – Drilling and completing long horizontals. – Multi-lateral technologies. – New wellhead and subsea template standard. – LP/LT X-mas tree.
All-electric subsea wells for longer tie-backs and/or deeper waters	× All-electric well: – All electric subsea production facilities. – All-electric X-mas tree. – All-electric safety valve. – All-electric downhole instrumentation and equipment, both drilling and production phase. – Downhole power supply. – Downhole to surface & downhole internal communication. – All-electric BOP. × Integration of components with other system components.

TTA3 PRIORITIZED TECHNOLOGY NEEDS	TECHNOLOGY NEED DESCRIPTION AND EXAMPLES
High North well bore positioning and navigation	× Improved well positioning that address the inaccuracy caused by proximity to magnetic North, e.g. seafloor reference beacon system.
Energy efficient rig power generation	× Increased fuel efficiency and decreased emission per produced kW electricity, × Hybrid systems: – Solid state generator (batteries pack) and automated control of multiple generators. – Mechanical storage of energy as back-up – flywheels, etc. – Electricity supply from subsea connector (in combination with electric subsea facilities). – Fuel cells.
Reduce intervention cost and increase reservoir exposure from existing subsea wells	× Riserless Light Well Intervention (RLWI) vessels providing wireline and coiled tubing services on NCS. × Put equipment on the seabed. × Fit for purpose vessels and equipment × Standardization of subsea equipment. × Through tubing drilling and completion and Through tubing MLT well construction. × Cost-efficient slot recovery..
Plugging and abandonment of wells	× Risk based methods and methodology. × Rigless methods and technologies. × Technologies to reduce time. × New methods for removing tubulars. × New plug materials. × Understand natural barriers and how they can be used as part of P&A. × Life cycle approach to well design. × Cost-efficient slot recovery.

TABLE 11 TTA4 – prioritized technology needs[2]

TTA4 PRIORITIZED TECHNOLOGY NEEDS	TECHNOLOGY NEED DESCRIPTION AND EXAMPLES
× Life extension of fields – Improved condition assessment. – Condition based maintenance – Establish and improve degradation models × More efficient produced water handling × Process simulation and optimization × Efficient marine operations	× Life extension - critical items: wellhead, subsea, riser, mooring, hull. Monitoring technologies. Automated monitoring. Load/response/capacity calculation methods and MetOcean design basis. Making equipment fit for future life of on field, including new tie-ins, with potential new fluids and conditions going forward. × Process simulation and optimization w/ automatic control or real-time guidance on process optimization. × Marine operations - New tools and methods for inspection, maintenance and repair. × Development of sensors and use of systems with varying degree of autonoomy (i.e. AUV, UAS(drones) and robots).
× Cost-efficient utilization of host platform by subsea developments – Subsea processing, transport of products and power distribution – De-bottlenecking of host platforms – Unmanned platform concepts w/ partial processing – Unmanned platform concepts w/ wells only – Life extension of host infrastructure	× Simplified satellite system: Single well solution. × Simplified subsea power conversion and distribution. × Simplified subsea communication and control power. × Subsea storage. × Simplified subsea compression and boosting. × All electric subsea system. × Subsea processing system solutions. × Improved risers with high production efficiency. × Fiscal metering subsea and topside. × Compact topside process equipment. × Flow assurance and compatibility issues for tie-in and host flows. × Distribution of products to meet specification at different hosts.
× Lean stand-alone field development concepts × Unmanned operations.	× Extended reach for multiphase transport – flow assurance (expanding operational envelope within wax and hydrate regime). × Flexible field developments. × Unmanned operations: Platform concepts, floating or fixed, with wells only or partial processing capabilities. × Lean subsea production systems. × Standard interfaces on subsea production systems.

[2] The table highlights the TTA top prioritized needs related to specific themes. It is defiantly so that several needs will materialize in more than one of the themes. Still, the table is made trying not to duplicate, but rather build on the needs identified within other themes.

