OIL AND GAS FOR THE 21ST CENTURY

OG21

RISK ASSESSMENTS AND IMPACT ON TECHNOLOGY DECISIONS

Final report

October 31st, 2018

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1 EXECUTIVE SUMMARY

OG21 has in this study investigated how risk management tools and practices influence technology decisions. The objective has been to identify measures that could facilitate earlier adoption of technologies. The work has been conducted by a cross-disciplinary OG21-team with input from the four OG21 technology groups (TTAs) and from Rystad Energy, a consultancy firm.

The Norwegian petroleum industry has over the last few years demonstrated remarkable efficiency improvements, and break-even costs are currently highly competitive with other oil producing regions, including US shale oil. Still there is uncertainty about the long-term competitiveness of offshore petroleum projects, mainly due to two factors: Renewable energy becomes cheaper and gain energy market shares, and shale oil projects offer shorter development times and earlier cashflow.

The competitiveness of the Norwegian continental shelf (NCS) going forward is hence dependent on maintaining low break-even prices and reducing project development times. This influences technology decisions: The industry needs to develop, qualify and implement technologies faster than before.

The study confirms that the enterprises invest considerable effort in reducing technology risks, whereas value adding opportunities related to the application of new technologies receive less attention. OG21 believes that the tendency of over-emphasizing risks over opportunities is exacerbated by risk-averse decision makers in oil companies and production licenses that add their perceived risks to technology investment decisions.

In addition, the final decision makers in a production license generally have a narrow objective of optimizing the value for the license, rather than for a portfolio of production licenses at company or national level.

OG21 believes the combination of risk management tools that fail to consider value creation opportunities, technology risk aversion among decision makers and a lack of portfolio thinking, lead to over-cautious technology decisions unless enterprise culture, leadership, objectives and incentives drive a different behaviour.

The value of technology is realized when it is applied, and faster technology adoption adds value. OG21 therefore recommends the following measures to reduce technology risk aversion and accelerate technology adoption:

1. **The ownership for technology should be at the executive level:**
    - Industry enterprises should have visible “technology champions” at the executive level.
    - Technology responsibility should start at the executive level and be distributed throughout the organization. The responsibility should be reinforced through key performance indicators and incentives.
    - Executive level technology managers should make sure that technology opportunities are identified and communicated to potential technology providers in a timely fashion.

2. **Production licenses should actively search for value-adding technology:**
    - Petoro's capacity to influence technology adoption across the SDFI portfolio, should be increased.
    - Oil companies should evaluate technologies across their portfolio and influence production licenses they partake in, to make technology decisions that optimize value on a portfolio wide basis.
    - Oil companies should collaborate on technology development and use across production licenses.
3. **Regulators should use established mechanisms to drive technology adoption:**
    - Regulators should remind licensees on the NCS about their responsibility for continuous evaluation of technical solutions to optimize petroleum production.
    - Regulators expectations to licensees for technology leadership and commitment, should be reinforced through PDO requirements.
4. **Oil companies should use common technology qualification procedures:**
    - Oil companies should develop and apply common qualification procedures for new technologies.
    - Oil companies should share data on technology qualification to reduce the burden of re-qualifications.
5. **Industry enterprises should collaborate on developing procedures and standards that enable data interoperability and efficient data sharing:**
    - Industry enterprises and regulators should agree on and develop common data protocols, data formats and data management principles and rules.
    - Production licenses should share within pre-defined data management principles and rules, technology experience data as well as operational data.
6. **The industry should develop and apply full life-cycle contracting models:**
    - New contract models should incentivize suppliers to propose technologies that create value over time.
    - Key performance indicators (KPIs) should be aligned between project participants.

There are on-going industry projects run by Konkraft and Norsk Industri addressing the two recommendations on data interoperability and sharing and contracting models. OG21 will follow up with these projects that the scope of the OG21-recommendations is covered.

On the other measures, OG21 will communicate the recommendations and need for action to regulators and the industry.

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. The strategy document was revised in 2016.

2.2 About the "Risk Assessments and Technology Decisions" project

The revised OG21 strategy illustrates the large value potential in efficient use of technologies. OG21 therefore encourages the development and implementation of technologies that maximize resource utilization, reduce environmental impact, reduce costs and improve productivity on the Norwegian Continental Shelf (NCS), (OG21, 2016).

