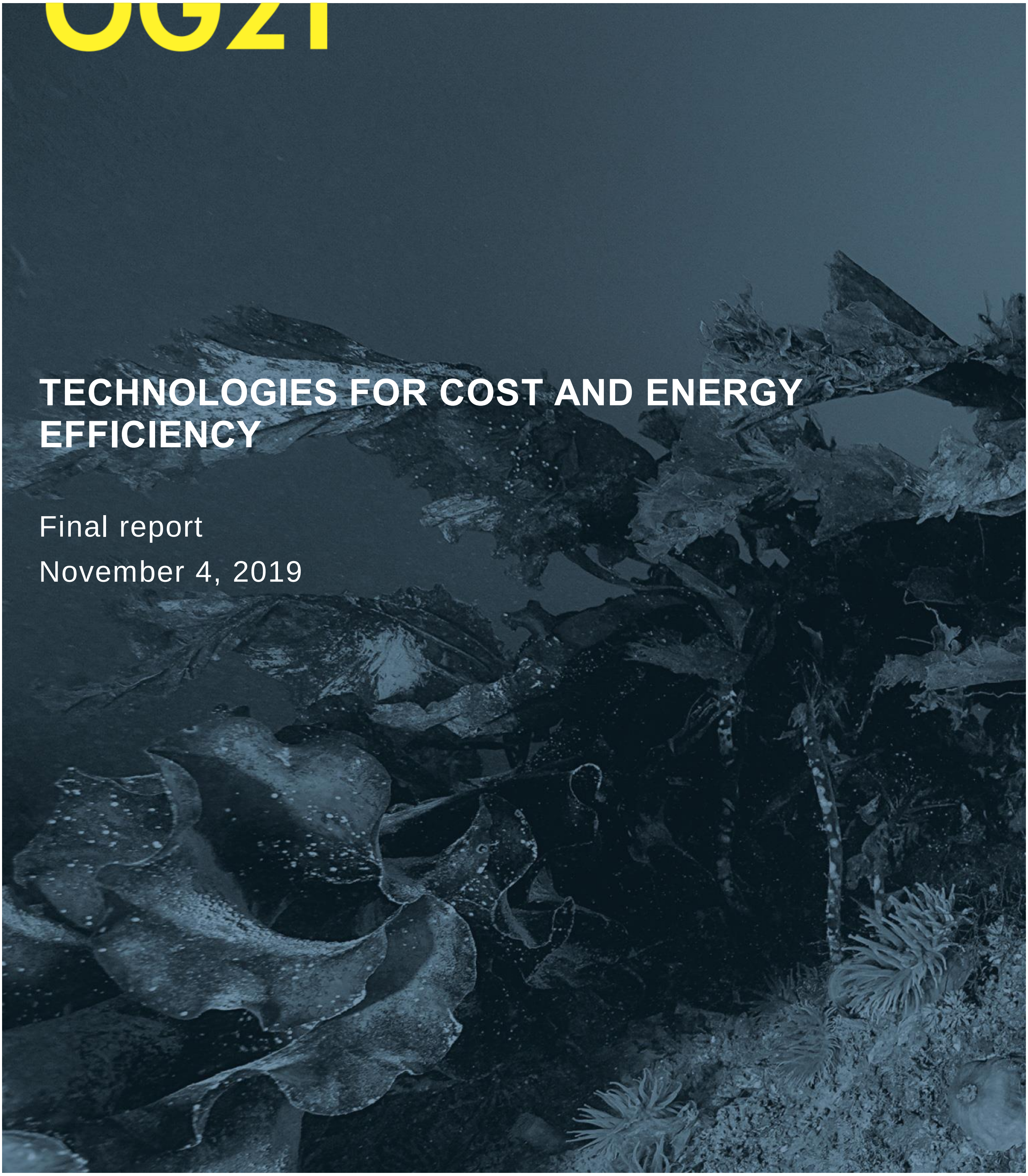
OG21



TECHNOLOGIES FOR COST AND ENERGY EFFICIENCY

Final report

November 4, 2019

Contents

1 EXECUTIVE SUMMARY

OG21 has in this study investigated how new technology can contribute to maintaining or improving the NCS competitiveness both short term and in the longer perspective. The work has been conducted by an OG21-team with input from the four OG21 technology groups (TTAs) and the consultancy firm Rystad Energy.

The demand for oil and gas from the NCS over the next few years is likely to remain strong. The global demand for oil is robust, and the NCS production is currently cost competitive. Norwegian gas is mainly sold to the European market, which is expected to maintain its demand for gas in the coming years.

The demand uncertainty long-term is increasing. Even though the global energy need is growing, the energy mix is changing as a result of: (i) renewable energy becoming cheaper and more abundant, and (ii) new end-user technology such as electrical vehicles, shifts energy demand over to new energy carriers. The underlying driver is the need for reduced CO_2-emissions, which is increasingly reflected in policies, economic incentives and investor behavior. The growing demand uncertainty creates a desire for shorter payback times and reduced CO_2-emissions. If petroleum demand should drop, there will be a downward pressure on prices favoring the more cost and carbon-efficient producers.

EU is currently discussing the implementation of a new energy vision with the objective of having a carbon-neutral energy mix by 2050. Even though Norwegian gas is likely to be in demand for at least another decade, contributing to a reduction of European CO_2-emissions by replacing coal, there could be little room for natural gas in the low-carbon 2050 vision. To prepare for such a scenario, Norway should evaluate alternative ways to monetize its gas.

A robust long-term strategy for the NCS addressing the demand uncertainty, requires efforts to reduce costs, reduce lead times and reduce CO_2-emissions. The development and application of new technology needs to support such a strategy.

This study confirms that the technology priorities of the current OG21 strategy are still highly relevant. We need the broad set of technologies described in the strategy to address the complex set of competition factors we see emerge. The study confirms that:

- Subsurface understanding is of paramount importance for value creation.
- Drilling technologies are key to reduce costs.
- Subsea technologies are vital not only to realize the vast resources in smaller discoveries, but also for timely and cost-efficient use of host facilities.
- Digitalization technologies contribute significantly to reduce costs and improve recovery.

The study also confirms that we need to develop and apply more technology for reduced CO_2-emissions. Low-emission technology often incurs higher investment costs and therefore struggles in the competition against other technology that reduce costs or shorten lead-times. We should therefore investigate how we better could stimulate the development and use of low-emission technology, and we should increase efforts to mobilize the industry and research communities to develop and use low-emission technology.

Based on results from several OG21-workshops, input from the OG21-TTAs, and research and input from Rystad Energy (2019), OG21 recommends the following:

Recommendation 1: Maintain priorities of the OG21 Strategy in petroleum R&D programs and increase public funding of petroleum R&D

- Priorities of the OG21 Strategy, last revised in 2016, have been confirmed. Priorities in the OG21 Strategy should continue to be the governing basis for public funded petroleum R&D.
- New technology is needed more than ever to reduce costs, find new resources, improve recovery and reduce CO_2-emissions. Public funding of petroleum R&D should be increased to reflect this.
- *Public funded petroleum R&D programs* should emphasize the importance of low-emission technologies and seek to increase the interest from industry and research partners to develop R&D projects within this area.
- *OG21 and petroleum R&D programs* should communicate the importance of exploration R&D. It improves subsurface understanding which is fundamental not only for improved recovery and added volumes, but also for cost reductions and important low-emission solutions.
- *Petroleum programs* should evaluate joint calls with other relevant RCN programs on low-emission technologies.

Recommendation 2: Strengthen R&D on CCUS

- *The Government* should strengthen R&D on CCUS with the objective of improving the cost-efficiency of value chains involving CCUS.
- CCUS is an essential part of the de-carbonization of energy systems, including power production from fossil fuels and de-carbonized energy carriers derived from fossil fuels. In addition, it could contribute to improved oil recovery on the NCS.