TTA4 PRIORITIZED TECHNOLOGY NEEDS	TECHNOLOGY NEED DESCRIPTION AND EXAMPLES
× Flexible field development concepts.	× Enable tie-backs up to 250 km for gas, 100 km for oil. × Cost-efficient concepts. × Technologies enabling phased expenditure in developments without increasing the total development cost. × Flexible energy management for reduced CO_2 footprint. × System for optimized integration of IOR/EOR measures. × Automation and autonomy in operation and maintenance.
× Autonomous components, systems and decision support. × «Integrated monitoring», combining models, sensors and big data/advanced data analysis, data fusion.	× Virtual asset that can emulate ongoing and planned operations. × Standardised communication, sensor interchangeability new and cost effective sensors, internet of things. × Vulnerability and cyber-security of components and systems. × Examples: HW in the loop, wireless components.
Energy generation and management to reduce emissions: × Efficient power generation × Optimize energy use locally × System level energy optimization × Low-emission production systems	× Fuel cells, hybrid systems, improved gas turbines, gas turbine bottom cycles, subsea local power generation. × Optimize operations to minimize energy need, including waste heat recovery. × Flexible power generation, integration between installations, distribution systems / power grids, integrating renewables, batteries. × Reduction of CO_2 emissions by step-change in cost efficient treatment of exhaust (for injection), monitoring and reduction of methane/nmVOC, improved flaring systems. × Full value-chain energy loss evaluations utilizing reservoir energy in a most efficient manner; pore to market. × Cost efficient system for CO_2 reduction through new, alternative hydrocarbon value chains.
× High North Flow assurance × High North shallow reservoirs, subsea facilities incl subsea compression	× Material solutions, platform and pipeline, insulation and flow assurance technologies for cold climate operations. × Subsea template solutions improving ability to drill shallow reservoirs. × Simplified subsea compression and boosting.

C.2. Technology needs overview map

An overview map of the prioritized technology needs described in Table 8 through Table 12, is presented in Table 13. The table presents technology needs only at a high level, and details are found in the specific TTA-tables.

The classification "Technology areas", explained in Table 12, has been introduced in the overview table to provide a link to the value potential estimates in Appendix D.

→

Pipe-laying from Solitaire.
Photo: Eva Sleire / Statoil

TABLE 12 Technology area categorization used for value estimates

TECHNOLOGY AREA	DESCRIPTION
Energy efficiency	Technologies contributing to more efficient energy production and less energy consumption, primarily at existing offshore facilities.
Zero carbon emissions	Technologies enabling renewable power supply to offshore facilities or «net zero» emissions through CCS. Includes electricity from shore, and delivery of de-carbonized energy carriers (e.g. hydrogen).
Subsurface understanding	Technologies that improve the understanding of petroleum systems and –reservoirs and thereby improve exploration success and reservoir sweep efficiency. Digitalization in the form of data acquisition, data management and data integration is key
Drilling efficiency	Technologies that reduce the overall work effort involved in well construction, hence lowering the cost of exploration and production wells
Production optimization	Processing, downhole and intervention technologies that increase the regularity, availability and productivity of wells and installations.
Improved subsea and unmanned systems	Technologies that are reducing development costs and increasing the capabilities of subsea and unmanned production systems, e.g. lean subsea production systems and unmanned platform concepts floating or fixed with wells only or partial processing.
EOR	Offshore technologies that increase production of mobile oil by coping with early water break-through issues or enabling production of immobile oil.