Risk aversion and conservatism among decision makers have been suggested to explain slow technology implementation in the petroleum industry. The OG21 strategy lists "High perceived risks" as one of several barriers to technology adoption, and the OG21-study in 2017 on business models to accelerate technology implementation, points to perceived risk being at the core of an industry dilemma: "New technologies have the potential to unlock substantial value, but a perception of high risk and challenging project economics, drive the use of traditional technologies".

The oil price shock in 2014 and subsequent lower prices than in the years leading up to 2014, led the petroleum industry into a recession with low profitability, lower investments and reduced activities. The industry responded with cost cuts as well as workforce reductions, resulting in considerably reduced break-even prices for new projects. Looking a few years ahead, the activity level on the NCS is predicted to be high. The activity level after 2022 is however still uncertain.

With the recent history in mind and the prospects of better times ahead, OG21 wanted to investigate whether established risk methodologies and how they are applied in the industry, lead to optimum technology decisions from a business as well as a societal perspective.

2.3 About the Rystad Energy study for OG21

The OG21-project included the commission of a study from the consultancy firm Rystad Energy (2018). The resulting Rystad Energy report "Risk assessments and impact on technology decisions", is available on the OG21 website.

The report from Rystad Energy is based on in-depth interviews with more than 25 executives in the Norwegian petroleum industry, in-house research and results from several OG21 workshops conducted as part of this OG21-project.

3 THE NEED FOR TECHNOLOGIES TO STRENGTHEN NCS COMPETITIVENESS

3.1 Offshore petroleum in demand for decades to come

Oil and gas are likely to continue to play an important role in the global energy mix in the decades to come. According to the International Energy Agency (IEA), demand for natural gas will increase towards 2040 in all scenarios, also if the world is successful in curbing greenhouse gas emissions. Demand for oil might peak before 2040 within stringent greenhouse gas emission policies but will probably still be considerable higher than what today's producing fields are able to produce (IEA, 2017).

3.2 Competitive landscape is changing to require faster returns

Rystad Energy has in its study for OG21 assessed the future call on oil supply from new fields as production from existing fields decline. The estimate on the future call for offshore oil in three different demand scenarios, indicates that NCS projects are highly competitive as compared to offshore projects in the rest of the world, see Figure 1. Most NCS projects would still be profitable in a scenario where oil demand peaks as early as in year 2025.

