OLJE OG GASS I DET 21. ÅRHUNDRE
REPORT

STRATEGIES FOR TECHNOLOGY DEMONSTRATION, AND OVERVIEW OF TEST FACILITIES

September 1, 2015

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1 SUMMARY

OG21 and Demo2000 has commissioned Rystad Energy ("the consultant") to evaluate strategies for successful technology demonstration and to map test facilities in Norway and internationally available to Norwegian technology suppliers.

In this report OG21 and Demo2000 summarize and discuss the main observations and recommendations proposed by the consultant. Furthermore we describe how the work will be followed up.

The report from the consulatnt is attached to this report. OG21 and Demo2000 believe that the consultant's report provides valuable advice for how to strengthen the possibility for successful demonstration and market introduction of new technologies. The report discusses two main elements of a strong technology demonstration strategy:

1. Build the right partnership
2. Develop a strong business case

OG21 and Demo2000 share the view that these two elements are essential to success for suppliers of new technologies. Furthermore we believe that the processes of developing partnerships and business cases are interlinked, dynamic and iterative. The business case for promising technologies grows stronger as new partners are brought in and access to their assets, competence and relationships are leveraged, which again would pave the way for attracting new, value-adding partners.

The consultant has provided a good overview of test facilities in Norway. We recommend that suppliers consult the list of test sites when they develop demonstration strategies for their technologies.

Many technologies need to be tested in or at field offshore, but many don't. OG21 and Demo2000 encourage suppliers, operators and licensees to carefully examining whether the offshore test scope could be reduced and replaced with onshore tests when new technologies are to be demonstrated.

OG21 and Demo2000 also encourage oil companies and industry organisations to harmonize demonstration and qualification standards and contracts to avoid duplication of efforts.

2 SCOPE AND PURPOSE

OG21-studies in 2013 and 2014 suggested that piloting new technologies presents challenges for many suppliers: It is costly, and it can be difficult to get access to good test facilities. For this reason OG21 and Demo2000 decided to conduct a study of technology piloting and demonstration opportunities in Norway and abroad.

Study scope:

1. Clarify the terms piloting and demonstration.
2. Describe strategies for technology piloting and demonstration
3. Provide an overview of test facilities in Norway with any particular limitations they might have. Also provide examples of test facilities abroad.
4. Categorize piloting opportunities for different types of technologies.
5. Identify technology areas with limited opportunities for piloting and demonstration.
6. Provide recommendations to improve Norwegian suppliers opportunities for piloting and demonstrating their solutions.

Task 1-5 are conducted by a consultancy project commissioned to Rystad Energy. The Rystad Energy deliverables for these tasks is attached as an appendix to this report.

Task 6 is carried out by a team consisting of OG21 and Demo2000 resources. This report discusses the main observations and recommendations made by the consultant, and provides the conclusions and recommendations made by the OG21/Demo2000 team.

3 THE CONSULTANT'S REPORT - DISCUSSION

The report from the consultant consists of two main elements:

1. Technology demonstration strategy
2. Technology demonstration facilities

3.1 Technology demonstration strategy

A major part of the consultant's report is devoted to how suppliers should develop a successful strategy for testing their new technologies. OG21 and Demo2000 are of the opinion that the consultant highlights some very important elements that a supplier would need to manage when planning for demonstration of its technologies. Summarized there are two main elements of a strong technology demonstration strategy:

1. Build the right partnership
2. Develop a strong business case

Understanding the stakeholders' positions and potential value of becoming partners is crucial to building the right partnership. A graphical presentation of the challenge is shown in Figure 1. Some partners will have little cost and high value of the technology innovation. Such partners are easy to persuade. Other important partners might have to carry costs or risks that don't justify the potential reward. One example is if the technology under development has important interfaces to existing equipment provided by other suppliers, and therefore poses risks to that particular equipment's performance or integrity. Another example might be licensees other that the field operator, that might have less use of the technology at question in their asset portfolio. In such cases the technology supplier might have to be willing to share more of the value creation to attract the right partners.

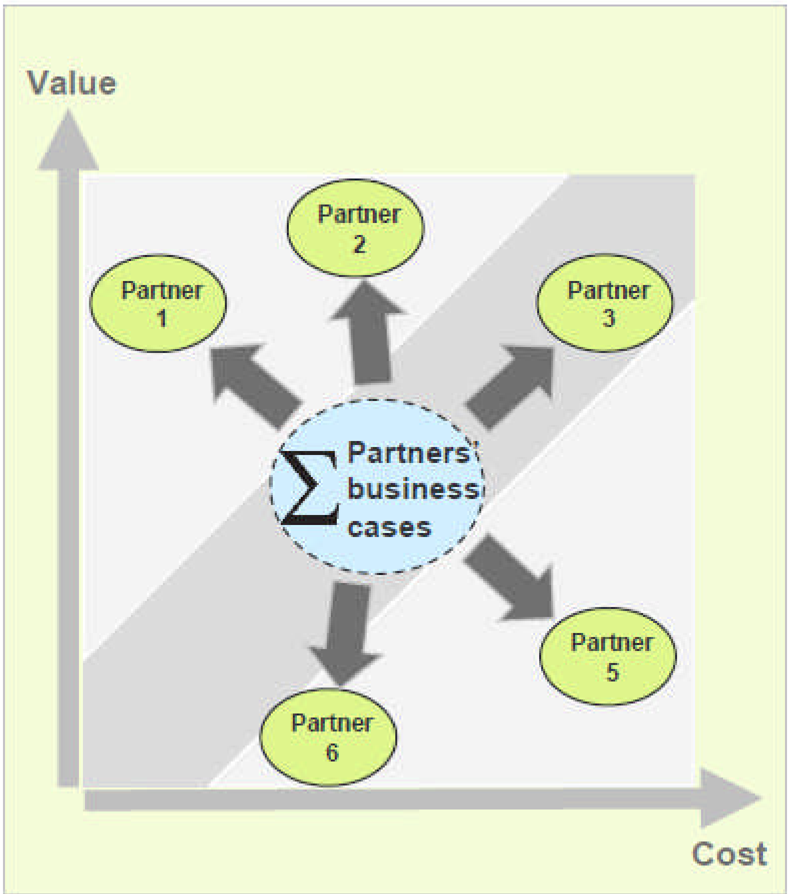


Figure 1 Building the right partnership

Of equal importance, but interlinked with creating the right partnership, is building a strong business case. Also for this element, the consultant has developed a graphical model:

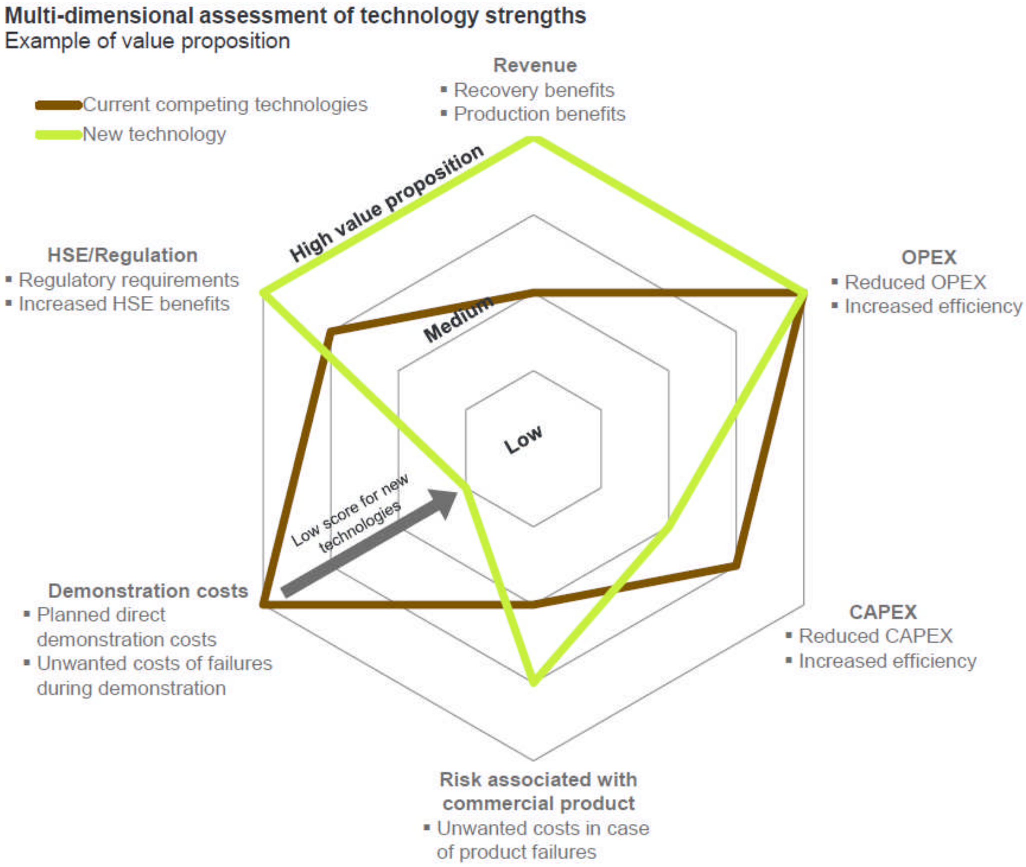


Figure 2 Model for building a strong business case

The model dimensions in Figure 2 are no different to the criteria used to evaluate Demo2000 project applications. The graphical model depicts well an important principle when proposing new technology solutions: *A new technology competes with existing solutions. To compensate for the demonstration and implementation risks and costs, it needs to be substantially better at other criteria such as revenue, OPEX, CAPEX and/or HSE.*

And it's the partnership behind the technology that together needs to demonstrate the value of a new technology. For this reason the value proposition for successful technology introductions should become stronger as partnerships evolve and new partners bring knowledge into the partnership. It would be an almost impossible task for especially small suppliers from the very beginning to understand the full value of their new technologies across oil companies' asset portfolios, or even across the asset portfolios of multiple licensees.

Demo2000 has implemented a "pre-project" support scheme, where technology suppliers with little experience in demonstrating business cases for their solutions, may obtain financial support for developing high quality applications for Demo2000 project funding. Through this scheme suppliers receive guidance and feedback on how to build strategic partnerships and improve their business cases.

Readers of the consultant's report should bear in mind that the processes of developing partnerships and business cases are interlinked, dynamic and iterative.

3.2 Technology demonstration facilities

In OG21's and Demo2000's view, the consultant's report provides a comprehensive overview of demonstration facilities in Norway. During the course of the project, it was agreed to only provide examples of international test sites, as it would be extremely resource demanding to compile such a list.

The test facilities in Norway are split into private and public sites. Each site is described at a high level on types of technology it is suited for.

The consultant's report also discusses to which extent existing test sites in Norway provide opportunities to test technologies related to technology gaps identified by OG21 in its strategy document. The is a general good coverage for technologies that can be demonstrated at onshore test facilities, with a possible exception for subsea technologies, for which there are only privately owned test facilities in Norway.

Some technologies can only be tested in or at field, with the particular challenges this represents.

OG21 and Demo2000 recommend that suppliers consult the list of test sites when they develop demonstration strategies for their technologies.

3.3 How OG21 and Demo2000 will follow up recommendations

Consultant's recommendations	OG21/Demo2000 follow-up
Challenge technology companies demonstration to develop strategies - both methodology and industry network	Communicate in presentations and strategy documents, the need for developing a demonstration strategy from the very beginning, based on the principles in this report.
Support harmonizing of demonstration/qualification standards used by various operators to optimize value of demonstration efforts.	Include in the communication to industry organisations.
Support process of reducing offshore testing scope, by moving as much as possible of testing tasks to onshore locations	Include in OG21's revised strategy document.
Provide transparency on available test infrastructure in Norway and highly relevant test infrastructure abroad	Communicate this report and make it available for suppliers to use.

APPENDIX – CONSULTANT'S REPORT

Technology demonstration strategy and existing test facilities

Final report
10th of February 2016

RYSTAD ENERGY

Introduction

Oil and Gas in the 21st Century (OG21) and DEMO2000 have contracted Rystad Energy to identify national and international opportunities for demonstration of new technologies relevant for the oil and gas industry in Norway.

The DEMO 2000 program aims to reduce costs and risks faced by the Norwegian Supplier Industry in developing new technologies by providing public funding to demonstration projects. The DEMO 2000 follows the guidelines set out by the OG21 strategy for research and development within the petroleum industry in Norway. The OG21 national technology strategy focus on sustained profitability in the Norwegian petroleum industry and resource optimization on the Norwegian Continental Shelf. It also aims to increase technology and knowledge exports by exploiting the competitive advantages and internationalization of the Norwegian service and supply industry.

The project is motivated by previous OG21 analysis, pointing to technology demonstration as an especially challenging phase in the development of new technology. Technology demonstration requires both sufficient funding as well as access to suitable test facilities. Demonstration of new technologies at field level, especially offshore, could put large values at risk. This, in combination with decentralization and fragmented decision-making structures could introduce significant barriers towards demonstration of new technology.

A framework addressing the fundamental aspects of a technology demonstration strategy is presented, focusing on the importance of a solid business case and a strong partnership.