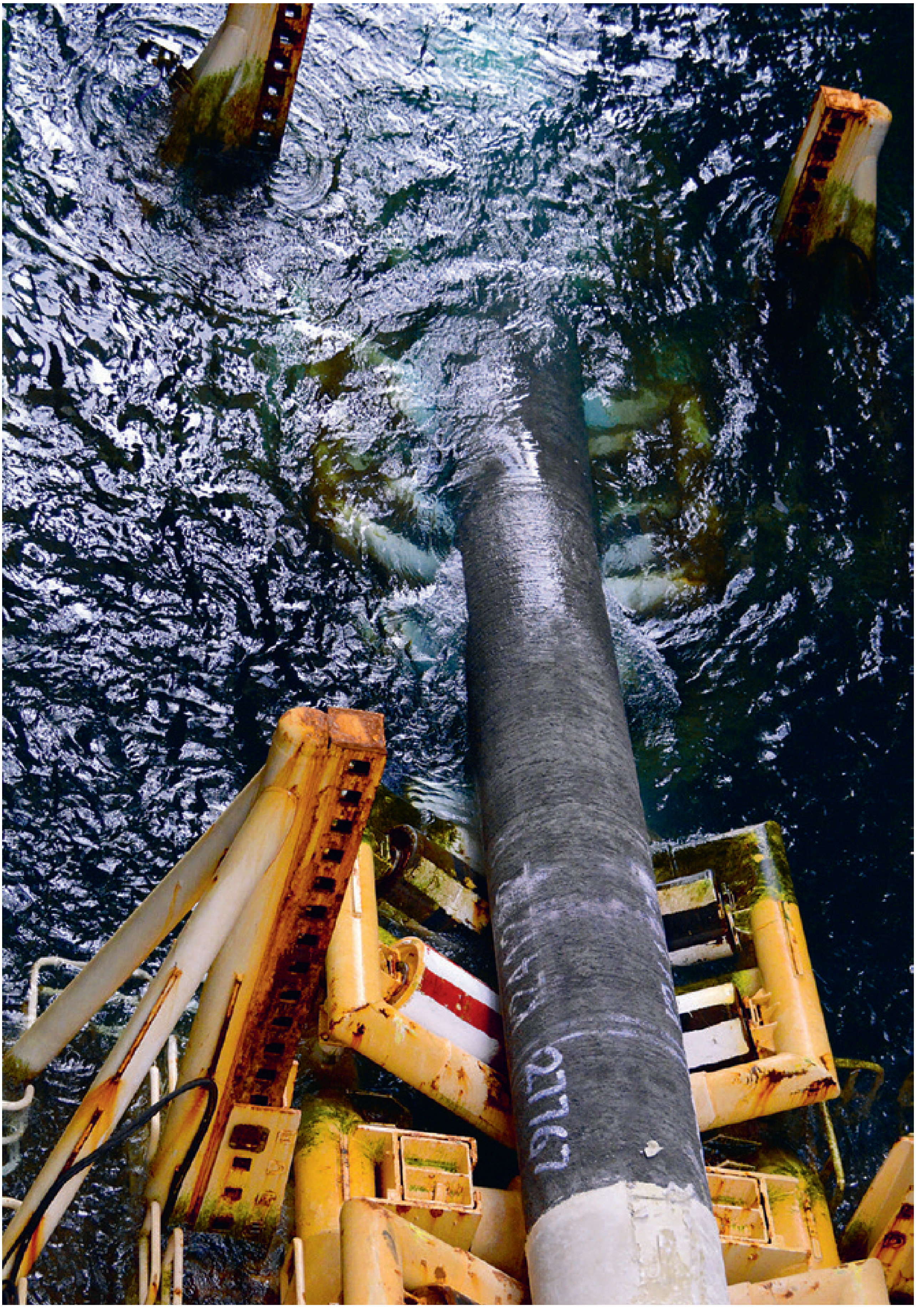


TABLE 13 Summary of prioritized technology needs split on Technology Target Areas (TTAs)

TOPIC	TECHNOLOGY AREAS			CROSS-TTA CATEGORIES
Energy Efficiency and reduced CO_2-emissions	Energy efficiency – existing facilities	"Zero carbon emissions" – New facilities		Improved efficiency of power and heat production
				Reduced energy consumption
				Other reduced GHG emissions
Digitalization	Subsurface understanding	Drilling efficiency	Production optimalization	Data acquisition
				Data management and data quality
				Data integration and decision support
				Data security
High North	Subsurface understanding	Drilling efficiency		Shallow reservoirs/ carbonates
	Improved subsea and unmanned systems			Long distances, logistics
				External environment

PRIORITIZED TECHNOLOGY NEEDS PER TTA (FURTHER DETAILS IN TTA-TABLES)			
TTA1	TTA2	TTA3	TTA4
× Improved efficiency of power and heat production		× Energy efficient rig power generation system	× Energy generation and management
		× Drilling automation and autonomy × Reduce intervention cost and increase reservoir exposure from existing subsea wells × Plugging and abandonment of wells	× Energy generation and management
	× CO_2 for EOR and storage		
× Integrated environmental monitoring and modelling systems	× Improved reservoir understanding and management × Improved exploration technologies	× Drilling automation and autonomy	× Integrated monitoring
× Vulnerability and security of components and systems			
	× Improved exploration technologies × Improved reservoir understanding & management × Improved HC-prospect identification	× High North shallow reservoirs drilling solutions	× High North shallow reservoirs, subsea facilities incl subsea compression
			× High North flow assurance
× Technical safety barriers High North × Oil spill preparedness × Weather forecasting High North × Communications High North		× High North wellbore positioning and navigation systems × Smart well solutions	