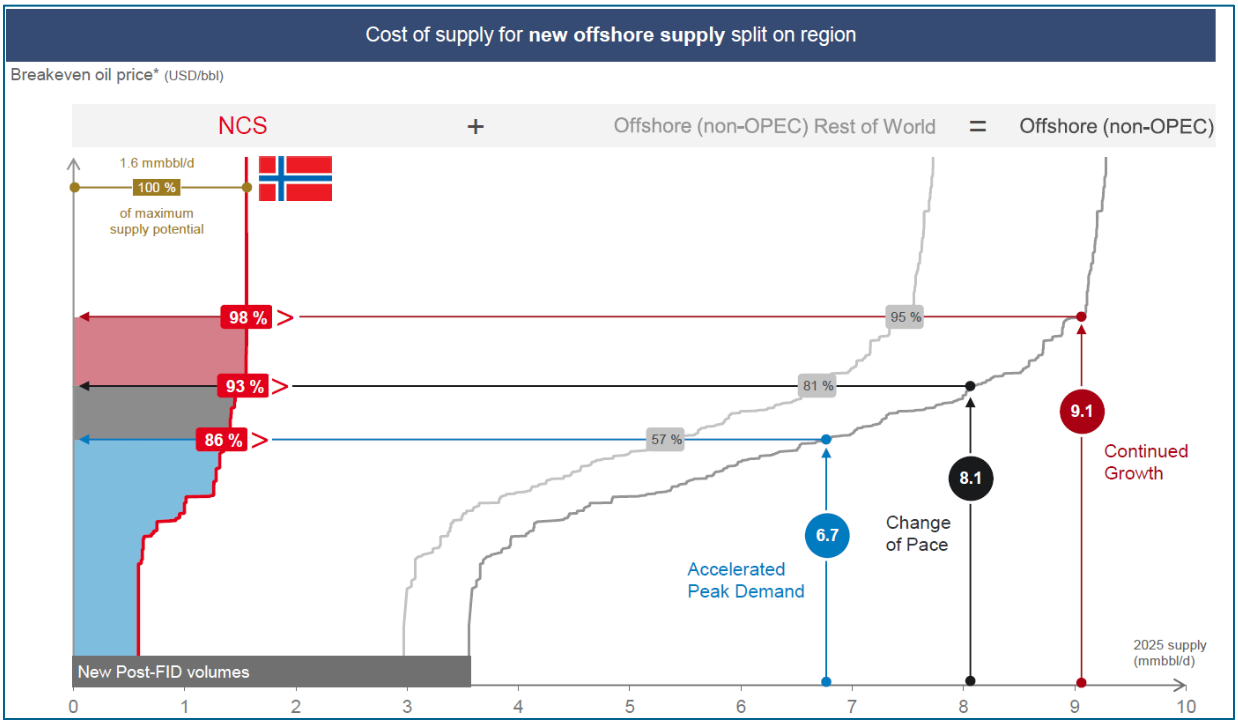


Figure 1 Demand for new offshore oil in three different scenarios "Accelerated peak demand", "Change of pace" and "Continued growth", (Rystad Energy, 2018)

However, the competition for investments depends on more than low and competitive break-even prices. Two factors especially have changed the competitive landscape over the last few years:

1. Uncertainty about future profitability of offshore projects as effects of greenhouse gas policies play out, both in terms of the supply of renewable energy and the demand for petroleum products.
2. The advent of shale oil offering shorter project lead-times and much faster payback times than traditional offshore projects, see Figure 2.

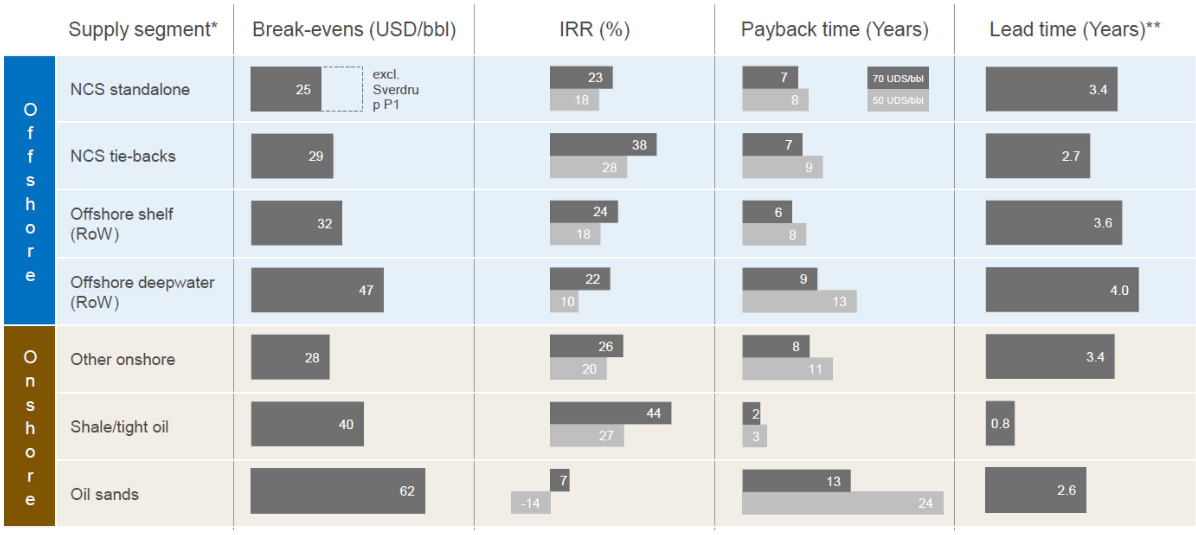


Figure 2 Comparison of new offshore and shale oil projects on economical metrics (Rystad Energy, 2018)

To stay competitive, offshore projects therefore not only have to offer competitive break-even prices, Net Present Value (NPV) and Internal Rate of Return (IRR) – they also must look for ways to offer earlier cashflow and faster returns.

This impacts the development and use of new technology, which on one side can provide better results on metrics such as break-even, NPV and IRR, but which on the other side may also add to project lead time and the risk for delayed production and cashflow. To harvest the value of new technology, technology development and adoption must respond to the changed competitive landscape by:

1. Reduce time from ideas to technology adoption
2. Reduce risks related to the adoption of new technology

3.3 Technology examples illustrate common implementation obstacles

OG21's technology target area groups (TTAs) have identified examples of technologies that offer high rewards, but which also are perceived to introduce high risks, and therefore have struggled to penetrate the market, see Figure 3. All examples are technologies addressing technology needs as described in the OG21 strategy document (2016).