Finally, an overview of existing test infrastructure in Norway is provided, with geographical location as well as ownership and technology coverage.

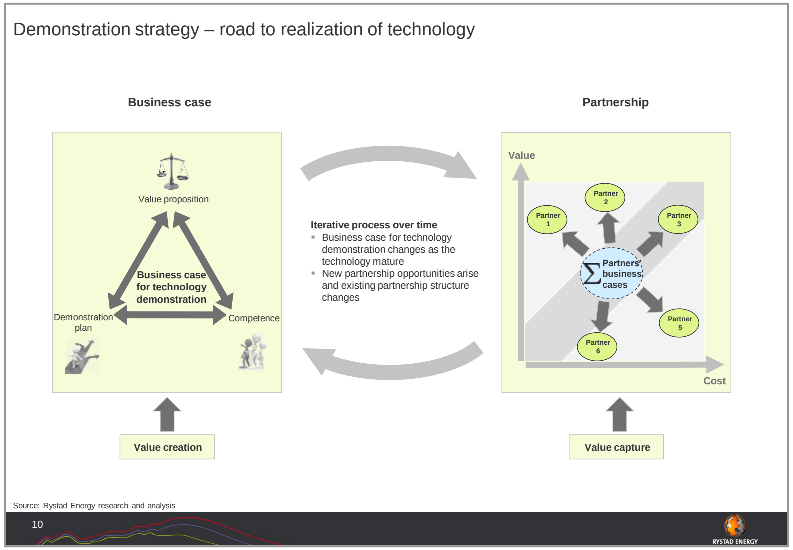
The report is developed in cooperation with OG21 and DEMO2000, based on interviews with a large group of industry experts from the operators, government, research institutes, suppliers and technology developers.

Rystad Energy, June 2015

Getting through the demonstration phase is first and foremost about having a solid business case and the right partnership

The demonstration phase is normally associated with significantly larger capital investments and risks than previous research and development phases. While also representing the transition into the commercial phase for the technology. Therefore, a business case with a solid foundation and strong partnership becomes even more important.

It is known that many technologies under development struggle to obtain funding and access to appropriate test facilities during the demonstration phase. Our assessment shows that in most cases, this is either due to the lack of capital or the need for new test facilities in the industry. A solid business case from a commercial perspective anchored with the right partnership, should normally be sufficient to secure funding and access to required test infrastructure in the demonstration phase. The lack of test infrastructure is not a major concern.



Think all the way from demonstration to commercialization – building a solid business case with a strong partnership

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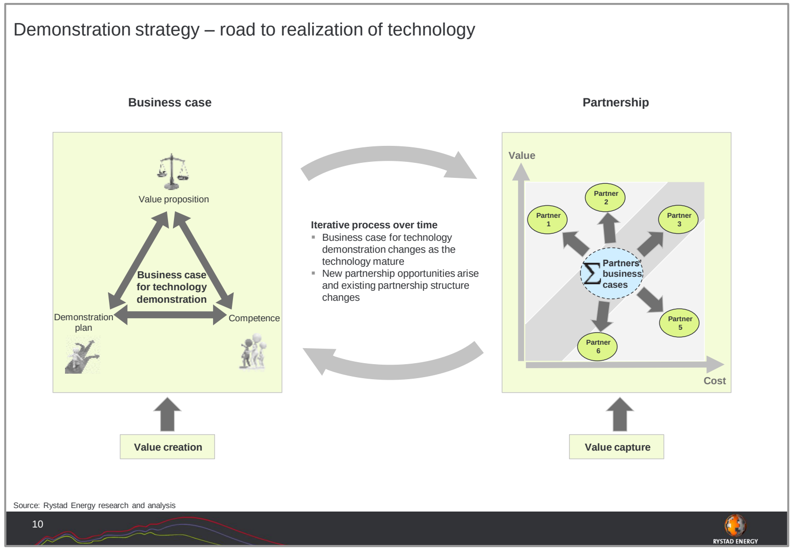
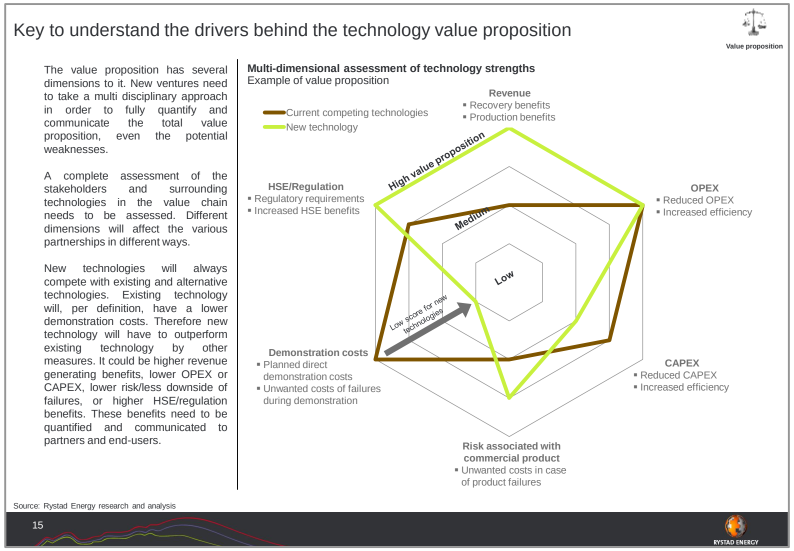
Building a strong business case for technology demonstration includes having a holistic view on the value of technology proposition, a realistic demonstration plan and people with the right competence involved. Optimizing the business case requires a multi-disciplinary approach. Industry case examples clearly show that both operators and technology companies often fail to understand the entire technology value proposition. A part of this is to understand the competitive environment for new technologies, where limitation in the capacity to take on-board new technology might hold back seemingly commercially attractive technologies.

The business case and partnership are interlinked. It is key to understand each partner's value and cost of joining the demonstration project. This enables deliberate measures to adjust the business case for each partner if required, and better understanding of how partners can contribute to the demonstration project. The final partner combination might for example include partners that are important to have on board in the commercial phase, despite only having a marginal role in the demonstration phase.





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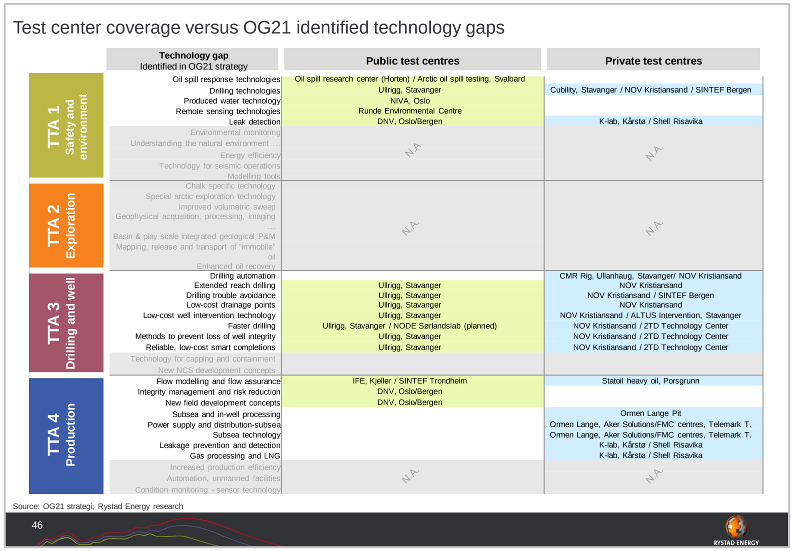
Most of the OG21 technology gaps identified have relevant test facilities in Norway

More then 30 relevant onshore test centers are identified. Test centers in the Eastern part of Norway are dominated by process, flow and material testing in the Porsgrunn area as well as subsea related test centers south of Oslo. Test centers in Southwestern Norway, including the Stavanger area, are primarily focused on drilling & well also including gas related test infrastructure. Western and Mid-Norway include a mix of test infrastructure mainly related to subsea, marine operations, multiphase flow and materials.

Overall the test infrastructure covers most of the identified OG21 technology gaps where onshore test centers are relevant. Especially TTA3 – Drilling and Well, is very well covered primarily due to the Ullrigg infrastructure in Stavanger.



Test center coverage versus OG21 identified technology gaps

	Technology gap Identified in OG21 strategy	Public test centres	Private test centres
TTA 1 Safety and environment	Oil spill response technologies	Oil spill research center (Horten) / Arctic oil spill testing, Svalbard	
	Drilling technologies	Ullrigg, Stavanger	Cubility, Stavanger / NOV Kristiansand / SINTEF Bergen
	Produced water technology	NIVA, Oslo	
	Remote sensing technologies	Runde Environmental Centre	
	Leak detection	DNV, Oslo/Bergen	K-lab, Kårstø / Shell Risavika
	Environmental monitoring	N.A.	N.A.
	Understanding the natural environment …		
	Energy efficiency		
	Technology for seismic operations		
	Modelling tools		
TTA 2 Exploration	Chalk specific technology	N.A.	N.A.
	Special arctic exploration technology		
	Improved volumetric sweep		
	Geophysical acquisition, processing, imaging …		
	Basin & play scale integrated geological P&M		
	Mapping, release and transport of "immobile" oil		
	Enhanced oil recovery		
TTA 3 Drilling and well	Drilling automation		CMR Rig, Ullanhaug, Stavanger/ NOV Kristiansand
	Extended reach drilling	Ullrigg, Stavanger	NOV Kristiansand
	Drilling trouble avoidance	Ullrigg, Stavanger	NOV Kristiansand / SINTEF Bergen
	Low-cost drainage points	Ullrigg, Stavanger	NOV Kristiansand
	Low-cost well intervention technology	Ullrigg, Stavanger	NOV Kristiansand / ALTUS Intervention, Stavanger
	Faster drilling	Ullrigg, Stavanger / NODE Sørlandslab (planned)	NOV Kristiansand / 2TD Technology Center
	Methods to prevent loss of well integrity	Ullrigg, Stavanger	NOV Kristiansand / 2TD Technology Center
	Reliable, low-cost smart completions	Ullrigg, Stavanger	NOV Kristiansand / 2TD Technology Center
	Technology for capping and containment		
	New NCS development concepts		
TTA 4 Production	Flow modelling and flow assurance	IFE, Kjeller / SINTEF Trondheim	Statoil heavy oil, Porsgrunn
	Integrity management and risk reduction	DNV, Oslo/Bergen	
	New field development concepts	DNV, Oslo/Bergen	
	Subsea and in-well processing		Ormen Lange Pit
	Power supply and distribution-subsea		Ormen Lange, Aker Solutions/FMC centres, Telemark T.
	Subsea technology		Ormen Lange, Aker Solutions/FMC centres, Telemark T.
	Leakage prevention and detection		K-lab, Kårstø / Shell Risavika
	Gas processing and LNG		K-lab, Kårstø / Shell Risavika
	Increased production efficiency	N.A.	N.A.
	Automation, unmanned facilities		
	Condition monitoring - sensor technology		

Source: OG21 strategi; Rystad Energy research

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DEMO 2000 and OG21 could support companies in establishing strong demonstration strategies, both project by project and by driving processes for common good

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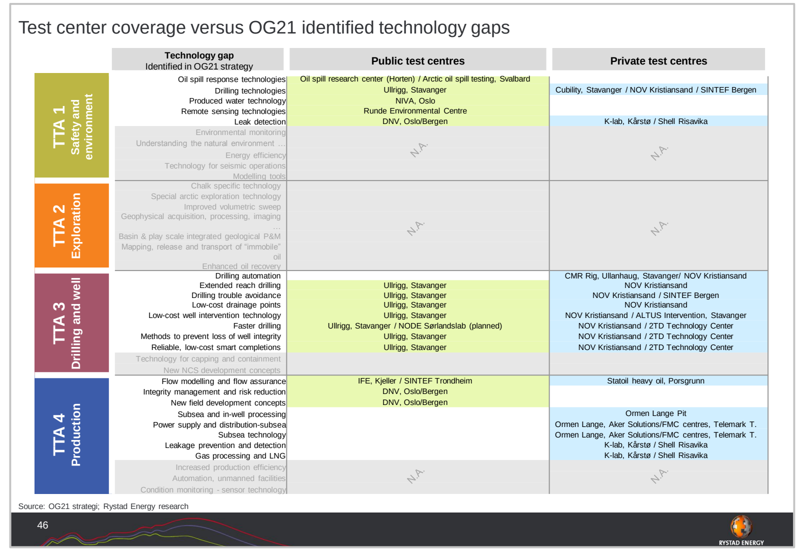
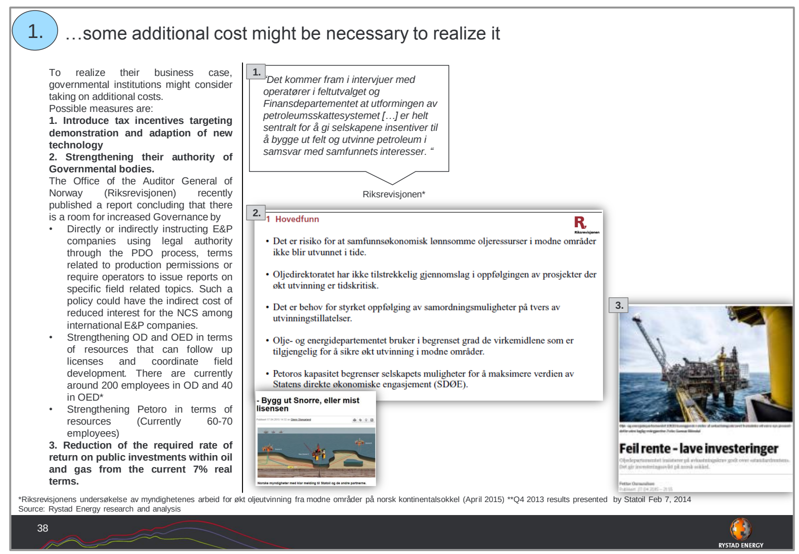