→ CONTINUES ON NEXT PAGE

TABLE 13 Summary of prioritized technology needs split on Technology Target Areas (TTAs)

TOPIC	TECHNOLOGY AREAS			CROSS-TTA CATEGORIES
Exploration	Subsurface understanding	Drilling efficiency		Exploration
Field development	Subsurface understanding	Drilling effciency	Improved subsea & unmanned systems	Small and medium discoveries[3]
	Production optimization			Large discoveries
Optimize production	Subsurface understanding	Drilling efficiency	Production optimization	IOR
	EOR			EOR
	Production optimization			Life extension
End of life				End of life

[3] In this context, large discoveries are those that traditionally would justify stand-alone developments, typically 150-250 mmboe and larger. Small and medium discoveries are those that traditionally would be tied back to a host.

	PRIORITIZED TECHNOLOGY NEEDS PER TTA (FURTHER DETAILS IN TTA-TABLES)			
	TTA1	TTA2	TTA3	TTA4
		× Improved HC-prospect identification × Improved exploration technologies	× Cost-efficient drilling and completion technologies for challenging reservoirs × Drilling automation and autonomy	
	× Cost effective subsea safety barriers × Oil spill preparedness	× Improved reservoir understanding and management	× All electric subsea wells × Smart well solutions	× Cost-efficient utilization of host platform by subsea development × Lean stand-alone field development concepts × Unmanned operations × Life extension
	× Cost effective subsea safety barriers × Oil spill preparedness		× Smart well solutions.	× Flexible field development concepts × Unmanned operations
		× Understand and maintain well productivity, and smart well solutions × Improved reservoir understanding and management	× Cost-efficient drilling and completion technologies for challenging reservoirs × Drilling automation and autonomy × Reduce intervention cost and increase reservoir exposure from existing subsea wells.	× Produced water handling × Flexible field development concepts × Unmanned operations × Process simulation and optimization × Efficient marine operations
	× PW management for EOR chemicals	× CO_2 for EOR and storage × Water diversion and radical new EOR methods × Improved reservoir understanding & management		× Flexible field development concepts
	× Cost effective subsea safety barriers		× Cost-efficient drilling and completion technologies for challenging reservoirs × Reduce intervention cost and increase reservoir exposure from existing subsea wells.	× Life extension × Efficient marine operations
			× Plugging and abandonment of wells	

APPENDIX D. VALUE OF ADDRESSING TECHNOLOGY NEEDS

Rystad Energy (2016) has evaluated the potential effects of addressing the prioritized technology needs described in Section 4. Summaries and conclusions are presented in the following sections, sorted under OG21's strategic objectives. Effects and value potentials have been estimated for the "technology areas" categories described in section C.2 of the appendices.

D.1. Maximizing resource utilization

Resource realization is in the study defined as moving resources from one maturity stage to another. The estimated added resources on the NCS by addressing the prioritized technology needs are shown in Table 14.

TABLE 14 Potential added resources by addressing technology needs (Rystad Energy, 2016)

TECHNOLOGY AREA	EXPLORATION	PRODUCTION	FIELD DEVELOPMENT	
	Increased discoveries	Increased recovery	Technically enabled	Marginal project sanctioning
Subsurface understanding	**3 bnboe**	**6 bnboe**		9% points higher recovery rate
Drilling efficiency	**1 bnboe**	**3 bnboe**		5-11% lower well cost
Production optimization	N/A	**2.5 bnboe** Optimized topside processing		4-9% higher production
Improved subsea systems	N/A	**1.5 bnboe** Low cost intervention and smart wells	**3.5 bnboe** Increased tie-in distance 2.5 bnboe Life extension 1 bnboe	20% lower cost of production systems
EOR	N/A	**3 bnboe** 1.1 bnboe from increased mobility control and 1.7 bnboe from immobile oil		8% higher recovery rate
SUM	**4 bnboe**	**14 bnboe**	**3.5 bnboe**	**4.7 bnboe** Platforms 0.7 bnboe Subsea tie-backs 4 bnboe

Exploration: Addressing the identified technology needs has been estimated to add 4 bnboe in increased discoveries, of which 3 bnboe is related to improved subsurface understanding and 1 bnboe to improved drilling efficiency if the savings of more efficient drilling is invested in more wells.