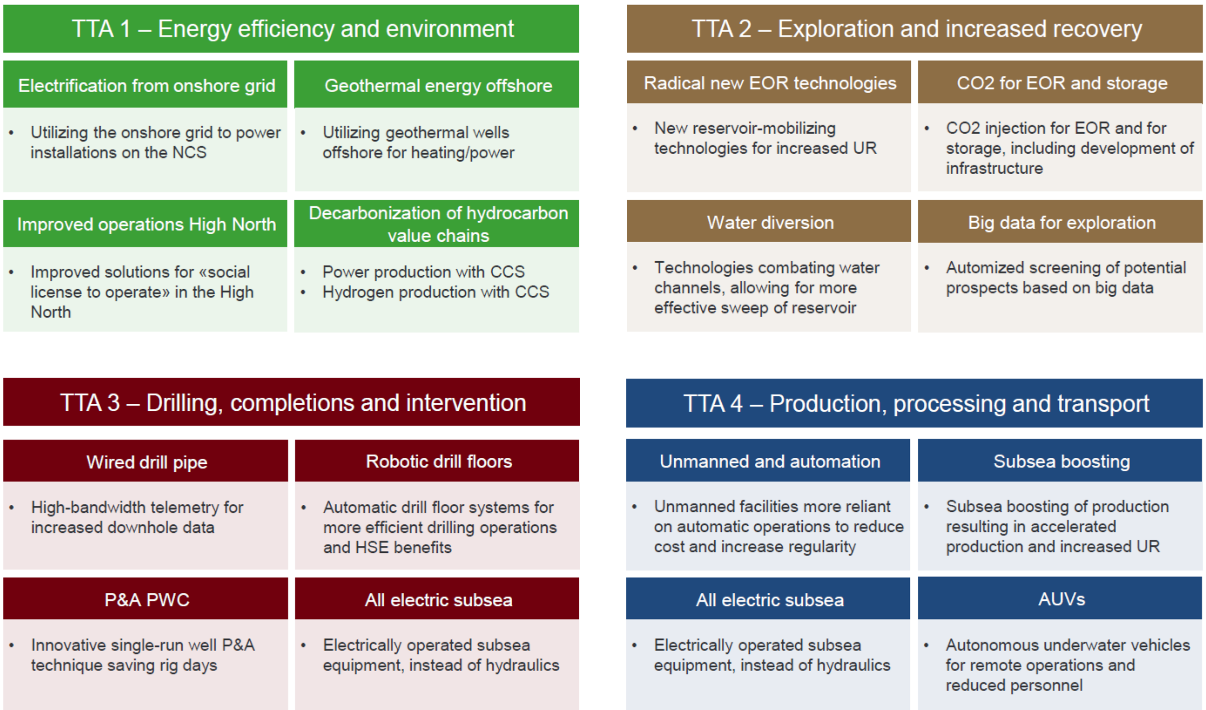


Figure 3 Example technologies identified by TTAs to illustrate technologies that offer high rewards, but which also are perceived to introduce high risks.

Main value drivers and key obstacles related to these types of new technology are illustrated in Figure 4.