Recommendations on how DEMO 2000 and OG21 could contribute to increase the probability of successful demonstration projects:

- Challenge technology companies demonstration to develop strategies - both methodology and industry network
- Contribute to standardized commercialization contracts between technology companies and partners during the demonstration phase
- Support harmonizing of demonstration/qualification standards used by various operators to optimize value of demonstration efforts
- Support process of reducing offshore testing scope, by moving as much as possible of testing tasks to onshore locations
- Provide transparency on available test infrastructure in Norway and highly relevant test infrastructure abroad



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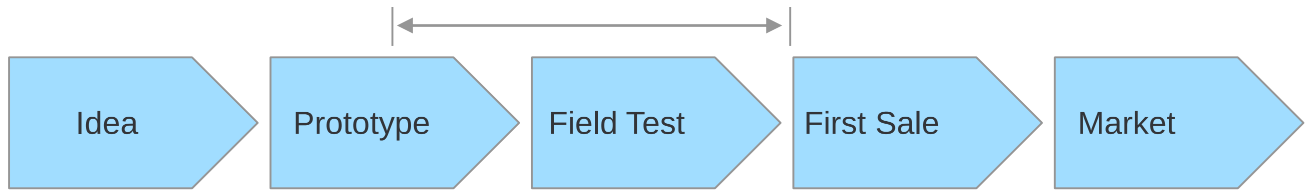
Technology demonstration phase – after laboratory testing, prior to first sale

The DEMO 2000 program is aimed primarily towards Norwegian supplier companies and subcontractors that, in cooperation with petroleum companies and/or other petroleum service companies, have a need to carry out pilot projects and demonstrate new technology for use on the continental shelf and for sale in international markets.

The DEMO 2000 program may provide up to 25 percent of the costs associated with piloting/demonstrating/qualifying the technology, typically within the range of technology readiness level, TRL (defined by API recommended practice), of 3-6. The demonstration phase does not include laboratory or model testing in an earlier stage of the technology development.

Steps towards commercialization of new technology

Demonstration phase
Real scale demonstration of a given technology in a operational environment, of which the results would decide whether it is basis for commercialization.



Source: Interviews, Rystad Energy research and analysis

Getting through “valley of death” requires a strong business case and partnership structure

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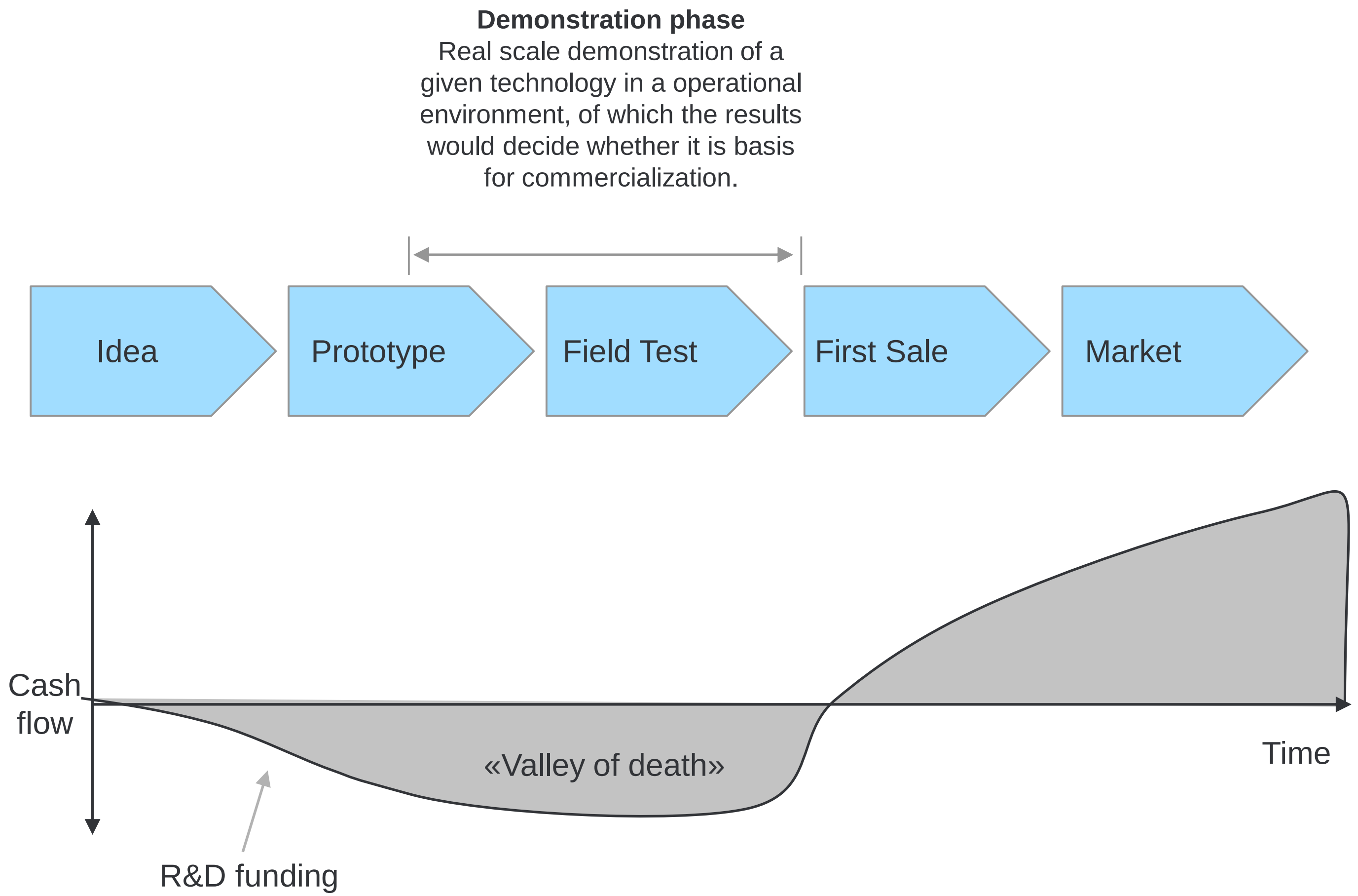
The demonstration phase is also called the “valley of death”. The costs typically increase significantly during the demonstration period compared to earlier phases of R&D. To compensate for these costs, the technology partners need to see a sufficient upside potential based on a strong business case and partnership structure.

Steps towards commercialization of new technology



Source: Interviews, Rystad Energy research and analysis

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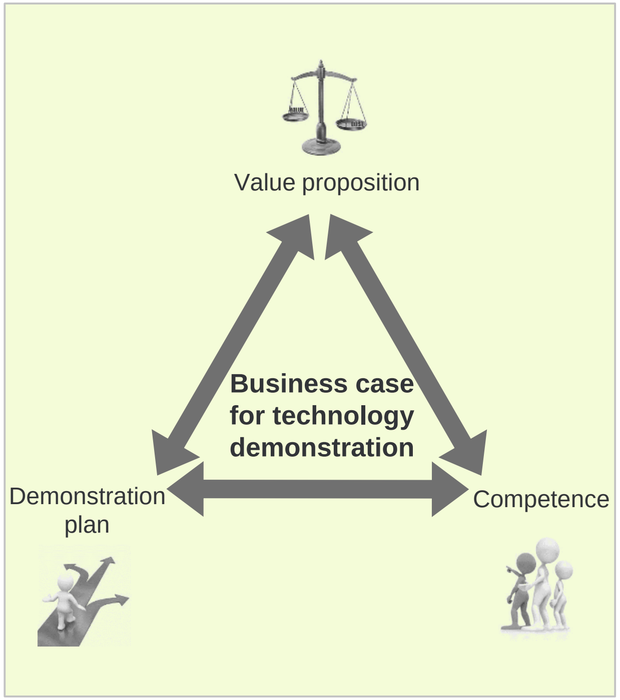
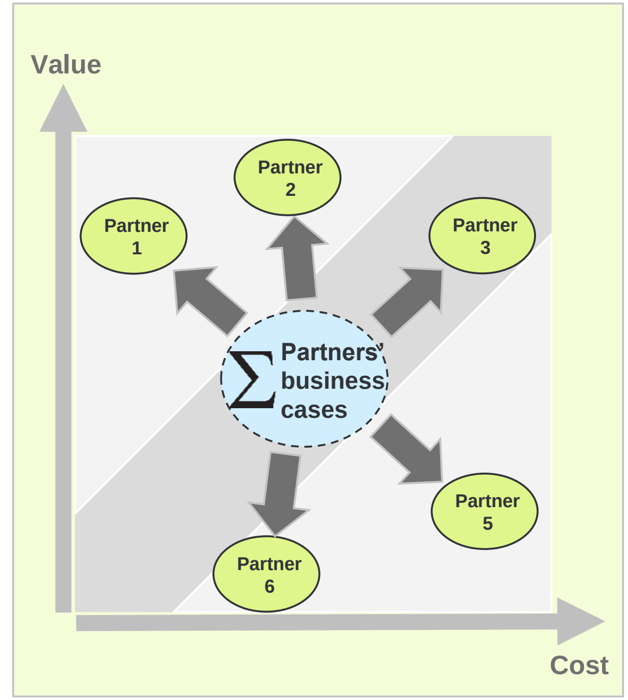
Demonstration strategy – road to realization of technology

Business case



Value creation

Partnership

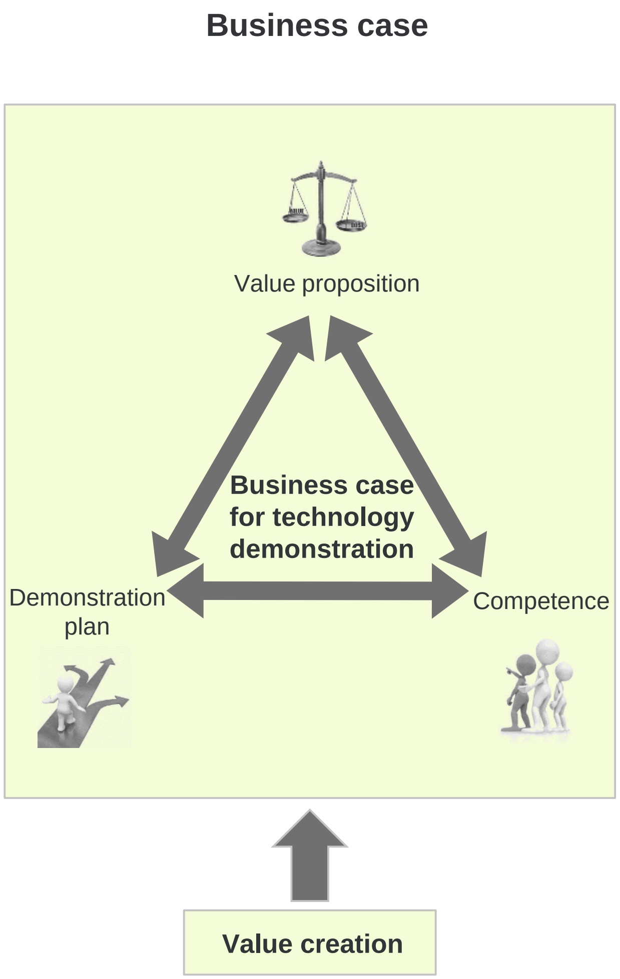


Value capture

Iterative process over time
- Business case for technology demonstration changes as the technology mature
- New partnership opportunities arise and existing partnership structure changes

Source: Rystad Energy research and analysis

Demonstration strategy – road to realization of technology



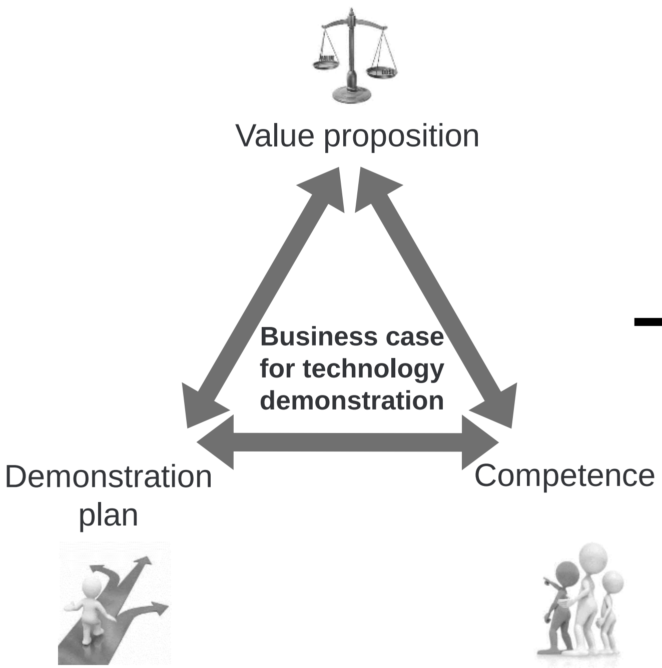
Business case for technology demonstration, based on three main building blocks:

1. Clear perspective on the value proposition of the technology
2. Cost efficient and realistic demonstration plan
3. Competence of people involved

Source: Rystad Energy research and analysis

Establish expected business case outcome to decide whether to proceed with demonstration

Develop business case based on three main building blocks

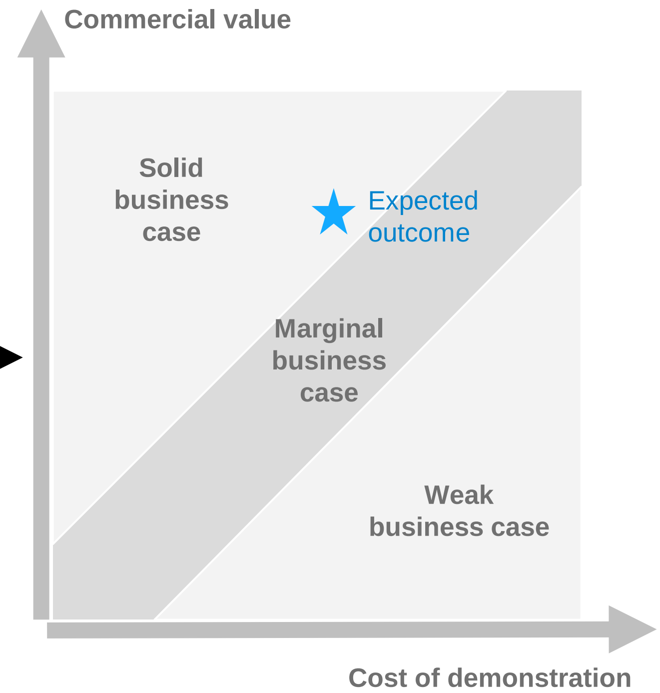


Alternative outcomes of business case for technology demonstration

Four combinations of technology value and demonstration cost outcomes, with assigned probability

	High demo. cost	Low demo. cost
High technology value	High value High cost	High value Low cost
Low technology value	Low value High cost	Low value Low cost

Expected outcome of the business case for technology demonstration



Source: Rystad Energy research and analysis

Key to understand the drivers behind the technology value proposition

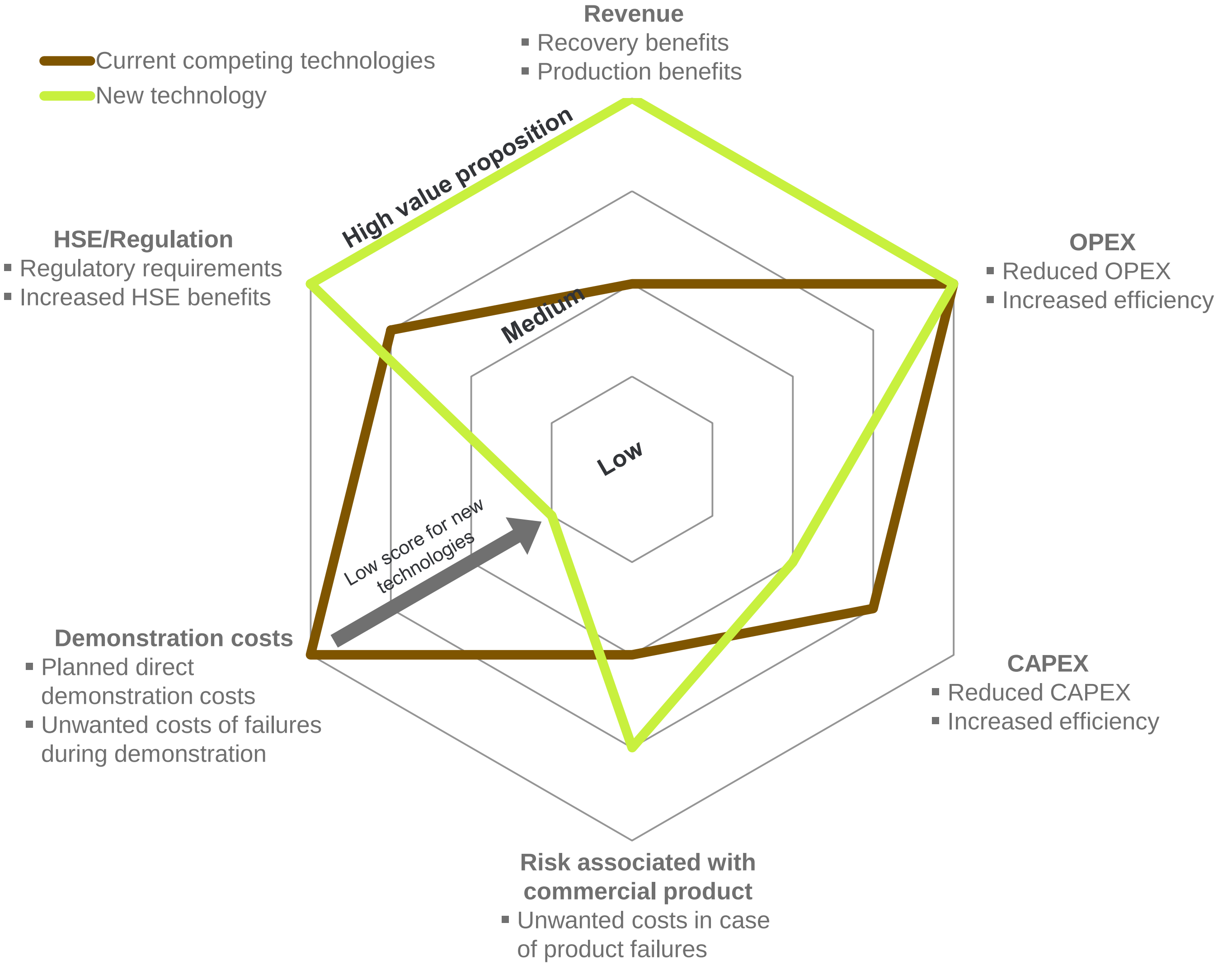
Value proposition

The value proposition has several dimensions to it. New ventures need to take a multi disciplinary approach in order to fully quantify and communicate the total value proposition, even the potential weaknesses.

A complete assessment of the stakeholders and surrounding technologies in the value chain need to be assessed.

New technologies will always compete with existing and alternative technologies. Existing technology will, by definition, have lower demonstration costs. Therefore new technology will have to outperform existing technology by other measures. It could be higher revenue generating benefits, lower OPEX or CAPEX, lower risk/less downside of failures, or higher HSE/regulation benefits. These benefits need to be quantified and communicated to partners and end-users. Also relevant to seek opportunities to reduce costs and/or risks through initiatives like DEMO 2000, Innovasjon Norge and Skattefunn.

Multi-dimensional assessment of technology strengths
Example of value proposition



Source: Rystad Energy research and analysis

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Both operators and technology companies could fail to understand the value proposition

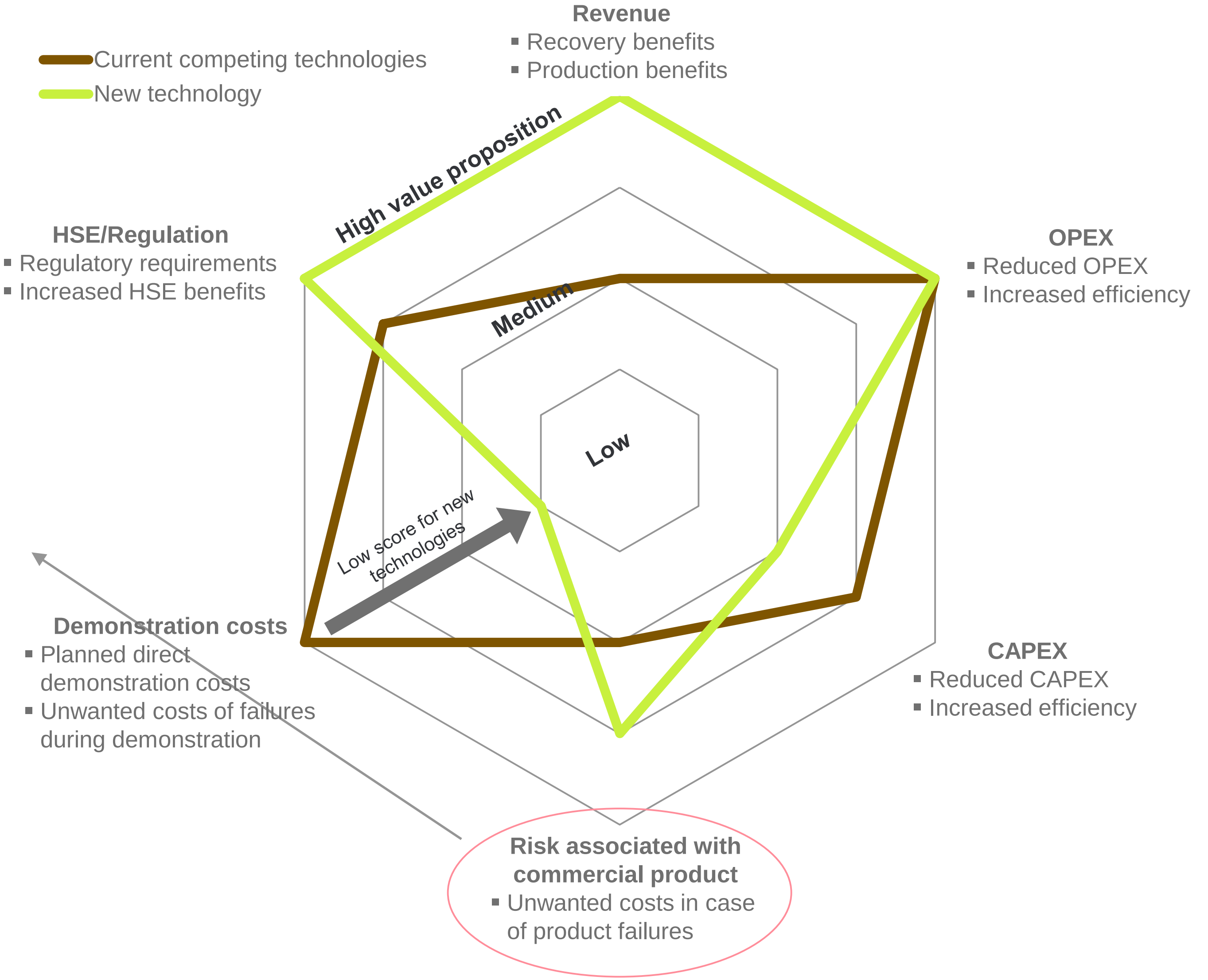
Value proposition

"Technology companies could often be focused on their limited part of the value chain, not understanding all dimensions and risks of introducing immature technology, both economically and with regards to HSE" - Operator NCS

"There are large variation among how the different operators assess the risk of introducing new technology. Whereas one operator concluded that there were no risk of introducing the new technology to their well, another operator concluded that one could loose the entire well if the technology failed"
- Downhole technology company

The risk willingness or risk aversion of an operator is often dependent on its asset portfolio. A smaller operator with only a few assets could for example be more reluctant to introduce any additional risk by demonstrating new technologies compared to a large operator with a large portfolio of assets. Any disruptions in production etc. will have a much larger impact on the smaller company's overall financials.