Field development is essential to realizing new resources, and on the NCS, improved subsea systems stands out as the dominant technology improvement area. Improved subsea systems may add 3.5 bnboe from a combination of increased tie-in distances that enable production outside of today's limits of approximately 65 km for oil and 150 km for gas, and life extension of hosts that enable production that would otherwise have been lost due to lack of available tie-back hosts. In addition, improved subsea systems are important to reduce project costs such that more marginal projects are being sanctioned. The estimated added resources could be up to 4 bnboe from future marginal subsea tie-back developments that have break-even prices of 50-90 USD/bbl with current solutions, and which would be in danger of not being sanctioned if break-even prices are not reduced.

Increased recovery: Improved subsurface understanding is also a main contributor to the increased recovery potential, contributing with 6 bnboe of the estimated total of 14 bnboe. But increased recovery is a result of addressing multiple technology needs: More wells as a result of more efficient drilling would contribute with 3 bnboe; production optimization topside improving reliability/availability is estimated to 2.5 bnboe; low cost interventions and/or smart well system could add 1.5 bnboe; and EOR-measures aimed at increased mobility control, as well as at immobile oils, could add an additional 3 bnboe.

The value of the potentially increased production could be around 5000 billion NOK, assuming an oil price of 400 NOK/boe.

D.2. Minimizing environmental impact

The Rystad Energy report is discussing the potential for reduction of GHG emissions. In addition OG21 believes it is of continued importance to minimize planned emissions and discharges as well as the risk for unplanned, acute discharges.

Figure 23 provides the overview of GHG emissions from the Norwegian petroleum industry in 2014. 11.4 million tons were related to offshore power generation. The base case for the NCS is approximately the same for year 2030. As the forecast for oil production shows, see Figure 20, approximately two thirds of the production in 2030 is likely to be through platforms that produce today, and for which major changes to power production facilities could be expensive. However, the operational thermal efficiency of gas turbines could be improved, more waste heat could be used/re-covered and operations could be optimized for lower energy use.

After 2030, new "zero-emissions" power supply and generation solutions could take a more dominant effect to reduce CO_2-emissions.

As discussed in Section B.3, CO_2-emissions from the processing and combustion of oil and gas products from the NCS are a lot higher than the emissions from the petroleum production on the shelf. The NCS, and particularly the North Sea, offer substantial opportunities for CO_2 storage (NPD, 2014). Developing solutions for CCS and putting in place a functioning CCS value chain would therefore offer opportunities for significantly reducing the CO_2 footprint from the NCS.

TABLE 15 Estimated potential for reduction of CO_2-emissions (Rystad Energy, 2016)

TECHNOLOGY AREA	YEARLY CO_2 EMISSIONS, REDUCTION (MT)	
	BEFORE 2030	AFTER 2030
Energy efficiency Main effect before 2030	1.7	0.8
Zero carbon emissions New platforms Main effect after 2030	0.5	1.3

D.3. Improve productivity and reduce costs

Table 16 summarized the estimated cost reductions potential of addressing the prioritized technology needs.

The study suggests that more efficient drilling could reduce annual costs on the NCS by more than 9 billion NOK. The estimate is based on historical data on time use for fixed and mobile drilling units, where the productive time (PT) typically is around 35 percent, the non-productive time (NPT) around 15 percent and 50 percent of the time is used for other operations such as preparations and completions. It was assumed that new or improved technologies typically would reduce PT by 30 percent and NPT by 50 percent. The dominant cost saving potential is related to MODUs, which combined for development/infill drilling and exploration drilling represent more than 8 billion NOK/year. The cost saving estimate for installations with drilling facilities is of an order of magnitude lower due to a combination of fewer such wells and lower potential effects of new technologies.

If the improved efficiency related to new drilling technologies was used for drilling new wells rather than realizing the cost saving potential, the study indicates that 415 more wells could be sunk over the 2016-2050 time interval, which again could result in 2.6 billion boe new resources.