Recommendation 3: Evaluate low-emission technologies across industry boundaries

- *OG21* should take the initiative to evaluate opportunities and challenges related to low-emission technologies that reach across industry boundaries.
- It includes, but is not necessarily limited to, technologies such as offshore wind connected to offshore and onshore power consumers, power exchange between onshore and offshore producers and consumers, and CCUS.
- OG21 should invite other strategy groups such as Energi21, Maritime21 and Digital21 as well as industry organizations, to take part in the discussions.

Recommendation 4: Evaluate measures to better stimulate investments in CO_2-reducing technology

- *Industry organizations* should identify and evaluate measures that would provide stronger incentives to reduce CO_2-emissions on the NCS cost-efficiently,
- The evaluation could for instance include a discussion on whether collected CO_2-levies could be better targeted at reducing offshore CO_2-emissions.

2 PURPOSE AND SCOPE

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.

Based on its mandate from the Norwegian Ministry of Petroleum and Energy, OG21 develops and maintains the technology strategy for the Norwegian petroleum industry.

2.2 About the "Technologies for cost and energy efficiency" project

We have seen over the last few years tremendous efforts on the NCS to bring costs down, resulting in competitive project break-even prices and operational costs. But the competition is not won – projects on the Norwegian continental shelf (NCS) compete continuously for investments and market shares. In addition, the industry's operational emissions need to align with national, regional and global targets.

The main objective for this project has been to describe how new technology can contribute to maintaining the NCS competitiveness both short term and in the longer perspective.

The project team comprised members from OG21's four technology groups (TTAs), with a steering committee from the OG21 board. Other members from the TTAs and from industry stakeholders have been engaged through workshops and interviews.

2.3 About the Rystad Energy study for OG21

The OG21-project included the commission of a study from the consultancy firm Rystad Energy. The Rystad Energy report is available on the OG21 website.

The report from Rystad Energy is based on in-depth interviews with stakeholders in the Norwegian petroleum industry, in-house research and results from several OG21 workshops conducted as part of this OG21-project.

2.4 Abbreviations

AICD	Autonomous inflow control valve
bbl	Barrels
boe/d	Barrels oil equivalent per day
CAPEX	Capital expenditure
CCUS	Carbon capture, utilization and storage
CO_2	Carbon dioxide
EOR	Enhanced oil recovery
EPC	Engineering, procurement and construction
FID	Final investment decision
G&G	Geology & geophysics
IEA	International Energy Agency
IOR	Improved oil recovery
IMR	Inspection, maintenance and repair
LNG	Liquified natural gas
MMO	Maintenance, modifications and operations
MODU	Mobile offshore drilling unit
NAM	North America
NCS	Norwegian continental shelf
NPV	Net present value
OPEX	Operating expenses
R&D	Research and development
TTA	Technology target area (OG21 has 4 TTAs on specific disciplines)
P&A	Plugging and abandonment
YTF	Yet-to-find
2DG	Two degree scenario

3 TECHNOLOGY TO STRENGTHEN NCS COMPETITIVENESS

3.1 Strong demand for petroleum in the short term – longer term demand is increasingly uncertain

3.1.1 Oil demand

Oil and gas are likely to continue to play an important role in the global energy mix in the decades to come, but the long-term demand is increasingly uncertain. Figure 1 shows the large span of liquid demand scenarios from recognized sources such as IEA, DNV GL, Equinor, BP and OPEC, especially after 2030 (Rystad Energy, 2019).

The scenarios compared can largely be grouped into two: "moderate growth" and "peak demand". The average oil demand in year 2050 is 113 million boe/d for the moderate growth group and 59 million boe/d for the peak demand group, compared to the current 97 million boe/d demand.

The "low carbon" case reflects major technological and investment shifts both on the energy supply and demand side. For instance, large scale electrification of road transportation could alone address 44% of today's oil demand (26% of the 2017 oil production was used for light vehicles and buses and 18% was used for light and heavy trucks).

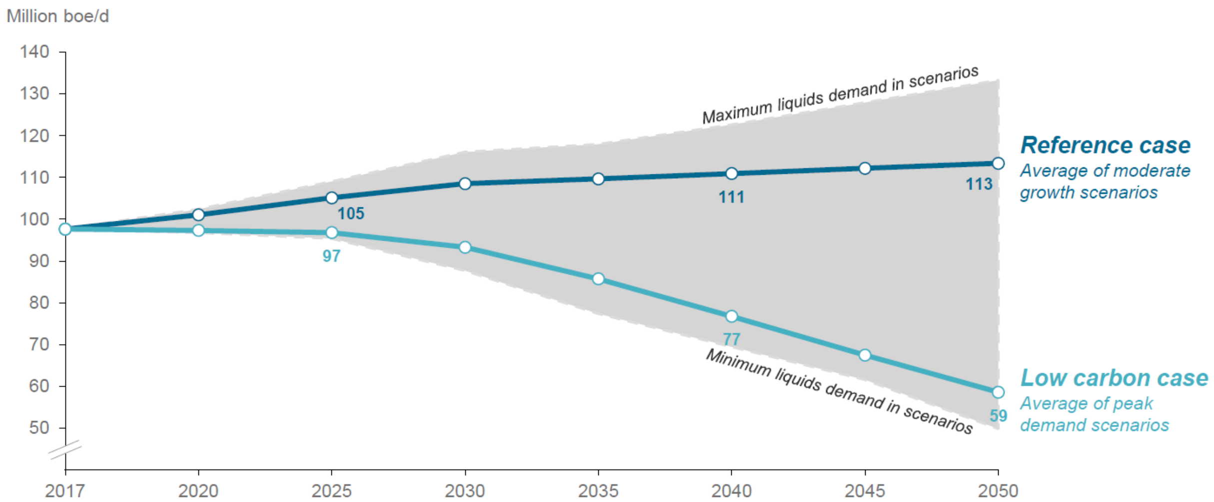


Figure 1 Global liquid demands in different scenarios (Rystad Energy, 2019)

3.1.2 Gas demand

Gas markets are regional to Asia, North America and Europe. Long distances between the regional markets, lack of import/export infrastructure and high shipping costs limit the trade between the markets.

More than 95% of Norway's gas production is piped to the European market, with the remainder shipped as LNG to other markets. The European market is therefore of key importance for the evacuation of natural gas from the NCS.

Most scenarios show robust demand for natural gas in Europe near-term and until year 2030. The use of natural gas in modern gas power plants results in only half the CO_2-emissions from coalfired power plants, and as such natural gas is an important energy carrier to reduce European emissions on the short to medium term.

However, EU is considering the implementation of a zero-emission vision for 2050, and in the scenarios supporting that vision, natural gas, at least without CCS, plays a limited role (European Commission, 2019). After 2030 the spread is large between scenarios for European natural gas demand, ranging from remaining on today's level towards 2050, to levels which are less than 10% of today's demand in 2050.