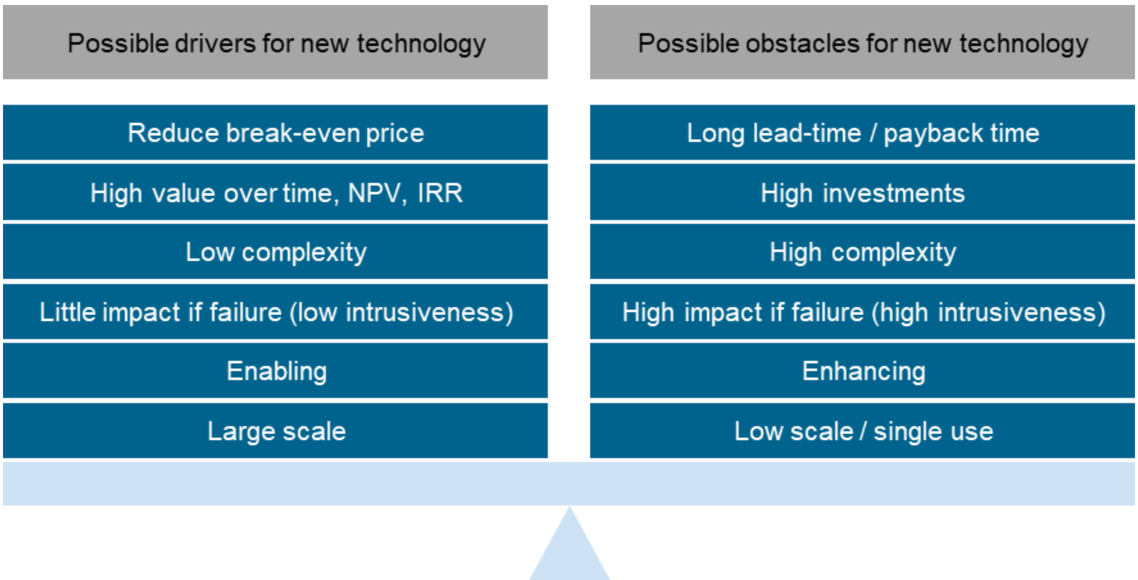


Figure 4 Main drivers and key obstacles for new technologies

Economical drivers and obstacles were discussed in the previous section: New technology generally increases productivity and therefore contributes to reduced break-even prices and increased NPV and IRR. However, new technology may be associated with uncertainty about development and implementation time and hence contribute to longer lead time for projects and potentially also longer payback time. New technology may also require substantial investments up-front.

Enabling or enhancing technology: If a technology is absolutely required to solve a problem (enabling), it stand a much higher chance of being supported than if it is only enhancing the capabilities and/or productivity. Most example technologies, albeit promising huge value potential, are enhancing rather than enabling.

Scale and applicability is important both for suppliers and oil companies. Most example technologies are single use by design unless oil companies or the industry on a national level can identify portfolios of application.

Intrusiveness is a term describing to which extent a technology could have direct negative effect on production or resources if it should fail. Many of the example technologies, but not all, are characterized by a high degree of intrusiveness. Increasing the reliability of the technology or reducing the degree of intrusiveness would often be required to sanction projects with new technology.

Complexity of change. A promising technology will in many cases require multi-disciplinary efforts or system changes. The potential high rewards may be linked to changes in systems, work processes or organizations, but these very changes introduce resistance and uncertainty that impede technology implementation.

3.4 Industry risk assessment methods add conservatism to technology decisions

Historically, development projects on the NCS have delivered only 65% of the planned economic value, NPV, as compared to the time of the Final Investment Decisions. The lost economic value results from too optimistic project delivery time, project cost estimates and production profiles. Expected mean values have been over-optimistic and outcome uncertainty ranges have been assumed too narrow (Bratvold, 2018).

Industry enterprises use risk management tools to reduce such value destruction. Enterprises in the petroleum industry have rich tool boxes for evaluating risks, including both quantitative and qualitative methods such as:

- Rational decision tree, economics analyses
- Hazard/risk identification and risk registers
- Integrated risk management
- De-risking
- HazOp – Hazard and operability analyses
- FMECA – Failure mode effect and criticality analyses
- Reliability analyses
- Technology Readiness Level (TRL) evaluations

Risk management is important to mitigate risks and reduce uncertainties, but the general issue with most risk management tools is that they mainly address potential negative outcomes, whereas opportunities for value creation related to making decisions under uncertainties are overlooked (Bratvold, 2018).

As tools for eliminating hazards and reducing risks during the development of new technologies, risk management methods function as intended. The typical pattern is that technology risks are reduced over the development and qualification period through the gathering and use of new data and knowledge, leading to improved design as well as better assumptions on technology characteristics and performance (Rystad Energy, 2018).

However, OG21 observations from interviews and workshops confirm the view that risk management tools emphasize hazards and risks with limited attention to opportunities related to the application of new technologies. New technologies offer potential added value which could be difficult to estimate, especially if new technologies bread the ground for future, unknown opportunities. Since new technologies often add uncertainty to cost, production and time estimates, and risk management tools by design are focused on identifying and reducing negative outcomes, risk assessments are inherently biased to favor proven technologies over new technologies.

The traditional technology development process has some other issues that also work against the implementation of new technologies. Firstly, if early assumptions are too conservative, promising technologies could be stopped before sufficient data and understanding has been collected. Secondly, the process is linear with little room for fast adjustments and learning from failures. And thirdly, the qualification and piloting step remains a hurdle where both access to funding and relevant test conditions are challenging.