Multi-dimensional assessment of technology strengths
Example of value proposition



Source: Interviews; Rystad Energy research and analysis

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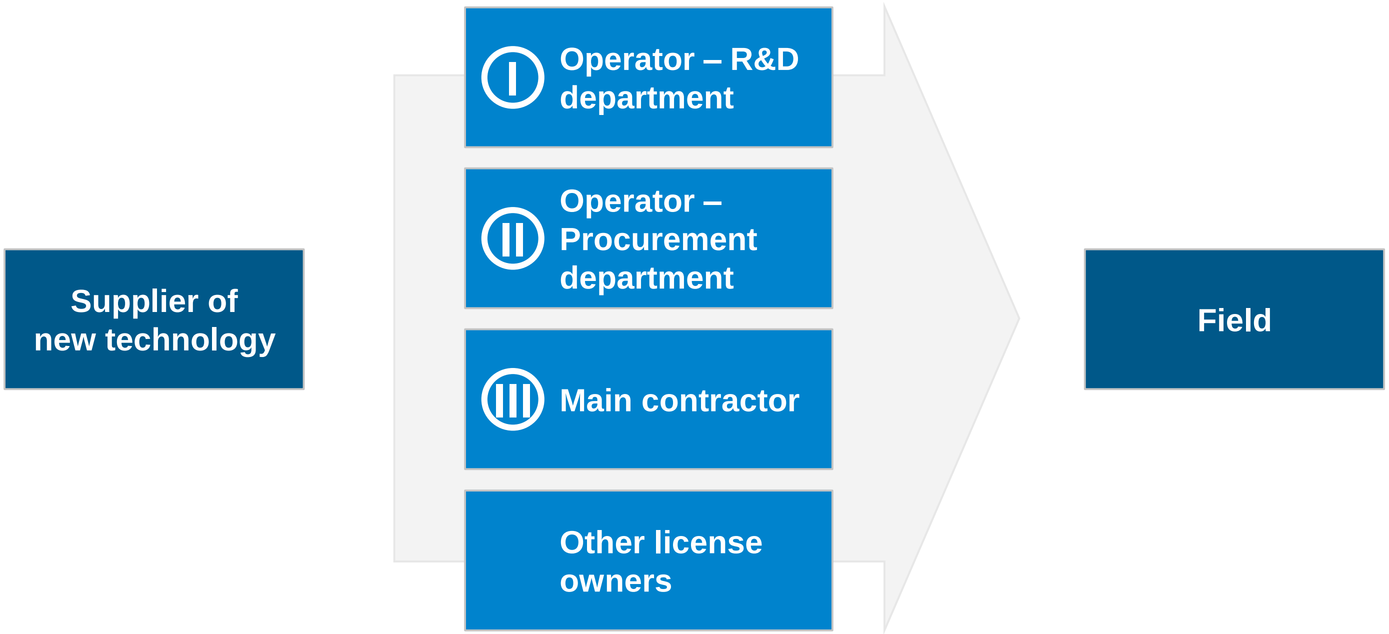
Understanding the technology decision structure and inhibiting factors for adoptions

Value proposition

Examples of potential stakeholders involvement in development of new technology



I — The typical first approach of a new technology supplier is the R&D department of an operator. They are technology experts, looking at new technologies in light of their technology strategy, with a company/portfolio perspective

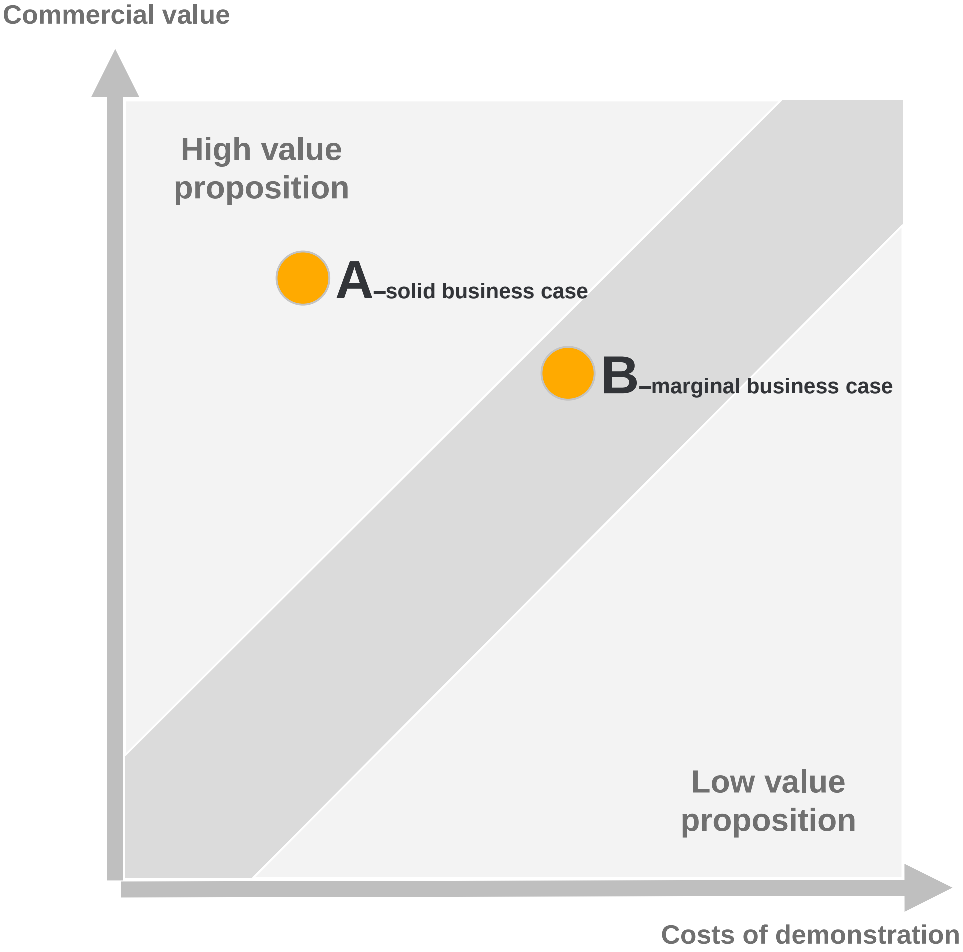
II — Technology suppliers, potentially in partnership with the operator's R&D department often needs to convince fields/asset owners to give access to a field test. The incentives and benefits of introducing a new technology is not necessarily the same for an asset owner as for the R&D department. Asset owners are normally not measured on their willingness to test new technology, rather focused on avoiding any disruptions in production/revenue

III — For certain technologies, FEED contractors and main contractors also needs to be involved in an early phase to secure adoption of the new technology. Even though the operators recommend using a new technology, subcontractors need to bid in the technology and understand its value proposition

- The technology value chain and its involved partners are crucial to understand
- Efforts to sell/push the technology to **all** key stakeholders in the value chain usually needs to be initiated early in the demonstration phase
- Missing key stakeholders can delay the demonstration process or even prevent it
- Technologies with asset specific value propositions would require new sales processes towards each asset owners within the same operator company – affecting future technology adoption rate

Source: Rystad Energy research and analysis

Competition for attention among new technologies – profitable technology is not necessarily enough to be commercially attractive



Competition among new technologies

- New technologies are competing for the attention of the end-user as well as access to demonstration facilities and other forms of support from the partners and end users
- There is often limited willingness to take onboard all new technologies, which leads to competition between new technologies

Technologies with a conceived marginally value proposition would normally be deprioritized as compared to technologies with a more solid value propositions

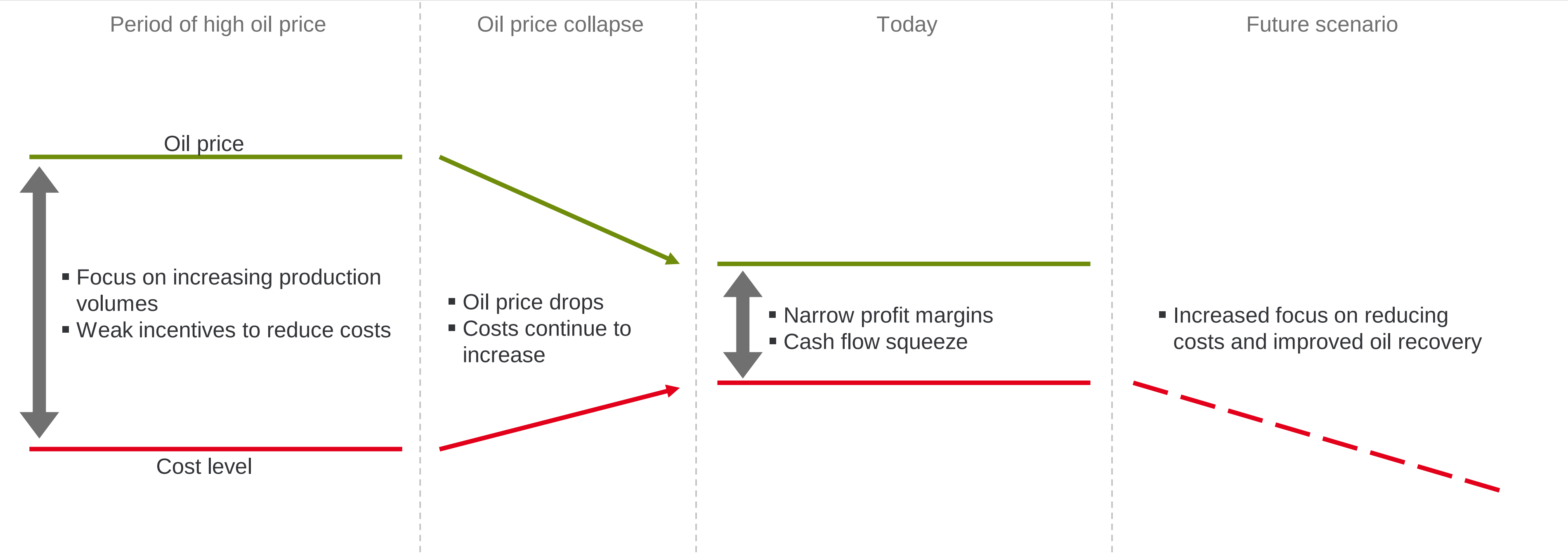
- Newbuilds: Suppliers of new technologies will try to get their technology installed on newbuilds. Due to large values at risk, failure of new technology could introduce severe costs to the project. The operator is therefore not likely to select new technologies with a marginal business case (B).

«Remember that a project leader for a 10 million demonstration project has limited impact on a field development of NOK 10 billion. There has to be a balance between the downside risk of the project and the upside potential of the technology»

- Existing infrastructure: The threshold could be lower for technologies that can be demonstrated at already producing facilities, as the amount of new technologies to be introduced is more limited. Hence, it is more likely that marginal and incremental technologies are selected and demonstrated by the operators in these situations

Source: Interviews; Rystad Energy research and analysis

However, incremental technologies are getting more attention from the operators



Narrow margins in the current market, give a stronger incentive to improve profitability to obtain more robust project economics

Incremental technologies are getting more attention from the operators in a narrow margin regime, as they no longer "only" make projects more profitable, but now could be essential to making projects profitable at all

Source: Rystad Energy research and analysis

Demonstration planning – reducing cost and increasing probability of success

Don't cross the stream to get water

Minimize demonstration effort	Examples
▪ Be up to date on the latest technology status to understand outstanding qualification scope	▪ Get all available information on the technology. Have other operators used it? Any information or experience that could be shared? Any available information from existing suppliers?
▪ Focus demonstration on core components and the right qualification level (TRL)	▪ “Offshore projects could include technology with lower TRL levels than TRL4, but this will often require a back-up solution” ▪ Consider using suboptimal components if this is non-core and reduces demonstration effort sufficiently ▪ Establish reasonable “operation window” – under which conditions the technology should be qualified for
▪ Seek cost-efficient demonstration routes to reduce technical risk	▪ Seek to perform component testing and early phase testing onshore instead of offshore ▪ Consider available test infrastructure in Norway and abroad, including US onshore, Saudi Arabia, Brazil etc. ▪ Use simulation software to design technology and early phase demonstration

Demonstration procedures and documentation	Examples
Align documentation procedure and test procedure with partners and other relevant stakeholders-	▪ “Statoil has a standard technology qualification process, aligned with DNV recommended practice 203” ▪ Be aware of alternative test requirements from different operators, avoid need to repeat demonstration effort to approach new clients.
Ensure high quality of documentation during the demonstration process	▪ Specific examples of unsuccessful demonstration due to poor demonstration execution from end customer at field

Source: Interviews; Rystad Energy research and analysis

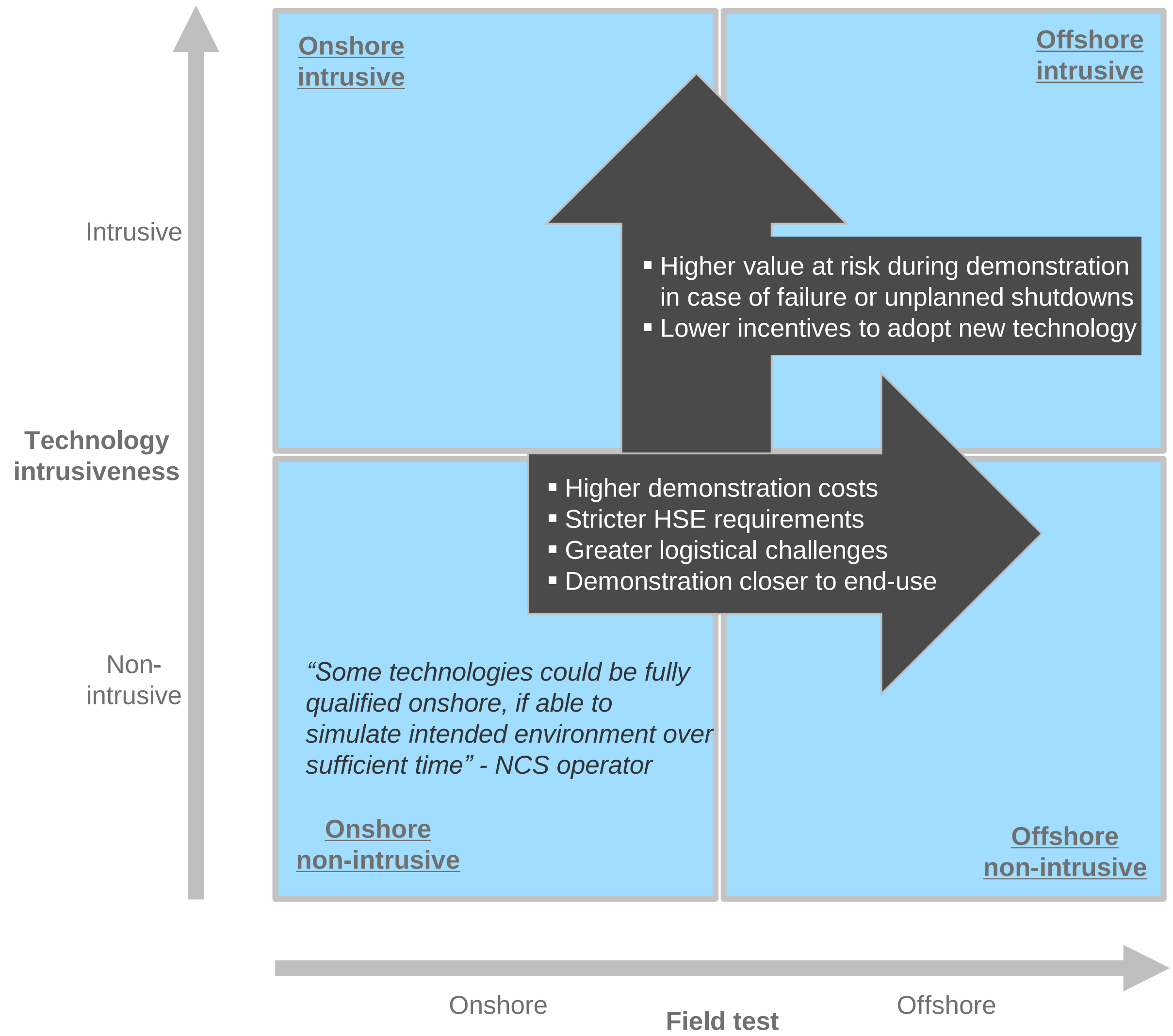
Four key groups of technologies with different characteristic of demonstrations