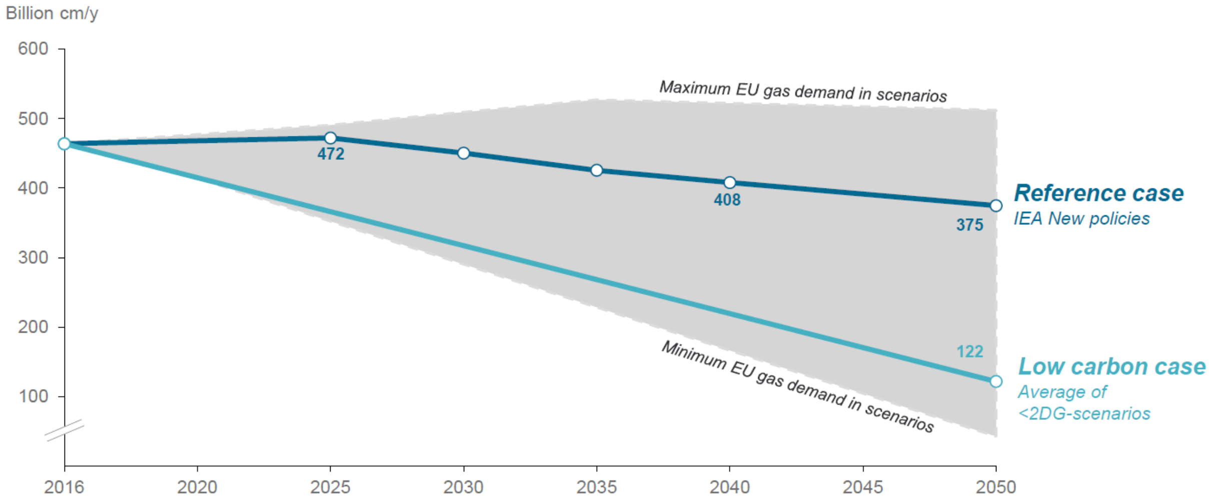


Figure 2 EU28 gas demand in different scenarios (Rystad Energy, 2019)

3.2 NCS competitiveness depending on cost, volume, lead time and emissions.

Capital projects are expected to return high value. Traditionally Net Present Value (NPV) and similar metrics have been used to assess the return of petroleum projects. If high commodity prices are expected/assumed, this may cause a drive for adding volumes as we saw from 2005 and until the oil price slump in 2013. Enterprises in the petroleum industry reacted by requiring robustness against low oil prices, putting more emphasis on reducing costs. New projects had to demonstrate low break-even prices, in terms of $/bbl, and addition to high NPV to become sanctioned.

The advent of shale oil in North America has highlighted the importance of yet another metric – the lead-time from investment decision to production. Motivated by the uncertainty about future oil prices, investors now are looking for faster returns in addition to high value (high NPV) and robustness (low break-even).

More and more investors and enterprises are also becoming wary about the carbon footprint of their investments and operations. This is partly driven by an expectation of rising CO_2-emission costs, and partly by their stakeholders concerns for climate change and expectations for action.

Going forward we therefore believe that the competitiveness of the NCS depends on the ability to find, develop and deliver low-cost volumes faster and with lower CO_2-emissions.

Estimates by Rystad Energy show that the NCS currently is competitive on low break-even prices, low operational costs and low CO_2-emissions as compared to other petroleum provinces in the world. Regarding faster returns (low lead times from FID to start-up), the NCS is currently competitive compared to other offshore provinces, but less competitive when compared to onshore provinces and especially the shale oil industry in North America.

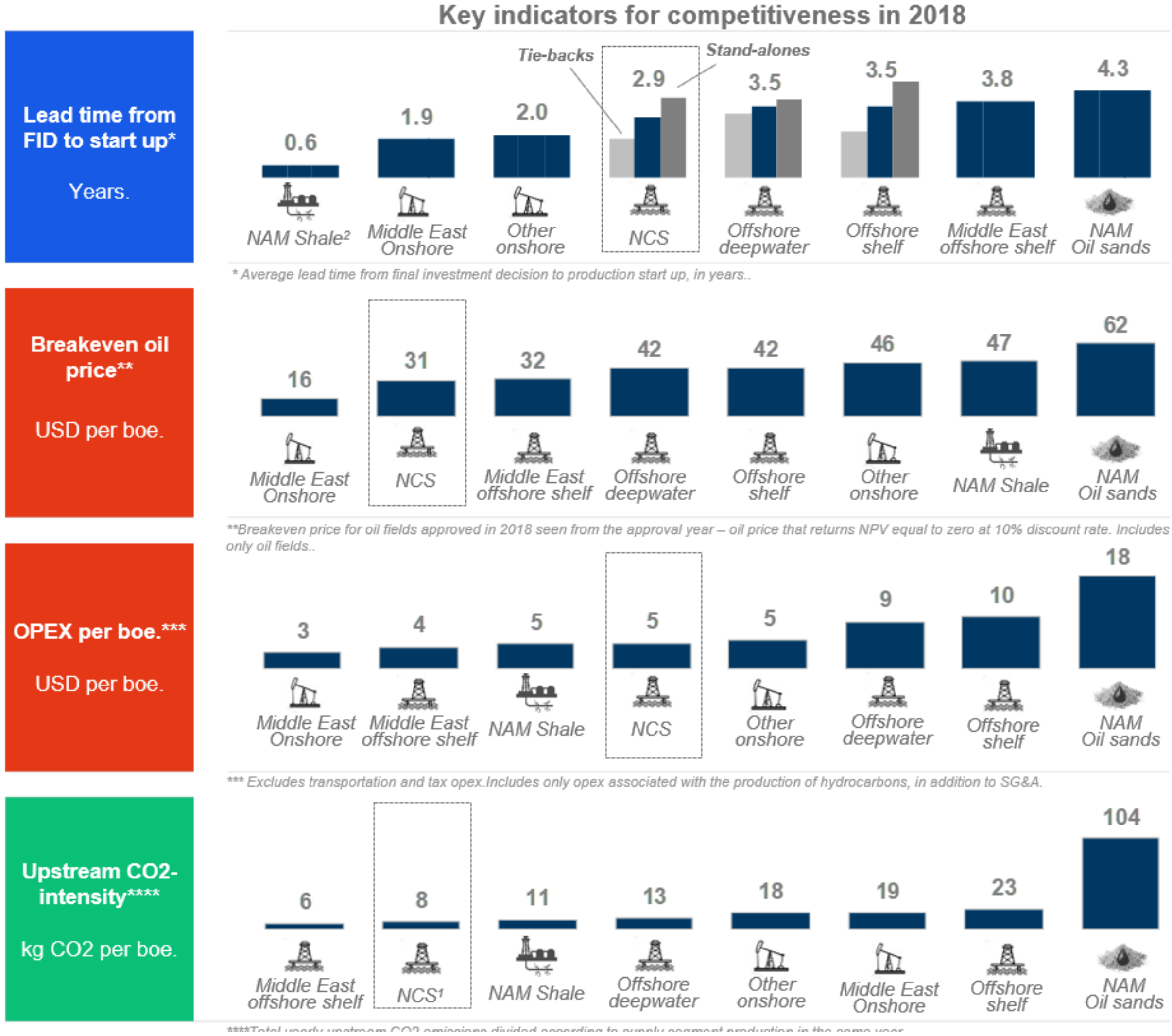


Figure 3 NCS competitiveness on key metrics (Rystad Energy, 2019)

Although very competitive today, moving forward the NCS is at risk of reducing its competitiveness on both the OPEX per barrel and the CO_2-intensity metrics. This is illustrated for the CO_2-emission metric in Figure 4. The reason is that both metrics are relative to the production level, and when production declines, as expected after 2025, both CO2-intensity and OPEX per barrel will increase unless measures are taken.