Technologies for subsurface understanding also have a high cost saving potential. To provide an estimate, it was assumed that the same volumes are produced, but that the improved subsurface understanding would be used to accelerate production. Fields could then be drained faster, saving late life OPEX. This highly theoretical calculation provided a cost saving estimate of 18 billion NOK per year. In real life, the improved subsurface understanding would more likely be used to find and realize more resources, as described in Section D.1.

D.3. Develop innovative technologies

In the Rystad Energy study the ability to develop innovative technologies is linked to the current capabilities of Norwegian innovation clusters, the current international market share and the future market growth potential. Under these assumptions the technology innovation potential was assessed, and the results are presented in Table 17.

The highest potential for developing innovative technologies for a global market were assessed to be within zero emissions technologies, subsurface understanding, drilling efficiency and subsea system.

D.4. Attract, develop and retain the best talents

For the OG21 strategic objective "Attract, develop and retain the best talents", Rystad Energy primarily focused on the attractiveness of the various technology improvement areas on students. The results, based on a survey among students, are shown in Table 17.

The results suggest that students want to work with "green" technologies and also within areas where technology challenges are perceived high. Energy efficiency and "Zero emissions" technologies are favourites among students, but also subsea systems and production optimization appear to be popular. Core petroleum subjects as subsurface understanding, drilling and EOR are currently less popular subjects

The study acknowledges that developing and retaining talents is a challenge when the cyclical petroleum industry is in decline as it has been over the 2014-2016 period. Combined with the relatively low attractiveness of core petroleum subjects to students, this may lead to organizational capability challenges when the activity level increases again.

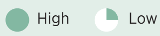
The study does not estimate the potential job creation of the increased activities that would result from more cost-efficient solutions and technologies. IRIS has estimated the total costs per employee in the supplier industry to be approximately 3 million NOK per year (IRIS, 2016). If we assume conservatively that half the annual cost saving potential presented in Table 16 is realized as increased activity, 6000-7000 new jobs could result.

TABLE 16 Estimated cost reductions by addressing technology needs (Rystad Energy, 2016)

TECHNOLOGY AREA	COST REDUCTION PER YEAR [BNOK REAL 2016]
Subsurface understanding	18
Drilling efficiency	9.1
Production optimization – processing	9.5
Production optimization – wells	5.5

TABLE 17 Assessment of innovation potential and attractiveness for new talents (Rystad Energy, 2016)

TECHNOLOGY AREA	INNOVATION	ATTRACTIVENESS FOR NEW TALENT
Energy efficiency	**Medium** Some Norwegian activity within energy transmission and use	
Zero carbon emissions	**High** Norwegian players have leading positions in an immature area	
Subsurface understanding	**High** Good existing talent base, high market share and strong growth	
Drilling efficiency	**High** Drilling clusters in Stavanger and Kristiansand	
Production optimization	**Low** Little expertise on processing optimization in Norway	
Production optimization	**High** High technology competence with long term growth outside Norway	
EOR	**Medium** Ongoing research and competency building. Limited industry uptake	



APPENDIX E.
IMPLEMENTATION AND FOLLOW-UP

E.1. Communication and stakeholder engagement

A successful implementation of the OG21 strategy is dependent upon efficient communication and engagement of the stakeholders.

To influence public petroleum R&D policy and priorities, OG21's goal is to provide well documented guidance on petroleum R&D to the MPE. Policy and priorities are generally reflected in annual allocation letters to the RCN. OG21's secretariat is co-located with the RCN which contributes to an efficient implementation of the recommendations.

An OG21 stakeholder feedback survey revealed that the previous version of the OG21-strategy was well known among the larger oil companies on the NCS, governmental bodies and research institutes and relevant industry organizations (OG21, 2015). The strategy was less known by small, independent oil companies and the general population of suppliers and service providers to the petroleum industry.

OG21's ambition is to influence technology strategies and encourage decisions of the major operators on the NCS and the service and solution providers to these operators, with the overall objective of aligning industry and OG21 priorities.

OG21 therefore needs to step up its communication and engagement efforts towards the service providers and suppliers to the petroleum industry, while maintaining its engagement with other stakeholders that already have a good knowledge of OG21. OG21 will engage directly with its key stakeholders in the oil companies and service companies, and indirectly through industry associations, cluster organisations and authorities.