The technologies are categorized into four groups. Each group has a different characteristic in the sense that the **path of least resistance to demonstration** differs.

Onshore/offshore
It is possible to distinguish between technologies that require either a field test onshore or a field test offshore in order to prove its commercial attractiveness.

Intrusive/non-intrusive
Another dimension that will influence the demonstration is whether the technology is intrusive or non-intrusive. Intrusive technologies are solutions that interfere with core processes of the operations such as the wellstream or process facilities where the risks associated with incidents or failures are very high, such as lost production or unplanned shutdowns of the field.

Technology demonstration characteristic for technologies to be used on NCS (offshore)



Source: Rystad Energy research and analysis

Not all technologies are required to be demonstrated offshore

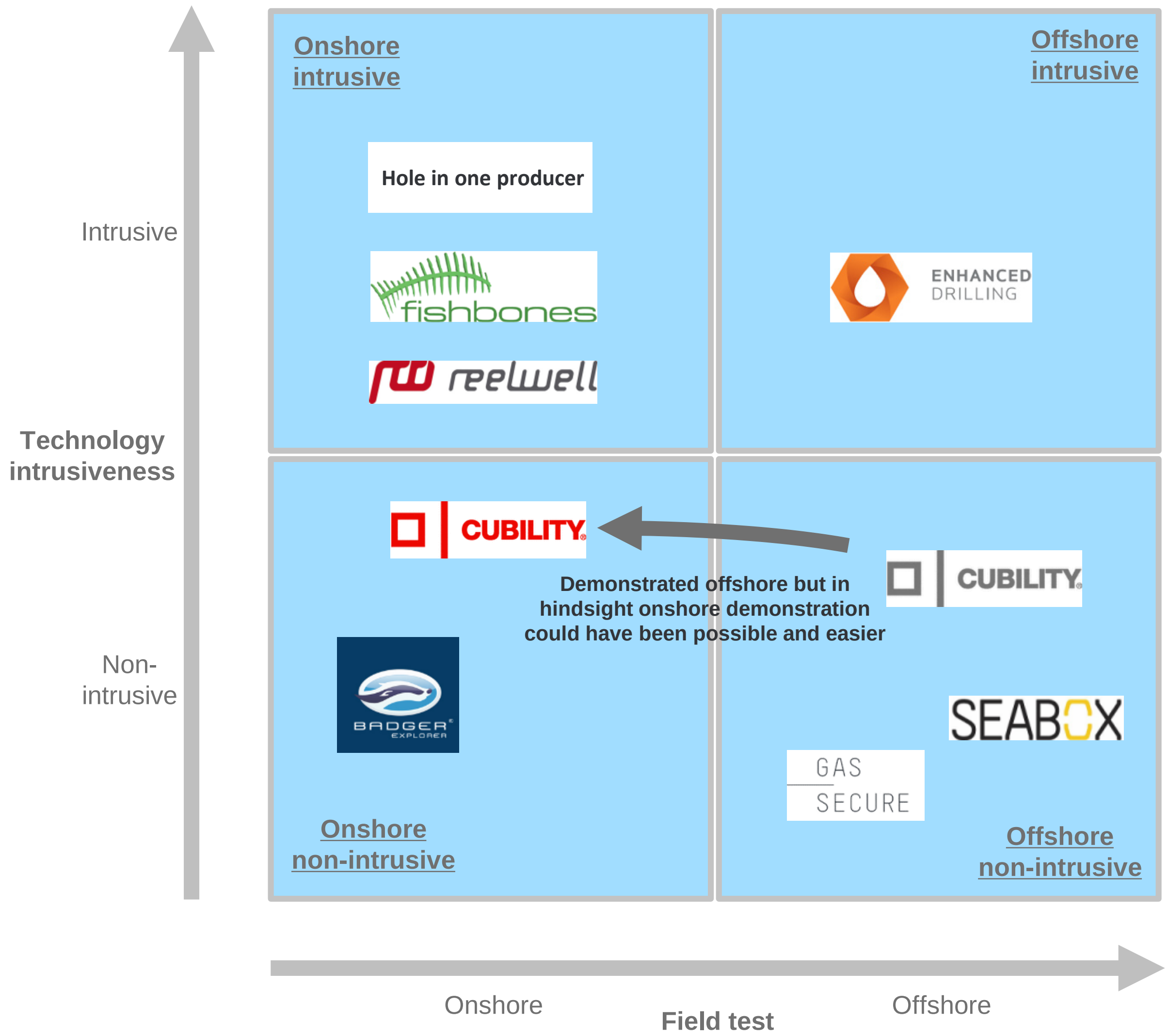
Not all technologies can be strictly put into one group but the segmentation can facilitate a discussion around the arguments and reasoning behind the selection of various demonstration strategies by previous ventures and how new technology ventures can learn from their experiences.

Based on the TTA focus areas, the illustration categorize these technology groups in the four demonstration groups.

Typically demonstration offshore is more complex than onshore. Even though all technologies will eventually target offshore applications, an **onshore demonstration could be satisfactory** to commercialize the product.

Moving from offshore to onshore demonstration requires a detailed understanding of what is possible to replicate onshore, potentially by expanding current onshore test facilities.

Technology demonstration characteristic for technologies to be used on NCS (offshore)



Source: Interviews; Rystad Energy research and analysis

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There are situations when building a proprietary test facility is the best option

Although most ventures use pre-existing test infrastructure to demonstrate their products, a few have chosen to build their own test centers.

Possible reasons to build proprietary test infrastructure:

- The test facilities needed are **highly technology specific**
- **Multiple tests** are required, making it more cost-effective to build own facilities rather than renting access to existing facilities
- The **timing** when the technology is ready to be tested is uncertain and could be mismatched with the occupancy at existing facilities

Examples of ventures building proprietary test infrastructure

Badger Explorer originally planned to conduct demonstration at an oil sand field in Canada. These plans were scrapped due to regulatory and organizational changes in the partnering companies. The second plan was to conduct the demonstrations at Ullrigg in Stavanger. However, after further consideration the company decided to build its own test infrastructure. The reasoning behind this was that the company saw that it needed to do several tests to reach a commercial product and that it would be more economic in the long run to do it in a proprietary test center

In 2004-2005, Cubility was considering how to demonstrate its MudCube technology. It is a solids control system that eliminates the traditional process of shaking fluid and solids. It got one engaged partner onboard which contributed with resources and helped to evaluate the testing opportunities available. With funding from the partner, Cubility decided to build its own test center to simulate an offshore drilling environment. The technology was qualified based on results from the test center.

Source: Interviews; Rystad Energy research and analysis

Competence and credibility to realize the technology potential

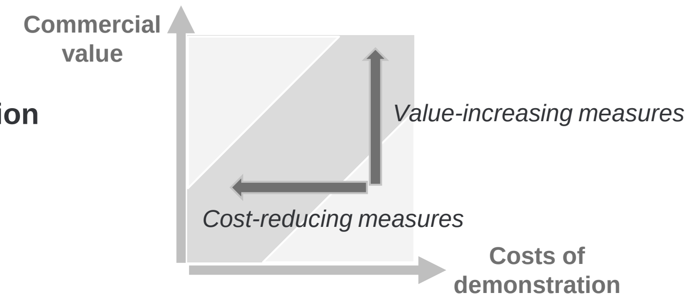
Competence	Examples
▪ Level of technical expertise	▪ "The developer needs to understand the technology and its business case better than the customer" – Technology developer ▪ "Immediately get the right technical expertise, and independent assessment of the technology"
▪ Professional organization	▪ Partners and stakeholders need to believe in the ability to deliver on time and with the required quality
▪ Industry competence and network	▪ Ability to gather relevant partners and stakeholders throughout the different phases of technology development and commercialization ▪ Strong industry network, including sub-supplier to realize technology demonstration and commercialization

"It is a hard job to communicate to all stakeholders that the technology is good and that you actually are able to deliver quality on time."
- Technology development company

Source: Interviews; Rystad Energy research and analysis

Several examples of adjustments to improve the business case

Examples of measures taken to improve the business case for technology demonstration

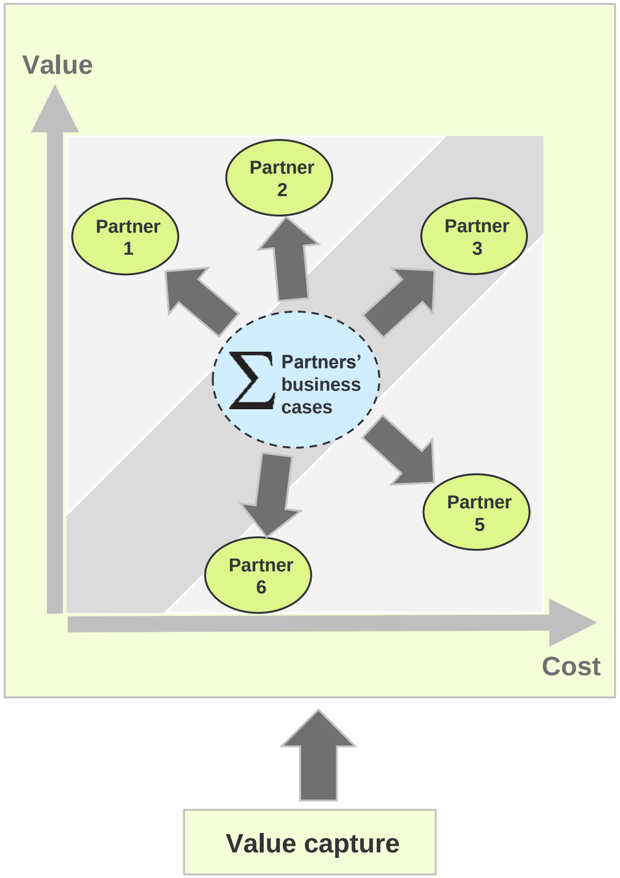


Cost-benefit improvement	Company/technology	Dimension	Description
Reduce costs	Well technology	Unwanted demonstration costs	Went through a longer **risk assessment** process with one operator. It resulted in a more detailed and quantified risk analysis. Instead of considering a lost well as the worst case scenario, now a ”regular” well without improvements brought by the new technology is considered the worst case scenario. .
Reduce costs	Reservoir technology	Planned demonstration costs	Could have used publically available infrastructure. However, after consideration, the company realized it would have to make multiple tests to demonstrate its technology and chose to build its **own test infrastructure** which would reduce the total direct demonstration costs.
Reduce costs	IOR technology	Planned demonstration costs	Company chose to do **sequential demonstrations** of subcomponents prior to a fully integrated test. Each subsequent test added additional costs. However, it would reduce uncertainty related to individual components and lower the cost for the integrated demonstration.
Increase value	Drilling technology	Convince client of value proposition	Presented its business case to operator’s R&D department which saw the value of the technology. However, the drilling department only saw a more expensive and unproven product compared to its existing technology. Had to **quantify improvements and communicate HSE benefits** to convince client
Increase value	Well technology	Maximize value of demonstration	Had a live field demonstration that was technically successful. The operator had a non-systematic approach and a ”least cost philosophy” which resulted in the operator not following up after the demonstration. In the next demonstration a more **relevant end user was chosen to maximize** the value of demonstration

Source: Interviews

Demonstration strategy – road to realization of technology

Partnership



Partnership is about maximizing and sharing value

1 Technology business case per partner

How motivated are the partners?
How can cost/benefit relationship be improved?