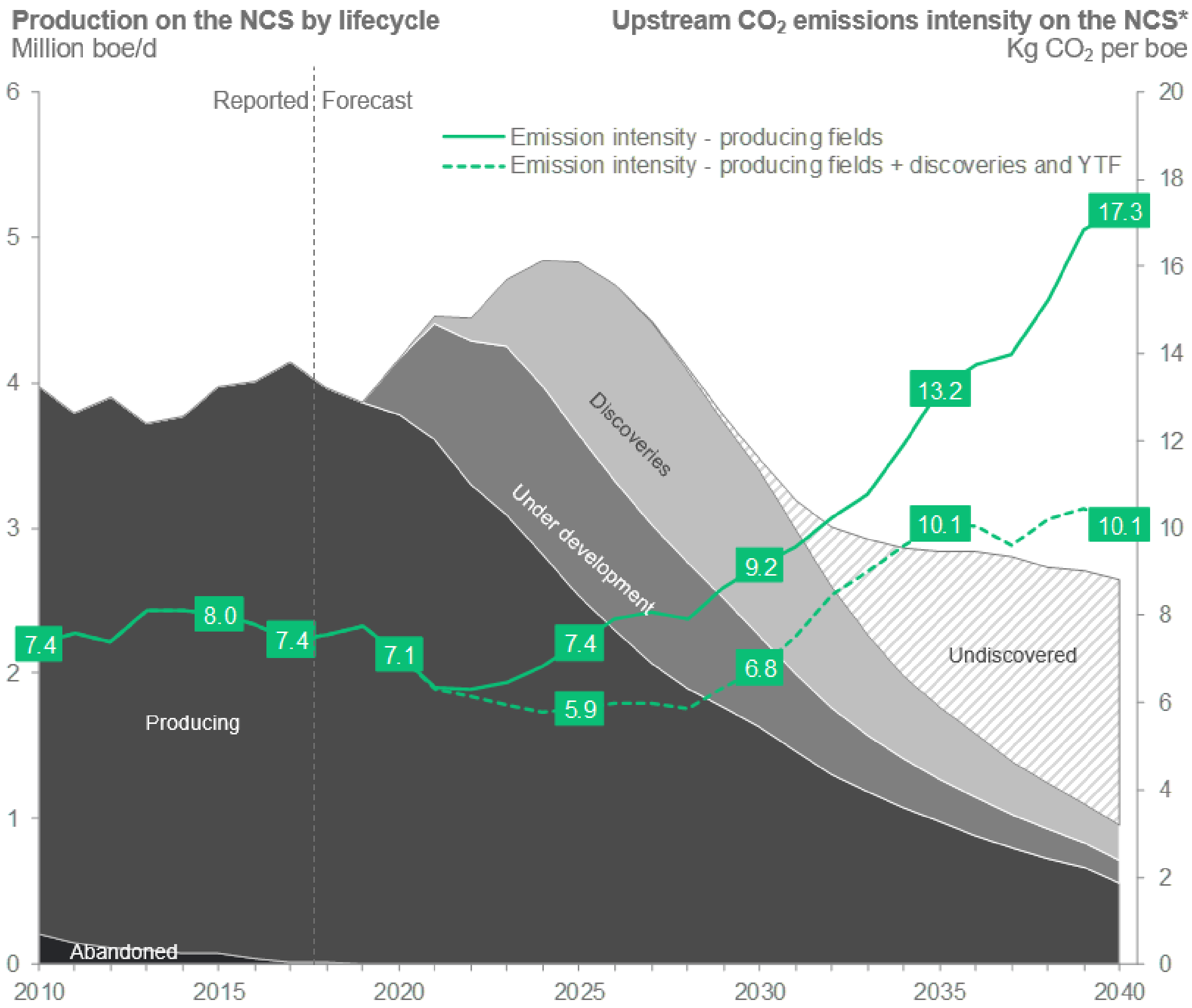


Figure 4 CO_2-intensity increases unless production is replaced (Rystad Energy, 2019)

Long-term competitiveness for the NCS is hence depending on the factors:

- Volume: Replacing reserves, improved recovery.
- Lead times: Shorter time from investment decisions to production.
- Costs: Lower capital cost, operating costs and drilling cost, without compromising structural integrity or safety.
- Emissions: Reduction of discharges and emissions, especially CO_2-emissions

New technology should address these factors in order to add value and strengthen the competitiveness of the NCS.

3.3 Stress-test of demand in low cost, low carbon environment

Rystad Energy has performed a stress test of the demand for oil and gas from the NCS in the short term (2025) and long term (2050). The stress test is a comparison of call for Norwegian oil and gas between the reference and low carbon cases shown in Figure 1 and Figure 2.

Figure 5 and Figure 6 suggest that oil demand from NCS is robust both in the short term (until 2025) and the longer term (until 2050) for the reference case. In the low carbon case there will be stronger price pressure. In the short term this has limited effect, but in the longer run a significant part of the discovery portfolio and YTF resources are at risk of not being competitive. This illustrates the strong need for continued efforts to reduce costs on the NCS.

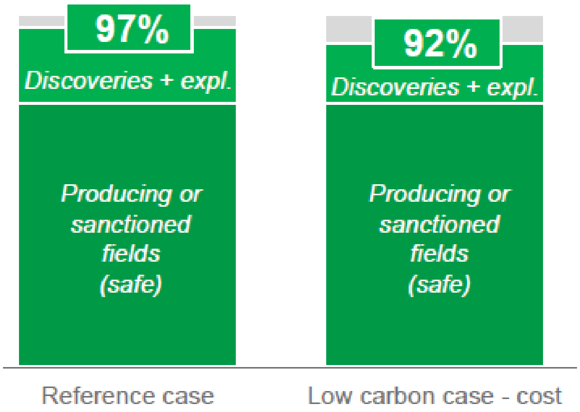


Figure 5 Competitiveness of NCS oil supply in the short term (2025), (Rystad Energy, 2019)

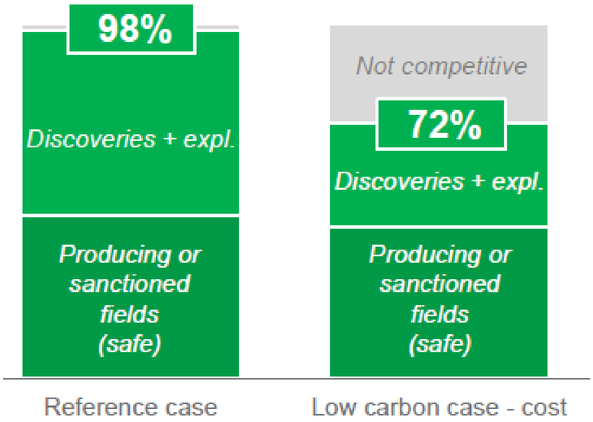


Figure 6 Competitiveness of NCS oil in the longer term (until 2050), (Rystad Energy, 2019)

Demand for Norwegian gas is likely to be strong in the short term until 2025, both for the reference case and the low carbon case, see Figure 7. Norwegian gas will likely continue to be important for European countries to reduce CO_2-emissions from the energy mix for at least a decade. In the longer run towards 2050, demand for Norwegian gas will still be high in the reference case, but in the low carbon case, demand for Norwegian gas will have fallen by almost 20%. Figure 8 suggests that almost all new gas discoveries will be at risk of being non-competitive in the longer run in the low-carbon scenario.

As for oil, continued efforts to keep costs down will be essential for the NCS. In addition, we should look for ways to de-carbonize the gas to reduce the market uncertainty.