The OG21 network, organized with a board, TTA core teams and TTA resource groups, is valuable for knowledge and experience transfer and a powerful tool for communication and engagement with key industry players. OG21 therefore wants to continue the TTAs also during the periods between strategy document revisions, although with less frequent meetings and interactions.

OG21 is dependent upon cooperation with industry organizations to communicate its recommendations to the industry. OG21 will further develop its good relationship with Konkraft, Intsok, Norsk Industri and the Norwegian Oil and Gas Association, and provide relevant information to these industry organisations.

To improve the awareness of OG21 in the supplier industry, OG21 wants to strengthen its relationship with relevant technology cluster organizations, and leverage these organizations member networks. The cluster organizations include:

- GCE Subsea
- GCE Node
- GCE Blue Maritime
- NCE System Engineering
- Arena Subsea Valley

OG21 with its network of experienced technology leaders, technology experts and scientists, is a unique pool of competence providing strategic guidance on technology policy and strategy. OG21 is therefore well positioned for taking an "expert role" on petroleum technology in the public domain. A more visible role in the public domain would result in increased awareness of OG21's recommendations, and possibly improved influence of the OG21 strategy on industry prioritizations.

OG21 consider industry conferences as important venues for communicating its recommendations. To the extent possible within the organization's capacity, OG21 accepts invitations to give presentations and participate in panels at such events.

The OG21-forum is OG21's own conference, taking place late fall at an annual basis. It is OG21's ambition that the OG21-forum becomes the most important technology conference for the petroleum industry in Norway. The OG21-forum is used for presenting OG21 recommendations, as well as discussing contemporary industry challenges where technologies are a major part of the solutions.

E.2. Implementation and follow-up

The OG21 board follows up the implementation of the strategy and the impact in its annual review. The results from this review are disclosed publicly through OG21's annual report.

Implementation will be evaluated against strategic objectives and operational targets. The overarching operational targets for OG21 are:

- The OG21-strategy continues to be the basis for public investments in petroleum R&D.
- The OG21-strategy is well known by decision makers in oil companies, supplier companies, research institutes and academia.
- The OG21-strategy influences technology and business investments of oil companies, supplier companies, research institutes and academia.

Detailed operational targets linked to OG21's strategic objectives are presented in Table 18.

TABLE 18 OG21 operational targets

STRATEGIC OBJECTIVE	HIGH LEVEL OPERATIONAL TARGETS	OG21 ACTIVITIES
Maximize resource utilization	× Meet NPD's reserve growth target of 1200 million Sm3 oil or 7.5 billion barrels 2014-2023. × Sanction and develop current portfolio of small and medium discoveries, corresponding to more than half the current resource base.	× Exploration and IOR parts of the public funded R&D portfolio, reflect the expected societal value. × Push for development and use of technologies that improve subsurface understanding. × Urge for the use of technologies to cost-efficiently develop small/ medium sized fields.
Minimize environmental impact	× Maintain Norway's leading position globally on low emissions and discharges.	× Call for increase of public funded petroleum R&D leading to lower GHG emissions. × Push for the use of more energy efficient power generation technologies on the NCS.
Improve productivity and reduce costs	× Avoid increase in operational costs as facilities become older. × Efficient use of existing infrastructure for IOR and tie-backs of new fields.	× Champion the development and use of cost-efficient technologies for life extension, technical integrity and efficient utilization of existing infrastructure.
Develop innovative technologies	× Increase global offshore market share. × Maintain market position in leading oilfield services segments such as subsea and drilling equipment. × Norway remains an attractive place for petroleum R&D.	× Influence development and introduction of new energy efficient petroleum technologies. × Communicate need for improving entrepreneurs' access to risk capital. × Communicate the need to maintain 2016-level public funding to Demo2000. × Communicate need for a significant increase in Petromaks2 funding from 2016-level.
Attract, develop and retain the best talents	× Maintain industry capacity to respond to NCS activity recovery. × Develop competence for the future job market. × Improve industry attractiveness to new talent.	× Communicate capacity risks resulting from down-sizing. × Engage with industry organizations to attract more students to petroleum relevant studies.

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