Companies or institutions with strongly linked business cases related to the new technology are natural partners in a demonstration project. The Technology Provider should seek to optimize the business case seen from potential partner's perspective to ensure full support throughout the project's lifetime

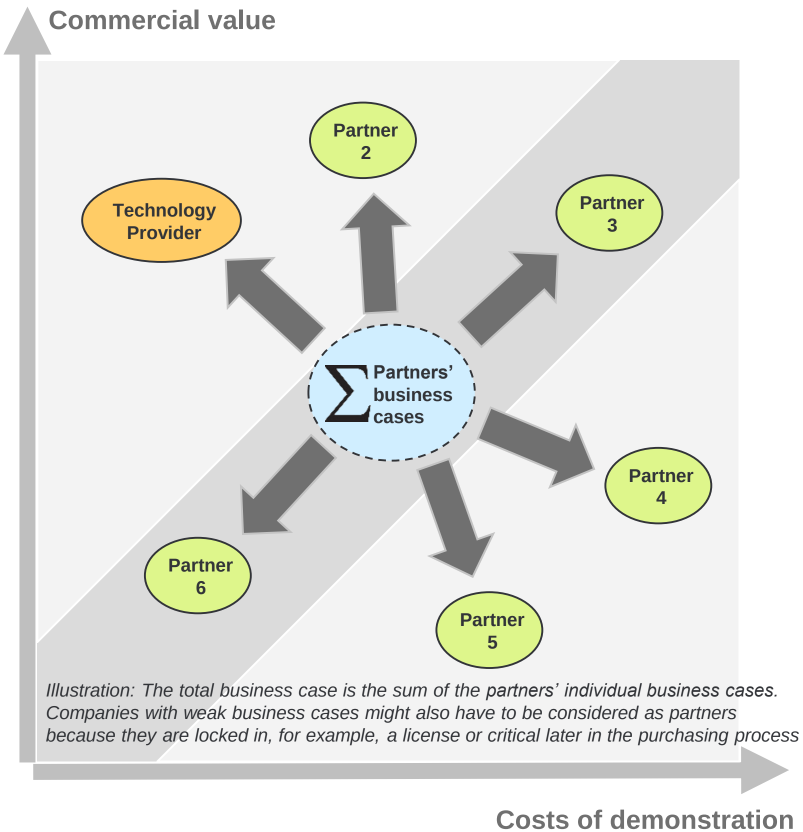
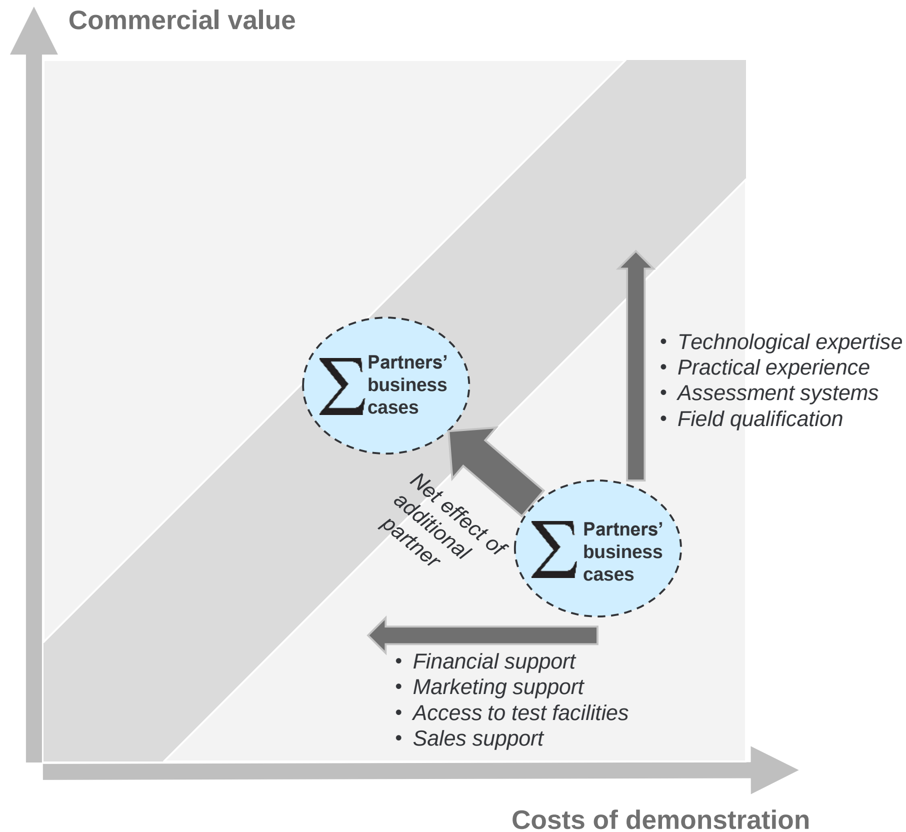


Illustration: The total business case is the sum of the partners' individual business cases. Companies with weak business cases might also have to be considered as partners because they are locked in, for example, a license or critical later in the purchasing process

2 Partner contribution to technology demonstration

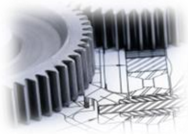
What could the partners contribute with in the project?

Companies or institutions have different capabilities when it comes to contributing to the technology demonstration project. Companies with the highest potential for contributing net positively to the project are natural partners



Source: Rystad Energy research and analysis

1 Potential partners in a technology demonstration project

Partner type		Description
	***Technology Provider***	*Company that is developing the new technology and is the driving force behind the technology demonstration. Normally, this company also is the primary owner of the IP rights. The Technology Providers are often start-ups based on ideas from an individual or a small group of individuals or spin-offs from research institutions like IRIS and SINTEF*
	***E&P company Technical / R&D***	*Technical staff and research departments within an E&P organization, funded through R&D budgets. Research departments are often open to new ideas and are tolerant with respect to risk, but less focused on commercial aspects and might lack access to operational test environments. Examples include Statoil research centers in Trondheim, Bergen and Porsgrunn, Shell Technology Norway*
	***E&P company Operational / Licenses***	*Department(s) within an E&P organization with responsibility for actual operations. Either centralized technology teams or single production licenses focused on optimization of one single asset. Such communities have a good understanding of the business case and have natural access to operational test environments. On the downside, operational KPIs and general risk aversion might reduce motivation for testing of new technology. In Norway, Statoil, Shell, ConocoPhillips and BP are among the most frequent partners in demonstration projects*
	***E&P suppliers***	***A) Equipment providers such as providers of well construction/logging tools or production systems*** ***B) Service providers such as EPC contractors and rig owners*** *Large oilfield service providers are capable of industrializing the technology and have access to full scale test environments. Some of the largest OSPs might have less willingness to take technological risks and are not set-up to demonstrate and commercialize new technologies. They might prefer to acquire technology companies when their technology is already commercially proven. Others OSPs are open for cooperation with smaller technology companies to ensure access to new technology.*
	Government	*Publicly funded institution supporting technology developments in the interest of maximizing exploitation of natural resources, stimulation of the national economy and job creation. They provide long-term thinking and require a strong business case, but possibly with higher emphasis on societal value. However, current institutions have limited funds and limited influence on E&P companies decisions. The main potential partners are DEMO 2000 and Innovation Norway.*

Source: Rystad Energy research and analysis

1 Identifying group of partners with the strongest business cases for participation

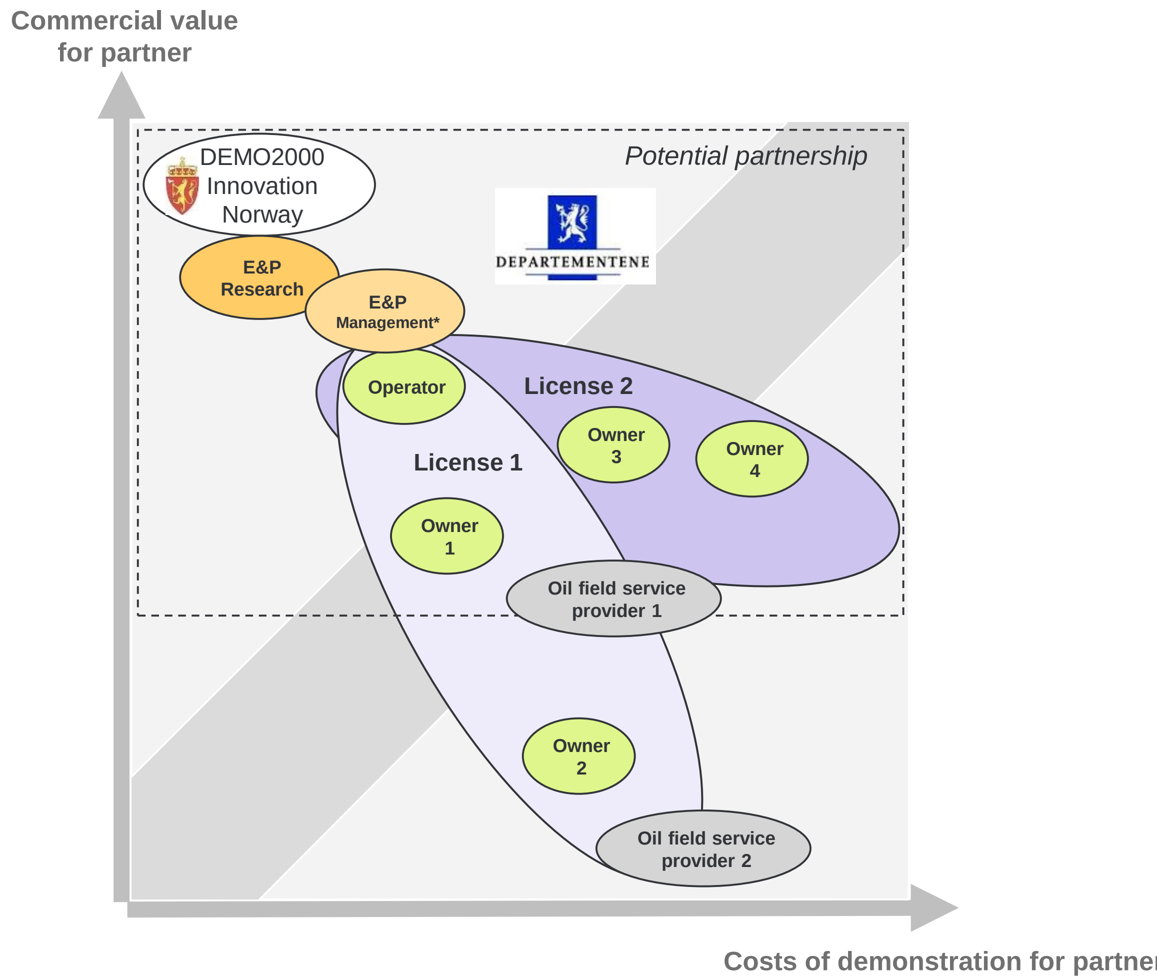
The interviews performed indicate that the forming of partnerships for demonstration projects are often ad-hoc and network based.

However, some successful cases illustrate that a partnership can be designed and to some extent optimized. Most interviewees also see in retrospect that a more structured approach to forming the partnership would have been beneficial.

It is also very important to not only optimize the partnership for one iteration of technology demonstrations, but to «think all the way» in terms of partners that would be important contributors in the following steps. In particular, it is important to secure the first commercial deliveries after the product has been field qualified. Having one or several operational departments/licenses as partners is key to commercial success. In the case that the technology must be installed or operated by an Oilfield Service Provider, commercial success is likely to depend on the relationship to such a company.

In the case of partnering with a license, there is a risk that some of the license owners have other priorities. Typically, operators and other large license owners, have a long term approach to maximizing asset value, while smaller license owners might be focused on maximizing short term cash flow.

Optimizing partnership by analyzing individual business cases
Relative positioning



*Some new technologies might be supported by E&P management in a top-down manner, f.ex. cost reducing technologies.