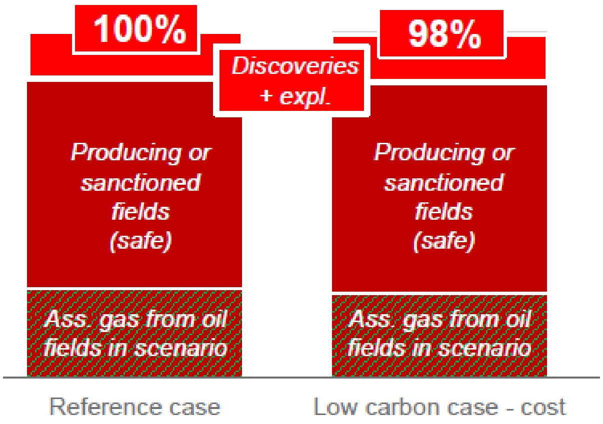


Figure 7 Competitiveness of Norwegian gas in the short term (2025), (Rystad Energy, 2019)

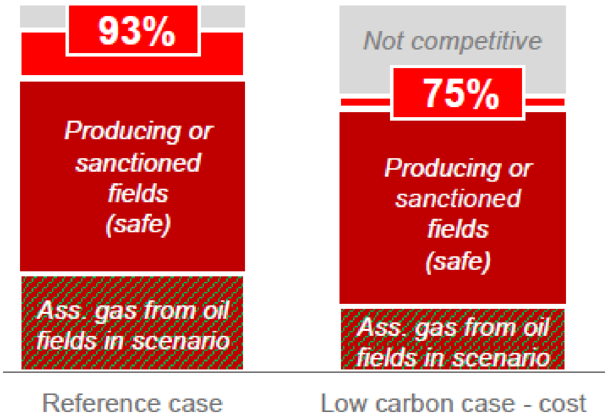


Figure 8 Competitiveness of Norwegian gas in the long term (until 2050), (Rystad Energy, 2019)

3.4 Time window for utilizing existing infrastructure is limited

When a field approaches tail-end production both the OPEX per barrel and the CO_2-intensity increases. This makes the field vulnerable to a low demand scenario (see Section 3.1.1), categorized by lower oil prices and increased pressure to reduce CO_2-emissions.According to Rystad Energy assessments, 25 of 38 field centers on the NCS are at risk of closing down in the low demand scenario.

Replacing host production is therefore crucial to make a field more robust against future demand uncertainties. This can be achieved either by improved recovery from the host reservoirs or by added production from tie-in fields.

The NCS discovery portfolio is dominated by small fields, and discovery sizes are declining. 75% of new volumes on the NCS will likely be wellhead or subsea developments tied back to existing hosts. This underscores the importance of keeping field centers alive.

The time window for realizing new volumes from the host field as well as tie-back fields, is however closing. As Figure 9 shows, sometime between 2030 and 2040, 79% of today's producing or sanctioned fields will be in the tail-end production phase with limited financial and organizational capability to accommodate new volume adding projects, tie-back modifications and sometimes life-extension initiatives.

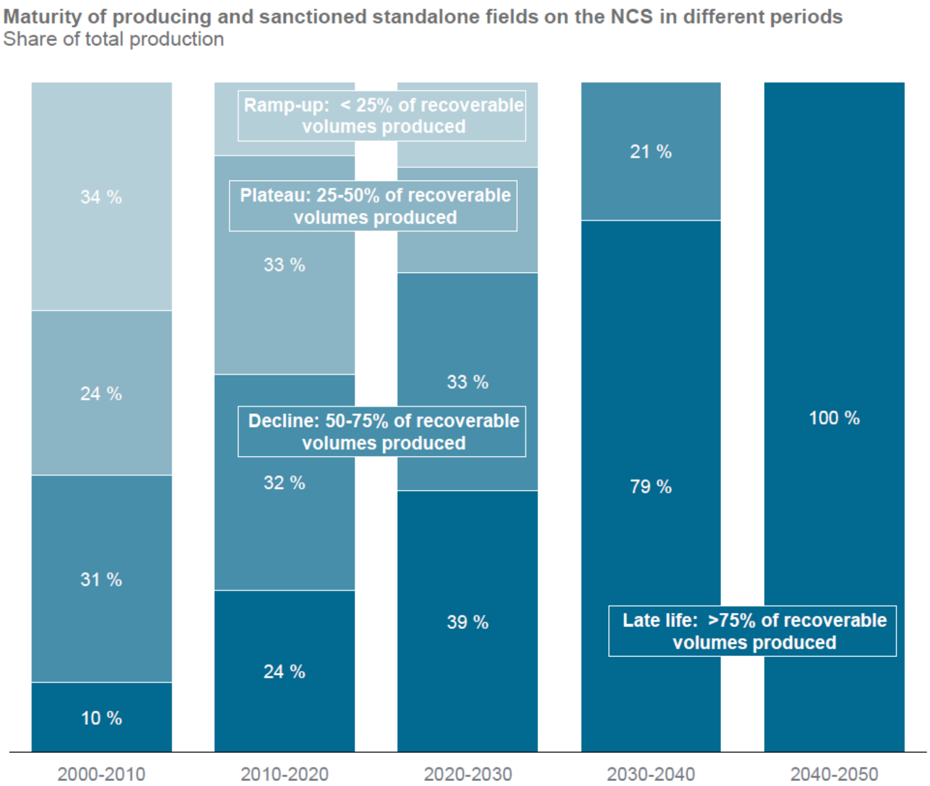


Figure 9 Maturity of stand-alone producing facilities on the NCS (Rystad Energy, 2019)

Adding to the challenges, tie-back fields could have different owners than the host, making it difficult to arrive at commercial terms in a timely fashion.

3.5 Drilling performance illustrate how technology contributes to productivity gains

After the oil price collapse in 2014, OPEX as well as CAPEX on the NCS have been reduced. As part of this study we have investigated to which extent efficiency gains and new technology have contributed to the cost reductions.

The average OPEX reductions on the NCS in the 2014-2018 have been estimated to 33%. 6% can be attributed to price reductions, 4% to activity reductions and 23% to efficiency gains. A further break-down reveals that the larger efficiency gains have been realized in maintenance heavy segments such as MMOs, subsea IMR and in the oil companies' organizations. The efficiency gains are mainly related to improved work processes. Technology, such as digital decision support tools, has contributed to improving work processes.

CAPEX is down by more than 40% in the same period, see Figure 10.

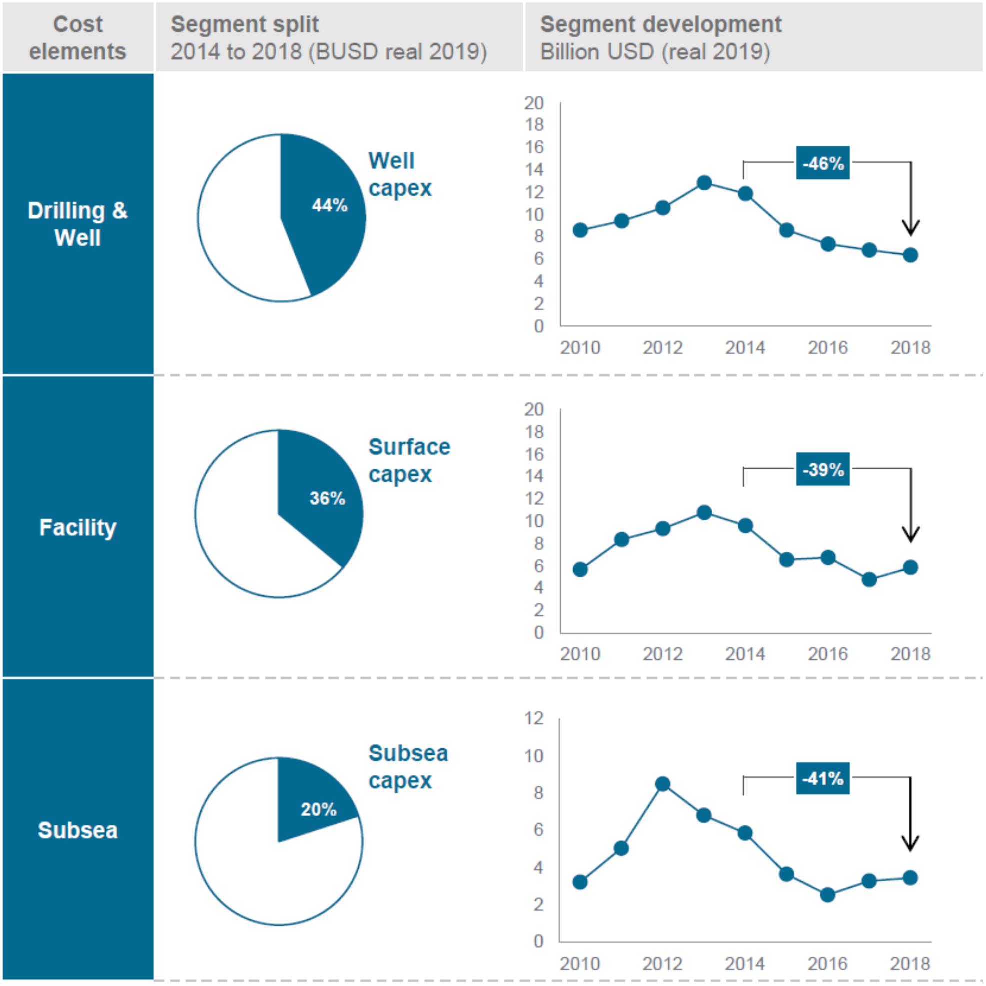


Figure 10 CAPEX reductions in the 2014-2018 period (Rystad Energy, 2019)