The issue of over-emphasizing risks over opportunities is exacerbated by a fundamental conservatism among decision makers. Decision makers that make the final calls add their perceived risks to technology investment decisions, as illustrated in Figure 5. Even though the assessed risks associated with a new technology should be reduced over a technology's development time line, the risk perception with decision makers along the value chain tends to increase because:

- Decision makers further out in the value chain naturally have less in-depth understanding of the technology in question than subject matter experts, and
- Decision makers further out the value chain have more responsibility for the results of the technology decisions, including the responsibility for negative outcomes.

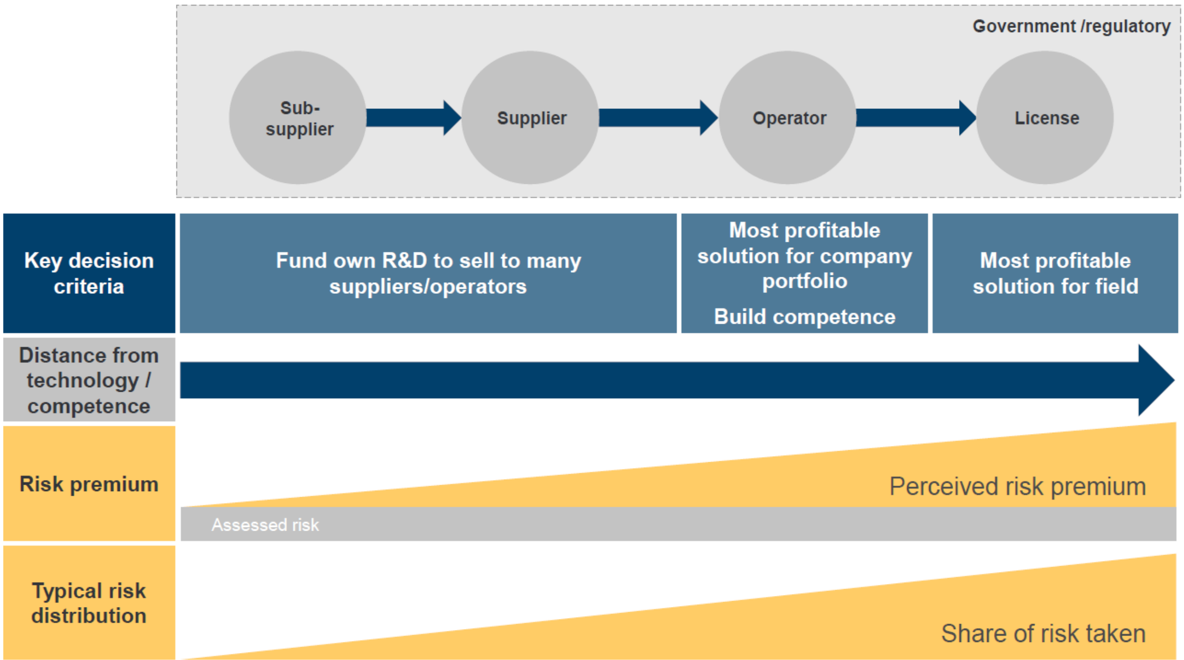


Figure 5 Illustration of how risks are assessed along the value chain (Rystad Energy, 2018)

Adding to this, the final decision makers in production licenses generally have a narrow objective of optimizing the value for the license/asset. The potential portfolio benefits for the licensees and for the NCS at large tend not to be considered.

The hurdle for new technology resulting from narrowly assessed benefits and opportunities, only becomes higher for maturing basins such as the southern parts of the NCS, where the average field size and consequently the economical ability to invest in new technology, is decreasing.