Market prices went down considerably during the period, reflecting an over-capacity as compared to the activity level. Rystad Energy has estimated that the prices within drilling&well fell between 16 and 41% during the period, prices within topside EPC fell by 20%, and subsea prices went down 30% during the period.

But efficiency gains also contributed to the experienced CAPEX reductions, typically 9% to 17% for drilling and well, 8% to 24% for topside facilities, and 10% for subsea. Much of the efficiency gains can be explained by simplification and standardization, but technology has also played an important role, especially within the drilling and well segment. During the period 2014-2018 we've seen new technologies such as drilling automation, improved slot recovery, wired drillpipe and AICDs become more widely applied.

A comparison between new and older rigs show that newer rigs have seen twice as high efficiency improvement as older rigs, see Figure 11. Assuming that similar efforts have been made to improve work processes for the two categories, the comparison suggests that new technology have profound effects on drilling efficiency.

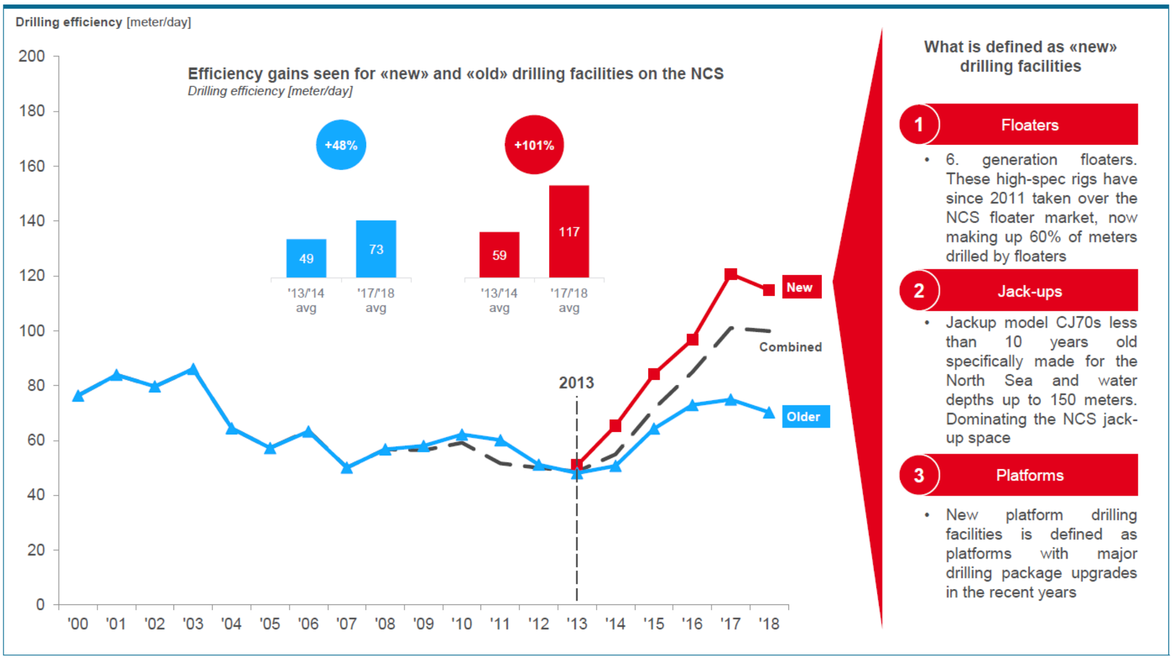


Figure 11 Drilling efficiency for new and old drilling facilities (Rystad Energy, 2019)

3.6 How robust is the OG21 technology strategy in the changing competitive landscape?

3.6.1 The OG21 strategic priorities largely confirmed

Technology priorities in the OG21 Strategy have been re-visited as part of this study. OG21's technology groups have discussed the technology needs listed in the OG21 strategy as well as the need for new, emerging technologies not covered in the strategy, against the competition factors listed in Section 3.2.

The technology needs identified by the TTAs are listed in Figure 12. The exercise largely confirmed the technology prioritizations of the OG21 Strategy.

	TTA 1	TTA 2	TTA 3	TTA 4
Focus	**Floating Offshore wind for offshore facilities** **Optimized gas turbines** **Energy effective IOR technologies** **Power from shore technologies** **Compact CCS for topsides**	**Water diversion** **Field and production optimization** **Cost efficient collection and processing of high quality data** **Big data exploration analytics** **CO2 for EOR**	**Wired pipe technologies** **Slot recovery technologies** **Automated drilling control** **Smarter smart wells** **Standardized subsea satellites**	**Predictive maintenance** **Unmanned platforms** **Carbon efficient supply of power and heating** **All electric subsea** **Flow assurance for long tie-ins**
Other technologies	Methane sensors and cold venting Technologies for produced water and cleaning Oil spill technologies Improved regularity and faster start-up of wells Energy efficiency sensory and digitalization software P&A technologies Combine heat and power Hybrid technologies for MODUs Barents – no pipeline technologies Gas to wire Lower production pressure in inlets Fuel cell technologies Subsea gas power generation Subsea processing technologies Technologies to reduce slugging Cooling and pressure drop in flowlines	EOR: surfactants Dry gas recovery Subsea processing technologies New completions designs Multilateral technologies Electrification of subsea wells Passive seismic and surveillance Life extension enabling technologies	Automated learning and execution in drilling Energy recovery in the draw works Hybrid technologies for MODUs Steerable liner drilling Connected wells Offshore cuttings processing on MODUs Coiled tubing drilling Data sharing systems MPD on floaters Rig less subsea intervention Thru-tubing rotary drilling	Water treatment technologies Lightweight platforms Alternative solutions to long tie-backs CCS technologies EOR:CO2 Wet gas dehydration Life-time extension technologies

Figure 12 Technologies identified by OG21 TTAs

The discussion of technologies against potential impact on volume, lead time, costs and emissions resulted in a limited set of "focus technologies" that have been further evaluated by Rystad Energy in their report (2019).

Main findings with relevance for OG21 are discussed in the following sections. Details on each focus technology with respect to effects on volume, costs, emissions and lead time can be found in the Rystad Energy report.

3.6.2 No silver bullet – a broad set of technologies needed to improve competitiveness

A broad range of technologies is needed to improve the NCS competitiveness. Generally, individual technologies only target a subset of volumes, installations and emission sources.

Combined, however, the evaluated technologies offer potential huge impact on volumes, costs and reduced emissions as illustrated in Figure 13.

	Technology area	Target volumes [Billion boe]	Lead time [Years]	Volume effect [Million boe]	Cost effect [Billion USD real 2019]	Emissions effect [Million tn CO_2]
TTA1 Energy efficiency and environment	Offshore wind for offshore facilities	22 (62%)	3-4 years	Neutral	16.0	-82
	Optimized gas turbines	8.4 (24%)	1-2 years	Neutral	-1.4	-7.6
	Power from shore technologies	10.8 (31%)	2-3 years	Neutral	24.7	-137
	Compact CCS for topsides	7.2 (20%)	2-4 years	Neutral	3.5	-61
TTA2 Exploration and improved recovery	Water diversion	18.5 (52%)	1-2 years	1850	18.6	-11
	CO_2 for EOR	18.5 (52%)	5-7 years	825	20.0	-330
	Field model optimization	10.4 (29%)	2-4 years	560	-40.8	-2.8
	Big data exploration analytics	9.5 (27%)	7-15 years	1900	-6.0	-0.7
TTA3 Drilling, completion and intervention	Wired pipe technologies	16.1 (45%)	6-12 months	3220	-14.3	-1.1
	Slot recovery technologies	11.5 (32%)	6-12 months	Limited	-5.6	-0.4
	Automated drilling control	16.1 (45%)	6-12 months	Limited	-21.2	-3.1
	Smarter smart wells	11.5 (32%)	6-18 months	580	Neutral	-12
TTA4 Production, processing and transport	Predictive maintenance	35.3 (100%)	1-2 years	1490	-42.9	-1.8
	Unmanned platforms	7.9 (22%)	2-4 years	335	-50.0	-4.7
	Standardized subsea satellites	10.4 (29%)	1 year	1500	-14.0	Neutral
	All electric subsea	10.6 (30%)	2-3 years	450	-12.0	-0.5
	Flow assurance	2.3 (6%)	2-3 years	Neutral	-14.1	Neutral

See appendix of Rystad Energy report for detailed assumptions and technology evaluations

Short term (2020-2025) *Long term (2025-2050)*

Figure 13 Estimated potential impact of focus technologies (Rystad Energy, 2019)

3.6.3 Subsurface understanding is still a high priority, and emphasizes the continued need for exploration and improved recovery R&D

Potential added volumes estimated for the TTA2 focus technologies water diversion, CO_2 for EOR, field model optimization and big data exploration analytics, illustrate the vast value associated with subsurface competence and technology. Added volumes for these four focus technologies are in the 560–3220 million boe range, equivalent to large new discoveries.

There are pros and cons for each of the technologies, e.g. water diversion technology could be implemented relatively fast, but with a considerable cost. CO_2 for EOR stands out as a technology that reduces CO_2-emissions substantially whilst increasing petroleum volumes, but it comes with a considerable cost and with a long lead time until improved recovery is realized.

The results reinforce the need for continued efforts to develop and apply methods and technologies for improved subsurface understanding.

3.6.4 Drilling technologies offer fast returns and reduced costs

Although drilling performance has improved substantially over the last 4 years, drilling & well is still the main cost element on the NCS, representing 37% of estimated expenditures on the NCS for the 2019-2040 time period (Rystad Energy, 2019).

Three of the identified focus technologies for TTA3 addresses the cost issue and offer potential large cost savings. These are: wired pipe, slot recovery and automated drilling. Wired pipe stands out as a technology that in addition could result in large added volumes.

The 4th focus technology, smarter smart wells, is cost neutral, but with a potential large impact on improved recovery.

Common for all the evaluated drilling & wells focus technologies is that they can be adopted fast and produce the intended results often within a year. This make such technologies especially attractive in a business environment where fast returns are favored. This may explain why such technologies have seen relatively high adoption rates during the petroleum recession period 2014-2018.

Another commonality for the focused drilling & wells technologies, except for smarter smart wells, is that they have limited effects on CO_2-emissions. Smarter smart wells results in reduced CO_2-emissions because of less produced water, reducing the need for energy demanding processing and re-injection.

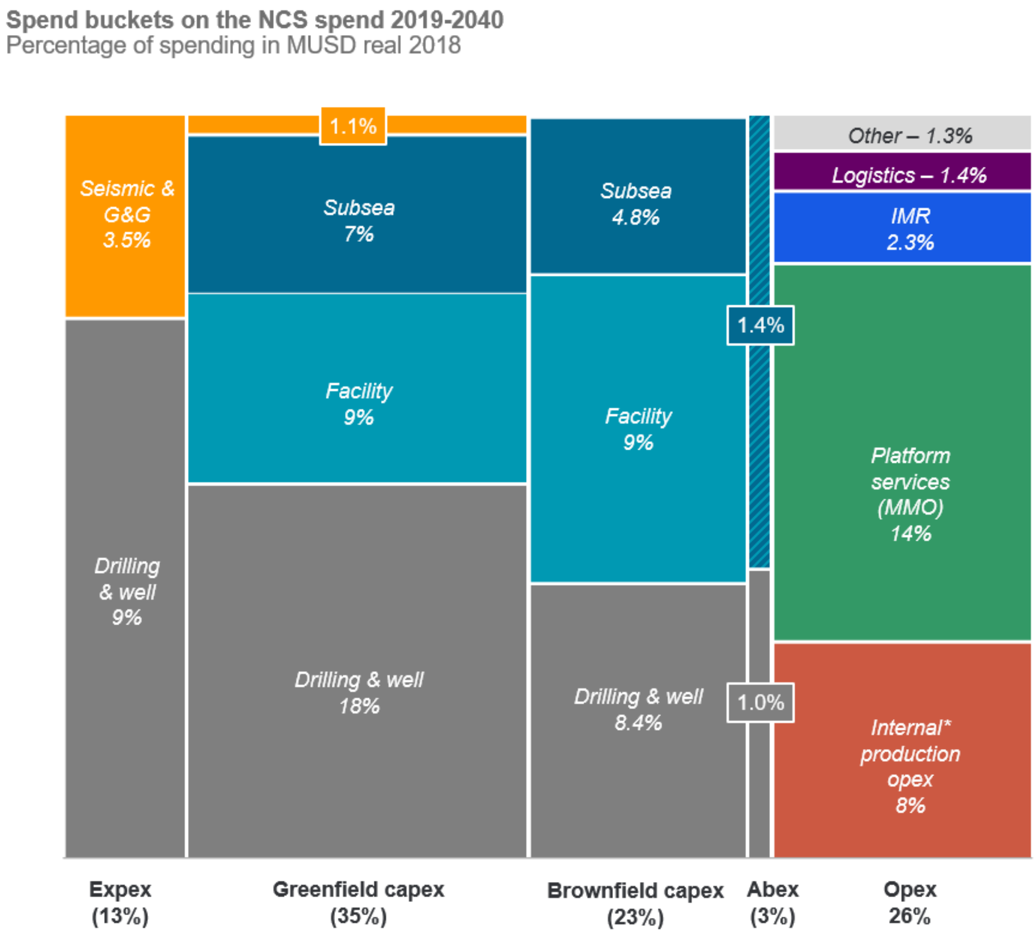


Figure 14 Cost elements on the NCS (Rystad Energy, 2019)

3.6.5 Technologies for lower emissions are important but expensive

The petroleum activities on the NCS contribute with approximately 30% of Norway's CO_2-emissions. Of the approximately 13 million tons CO_2-emissions annually, 85% originates from gas turbines. Gas turbines generate power but are also used for driving compressors directly.

Optimized gas turbines are one of the four focused TTA1 technology needs. It has a potential large impact on CO2-emissions, it can be implemented relatively fast and it's almost cost-neutral.

Nevertheless, the other TTA1 focus technologies: offshore wind, power from shore and compact CCS for topside, could have even larger impact on CO_2-emissions. The drawback is that the technologies drive costs without contributing to improved recovery.

The TTA2 focus technology, CO_2 for EOR, should also be mentioned among the technologies with the highest potential for reducing CO_2-emissions. In addition, it improves recovery significantly. Costs are high though, and it takes years until improved recovery is realized.