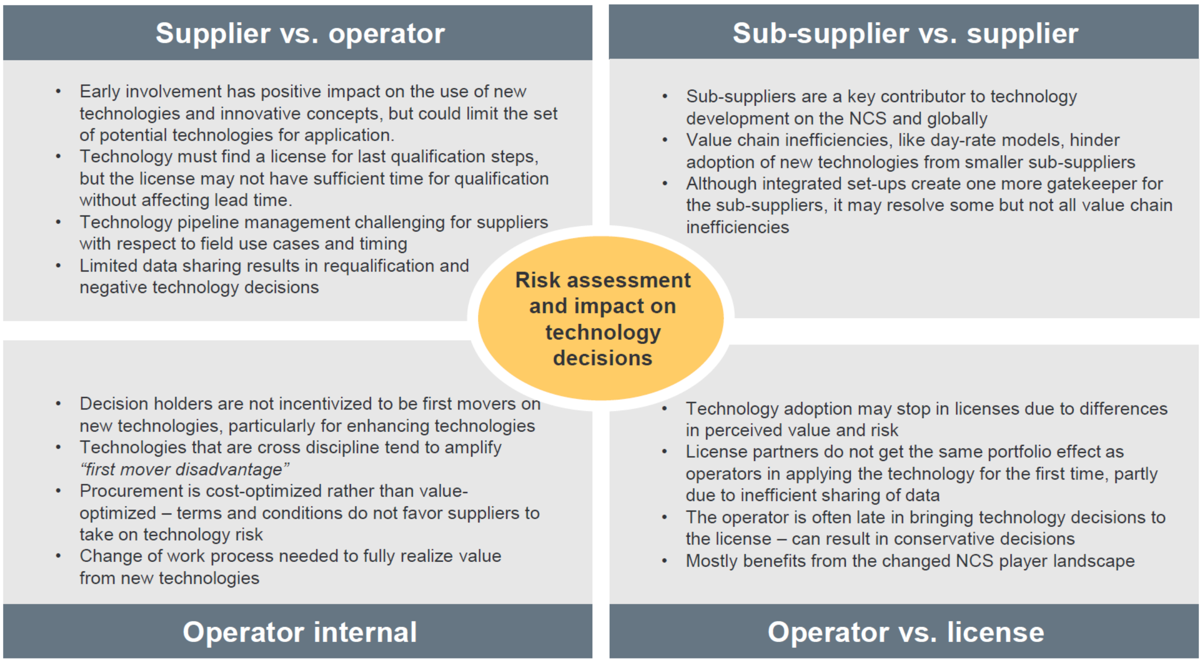
OG21 believes the combination of risk management tools that fail to assess value opportunities, the high perceived technology risks among final decision makers, and technology effects being evaluated in isolation, lead to over-cautious technology decisions unless enterprise culture, leadership, objectives and incentives drive a different behaviour.

3.5 Four perspectives add insight to slow technology adoption

Figure 5 depicts the value chain with four main players:

1. Sub-supplier of technology.
2. Supplier – often system supplier that integrates sub-suppliers' technologies.
3. Operator – oil company engaging supplier and sometimes directly sub-suppliers/ technology providers.
4. License with ownership of several oil companies, making the final decision on technology implementation.

There are obstacles to technology adoption within each of these four players' organizations and at the interfaces between them. Industry interviews conducted by Rystad Energy (2018), as well as discussions in OG21-workshops, suggest the following obstacles as seen from the four perspectives:



Going one step behind the obstacles, OG21 believes three direct causes explain a slow technology adoption pace:

1. **Technology opportunities across portfolios are not fully explored.** This relates to the entire project portfolio of NCS, individual project portfolios of oil companies and intersection of project portfolios between oil companies. Consequently, (i) technology risks and costs are inefficiently spread on potential beneficiaries, and (ii) potential value is underestimated.
2. **Project opportunities are not timely communicated to technology providers.** This results in poor predictability of market demand and hence uncertainties for suppliers, as well as potential non-optimal technology decisions in the projects.
3. **Lack of incentives that promote innovation.** Key performance indicators both at enterprise and individual levels, can, if poorly designed, encourage isolated short-term gains at the expense of long-term portfolio value creation. Proven technology is in such cases locked-in at the expense of new technology that could add more value.

And behind these three direct causes, OG21 believes there are two main root causes:

- **Lack of technology vision and leadership**
- **Cautious enterprise culture**

4 OG21 RECOMMENDATIONS TO ACCELERATE THE ADOPTION OF HIGH REWARD TECHNOLOGIES

OG21 recommends six measures to reduce technology risk aversion and accelerate technology adoption. An overview of the recommendations is given in Figure 6, with details described below.

The recommended measures are based on results from several OG21-workshops, input from the OG21-TTAs and research and input from Rystad Energy (2018).