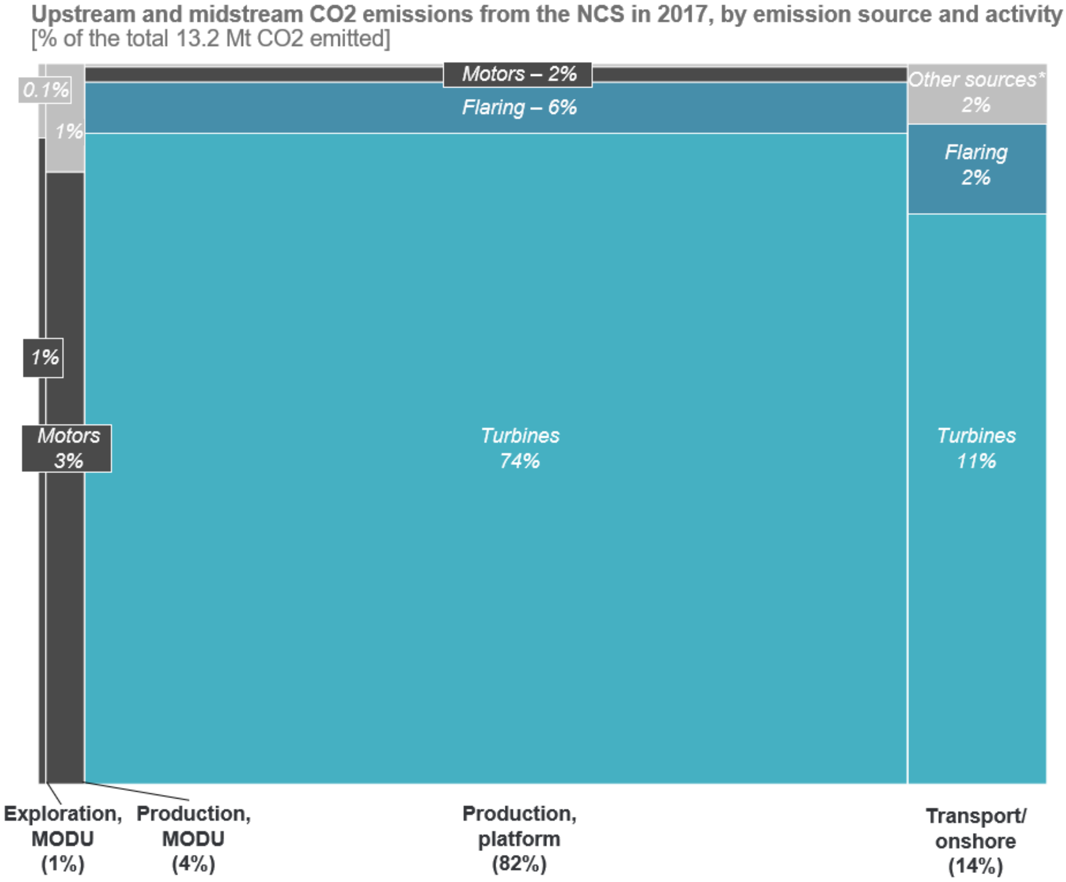


Figure 15 Contributors to CO_2-emissions on the NCS (Rystad Energy, 2019)

3.6.6 Subsea and tie-back technologies in addition to timely and cost-efficient use of hosts, are key to unlocking new resources

Unmanned platforms are among the focus technologies TTA4 have identified for this study. Such platforms target medium sized fields and larger. Cost savings both on capex and opex are potentially large as compared to manned installations. Added volumes are also significant, mainly due to improved regularity resulting from digital technologies.

The NCS discovery portfolio is however dominated by small fields, and discovery sizes are declining. 75% of new volumes on the NCS will likely be wellhead or subsea developments tied back to existing hosts (Rystad Energy, 2019).

Two of the TTA4 focused technologies, standardized subsea satellites and all-electric subsea, address the tie-back opportunity directly. Both contribute with a large potential for adding volumes as well as reducing costs. Both are attractive also from a lead time perspective with realized value within 1-3 years from investment decision.

Predictive maintenance is the only technology among all the 17 focus technologies of this study, that targets all potential volumes on the NCS. It’s an extremely important technology to save costs and adding volumes. A short lead time makes it even more attractive.

Subsea processing has not been evaluated in this study as part of the focus technologies. Discussions in the workshops did nevertheless, identify subsea processing as a key technology to reduce tie-back challenges related to hosts, including power demand, weight and deck space and commercial issues with host owner.

3.6.7 Digitalization technologies add value on most metrics, but especially on reduced costs and increased volume

Many of the focus technologies of the TTAs can also be categorized as digital technologies, e.g.:

- Field model optimization
- Big data exploration analytics
- Wired pipe
- Automated drilling control
- Predictive maintenance
- Unmanned platforms

The evaluated digital technologies have some positive effect on CO_2-emissions, but the main value drivers are significantly reduced costs and large added volumes.

Realizing the effects of digital technologies often depends on the application of other digital technologies, e.g. field models depend on real-time data from wired pipe, and unmanned platforms are dependent on predictive maintenance, automated drilling and other digital technologies.

4 NEW OG21 RECOMMENDATIONS

Based on results from several OG21-workshops, input from the OG21-TTAs and research and input from Rystad Energy (2019), OG21 recommends the following:

Recommendation 1: Maintain priorities of the OG21 Strategy in petroleum R&D programs and increase public funding of petroleum R&D

- Priorities of the OG21 Strategy, last revised in 2016, have been confirmed. Priorities in the OG21 Strategy should continue to be the governing basis for public funded petroleum R&D.
- New technology is needed more than ever to reduce costs, find new resources, improve recovery and reduce CO_2-emissions. Public funding of petroleum R&D should be increased to reflect this.
- *Public funded petroleum R&D programs* should emphasize the importance of low-emission technologies and seek to increase the interest from industry and research partners to develop R&D projects within this area.
- *OG21 and petroleum R&D programs* should communicate the importance of exploration R&D. It improves subsurface understanding which is fundamental not only for improved recovery and added volumes, but also for cost reductions and important low-emission solutions.
- *Petroleum programs* should evaluate joint calls with other relevant RCN programs on low-emission technologies.

Recommendation 2: Strengthen R&D on CCUS

- *The Government* should strengthen R&D on CCUS with the objective of improving the cost-efficiency of value chains involving CCUS.
- CCUS is an essential part of the de-carbonization of energy systems, including power production from fossil fuels and de-carbonized energy carriers derived from fossil fuels. In addition, it could contribute to improved oil recovery on the NCS.

Recommendation 3: Evaluate low-emission technologies across industry boundaries

- *OG21* should take the initiative to evaluate opportunities and challenges related to low-emission technologies that reach across industry boundaries.
- It includes, but is not necessarily limited to, technologies such as offshore wind connected to offshore and onshore power consumers, power exchange between onshore and offshore producers and consumers, and CCUS.
- OG21 should invite other strategy groups such as Energi21, Maritime21 and Digital21 as well as industry organizations, to take part in the discussions.

Recommendation 4: Evaluate measures to better stimulate investments in CO_2-reducing technology

- *Industry organizations* should identify and evaluate measures that would provide stronger incentives to reduce CO_2-emissions on the NCS cost-efficiently,
- The evaluation could for instance include a discussion on whether collected CO_2-levies could be better targeted at reducing offshore CO_2-emissions.

5 REFERENCES

European Commission (2019). *A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy.* https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52018DC0773.

Rystad Energy (2019). *Technologies to improve NCS competitiveness.* Report commissioned by OG21. https://www.og21.no/strategi-og-analyser/og21-studier-og-analyser/

OG21 (2016). *Strategy document.* https://www.og21.no/strategi-og-analyser/og21-strategien/

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