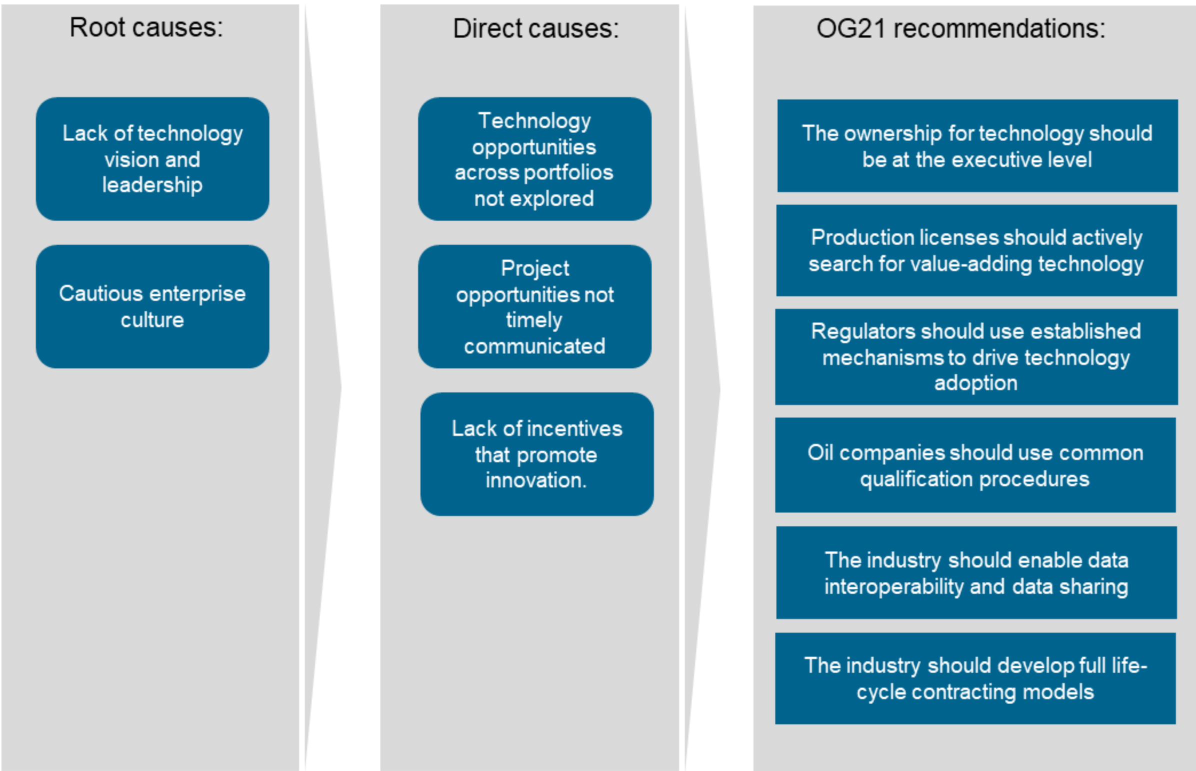


Figure 6 OG21 recommendations to address direct causes and root causes for slow technology adoption

Details on the six new OG21 recommendations:

1. **The ownership for technology should be at the executive level:**
    - Industry enterprises should have visible "technology champions" at the executive level.
    - Technology responsibility should start at the executive level and be distributed throughout the organization. The responsibility should be reinforced through key performance indicators and incentives.
    - Executive level technology managers should make sure that technology opportunities are identified and communicated to potential technology providers in a timely fashion.

2. **Production licenses should actively search for value-adding technology:**
   - Petoro's capacity to influence technology adoption across the SDFI portfolio, should be increased.
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   - Regulators should remind licensees on the NCS about their responsibility for continuous evaluation of technical solutions to optimize petroleum production.
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5. **Industry enterprises should collaborate on developing procedures and standards that enable data interoperability and efficient data sharing:**
   - Industry enterprises and regulators should agree on and develop common data protocols, data formats and data management principles and rules.
   - Production licenses should share within pre-defined data management principles and rules, technology experience data as well as operational data.
6. **The industry should develop and apply full life-cycle contracting models:**
   - New contract models should incentivize suppliers to propose technologies that create value over time.
   - Key performance indicators (KPIs) should be aligned between project participants.

The recommendation on data interoperability and data sharing is currently being addressed by industry projects run by Konkraft with broad and relevant industry representation. OG21 will communicate its recommendation to the Konkraft projects to reinforce OG21's support.

The recommendation on full life-cycle contract models is partly being addressed by an on-going industry project on contract models for field developments managed by Norsk Industry. OG21 will communicate its recommendation to the project with the aim of aligning the project's scope with OG21's recommendation details.

On the other measures, OG21 will communicate the recommendations and need for action to the Government, to regulators and to the industry.

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