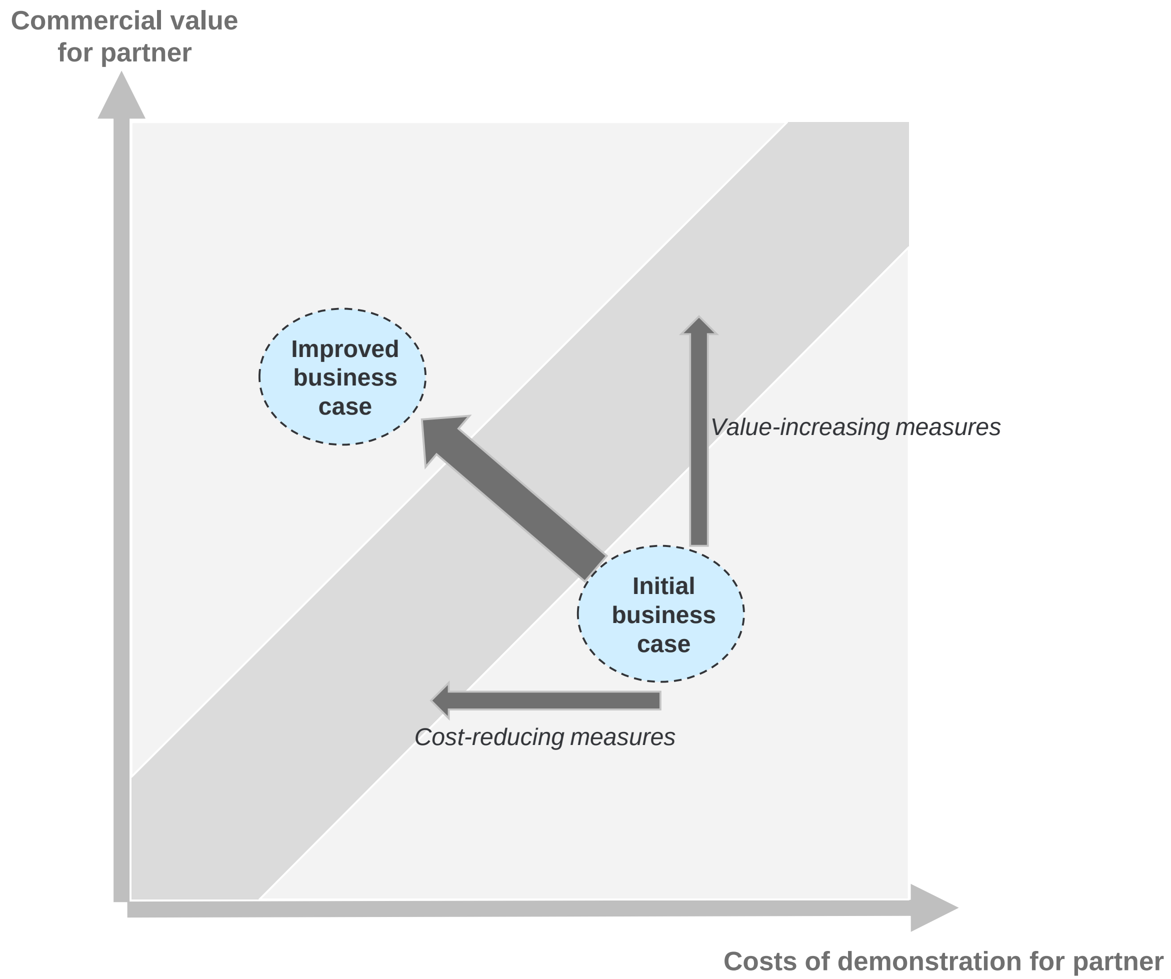
1 Getting a partner onboard by optimizing its business case

The sketch illustrates how the Technology Provider typically can improve the business case of a potential partner in a technology demonstration project.

The value of joining the project could be increased by increasing value and/or reducing cost and risk as seen by the potential partner.

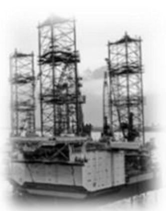
Industry interviews indicate that the perceived business case of the potential partner could often be significantly improved by ensuring that the probability and nature of the actual worst case outcome and associated cost of the demonstration project is correctly understood. This is particularly applicable to intrusive technologies, e.g. downhole drilling tools. In a drilling related demonstration project, the operator initially thought that there was a danger of losing the well as a result of the demonstration project. But after thorough technical investigations, they realized that the worst possible outcome would be that the well was functioning as it would without the new technology. This insight naturally changed the business case completely.

Optimizing business case for a potential partner in a technology demonstration project



Source: Rystad Energy research and analysis

1 Measures that can improve business case for potential partners

Partner type	*Increasing commercial value for partner*	*Reducing demonstration costs for partner*
 ***E&P company Technical / R&D***	• *Increase technology relevance by aligning demonstration program with E&P companies research strategy and focus* • *Offer sharing of intellectual property rights*	• *Reduce risk of failure by performing low-cost demonstration of key features* • *Plan and think «all-the-way» in terms of qualification and commercial arrangements. This will ease the transfer time and cost from research to operations*
 ***E&P company Operational / Licenses***	• *Increase technology relevance by possibly extending technology footprint to cover important challenges that the company is facing in the near future* • *Increase technology value by ensuring relevance for several projects (portfolio effect)* • *Ensure relevant timing of project with respect to ongoing field development projects*	• *Identify and communicate actual cost of worst case failure under demonstration. Consequences of failure could be perceived worse than what is the actual case.* • *Quantify probability of worst case failure* • *Award E&P partners exclusive rights to purchasing the final product for a period of time («First right to buy»)* • *Discount on commercial products for sponsors reduces the total cost for E&P companies if demonstration is successful* • *Avoid single-source problems for essential technologies by opening up for commercialization by multiple vendors*
 ***E&P suppliers***	*Equipment providers* *Adjust technology footprint to improve fit with* • *Current product portfolio* • *Company strategy* • *Market position (key clients and projects)* *Both equipment providers and service providers* *Ensure «Quality stamp» and expressed interest from E&P companies*	*Service providers* *In many cases, the main potential cost for a service provider is a reduction of revenue as the effect of the new technology, often related to day rate-based services combined with new technology that increases effectiveness. Measures focusing on increased market share, competitive advantages and HSE effects could mitigate for the lost revenue*
 ***Government***	*Increase technology value in terms of national interest such as resource exploitation, health and security, environmental impact, national competency or job creation. Also, increasing export of technology and services would be of national interest*	*Apart from direct financial contributions, most technology demonstration projects generate cost for the Government through the tax system. Cost-reducing measures targeted towards E&P companies will therefore be beneficial*

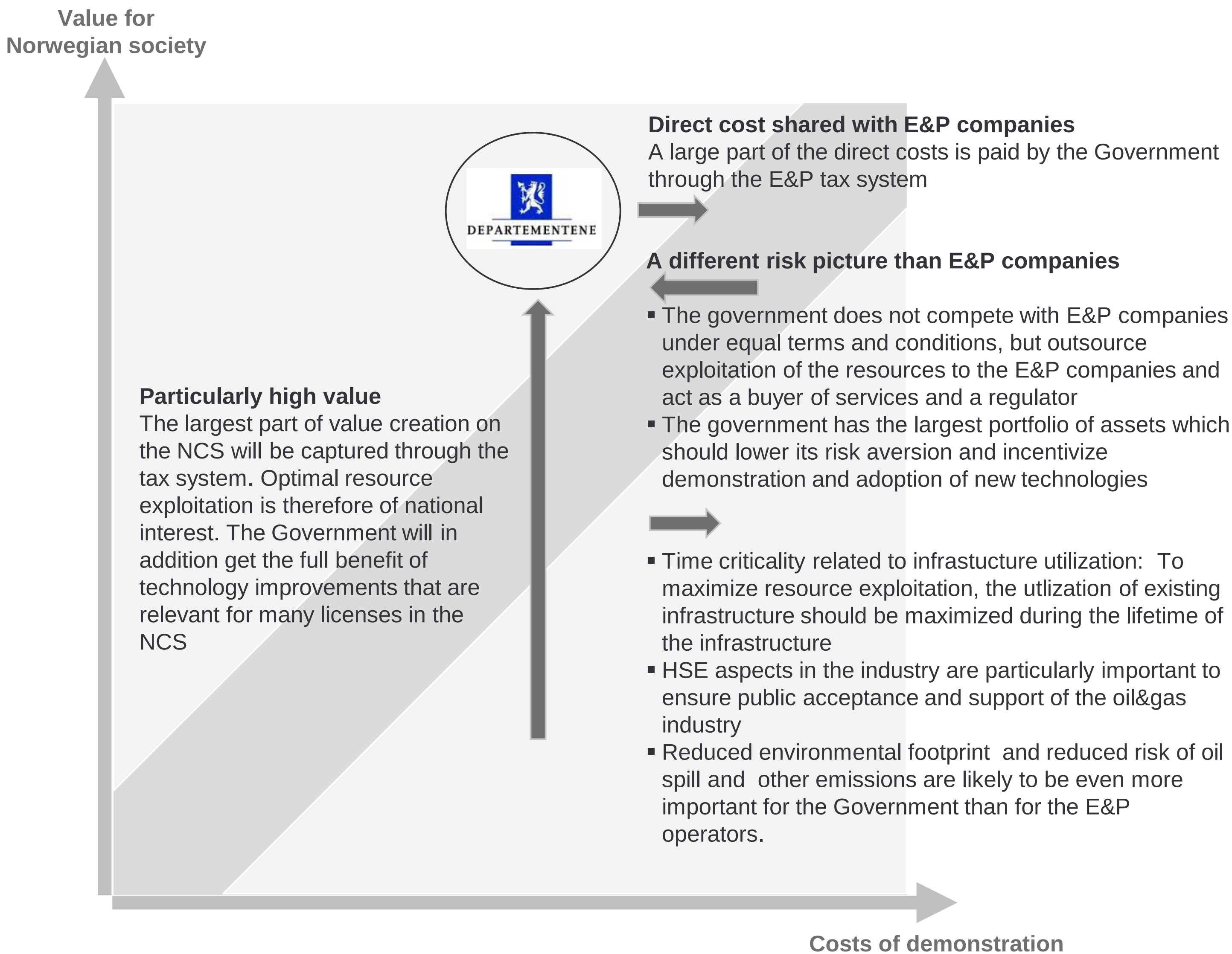
Source: Interviews; Rystad Energy research and analysis

1 Norwegian government has a special business case…

The sketch illustrates the special business case of the Norwegian government related to demonstration and adoption of new technology. A large share of the revenue coming from additional production will be income for the Norwegian state.

The direct cost structure is shared with the E&P companies while one can argue that the Government's risk in technology development projects is lower. This expected risk is expressed in the required rate of return for public investments. This rate is currently 7% real terms for oil & gas related investments compared to 4% in other sectors.

Currently, E&P companies struggle to get a positive free cash flow and are forced to invest only in projects with a high internal interest rate. Statoil is talking about strengthening profitability in new projects up to 24% IRR*.



*Q4 2013 results presented by Statoil Feb 7, 2014
Source: Rystad Energy research and analysis

1 …but some additional cost might be necessary to realize it

To realize business cases with higher societal value, but possibly less favorable value proposition for industry sponsors, governmental institutions might consider cost and risk reducing incentives.

Possible measures are:

1. **Introduce tax incentives targeting demonstration and adaption of new technology**
2. **Strengthening their authority of Governmental bodies**
   The Office of the Auditor General of Norway (Riksrevisjonen) recently published a report concluding that there is room for increased Governance by
   - Directly or indirectly instructing E&P companies using legal authority through the PDO process, terms related to production permissions or require operators to issue reports on specific field related topics. Such a policy could have the indirect cost of reduced interest for the NCS among international E&P companies.
   - Strengthening NPD and MPE in terms of resources that can follow up licenses and coordinate field development. There are currently around 200 employees in OD and 40 in OED*
   - Strengthening Petoro in terms of resources (Currently 60-70 employees)
3. **Reduction of the required rate of return on public investments within oil and gas from the current 7% real terms**

1.

"Det kommer fram i intervjuer med operatører i feltutvalget og Finansdepartementet at utformingen av petroleumsskattesystemet […] er helt sentralt for å gi selskapene insentiver til å bygge ut felt og utvinne petroleum i samsvar med samfunnets interesser "

Riksrevisjonen*

2.

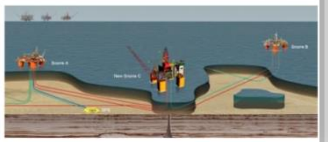
Riksrevisjonen

1 Hovedfunn

- Det er risiko for at samfunnsøkonomisk lønnsomme oljeressurser i modne områder ikke blir utvunnet i tide.
- Oljedirektoratet har ikke tilstrekkelig gjennomslag i oppfølgingen av prosjekter der økt utvinning er tidskritisk.
- Det er behov for styrket oppfølging av samordningsmuligheter på tvers av utvinningstillatelser.
- Olje- og energidepartementet bruker i begrenset grad de virkemidlene som er tilgjengelig for å sikre økt utvinning i modne områder.
- Petoros kapasitet begrenser selskapets muligheter for å maksimere verdien av Statens direkte økonomiske engasjement (SDØE).

- Bygg ut Snorre, eller mist lisensen

Publisert 17.04.2015 14:32 av Glenn Stangeland



Norske myndigheter med klar melding til Statoil og de andre partnerne.

3.

Required rate of return used by the Ministry of Petroleum and Energy

- The Ministry of finance has decided that the general required rate of return from public investments should be 4% real terms, including a 0.5% addition for a general risk level.
- The Ministry opens up for a higher required rate of return if the investment is done under higher systematic risk; in particular if the investment is exposed to a high degree of market cyclicality or if the project contains large capital investments in early phases of the project
- The Ministry of Petroleum and Energy has on that basis decided on a required rate of return of 7% real terms for public investments within the E&P industry

Olje- og energidepartementet (OED) kunngjorde i vinter at avkastningskravet fremdeles vil være syv prosent - dette uten faglig redegjørelse. Foto: Gunnar Blöndal

Feil rente - lave investeringer

Oljedepartementet insisterer på avkastningskrav godt over «standardrenten». Det gir investeringssvikt på norsk sokkel.

Petter Osmundsen
Publisert: 27.04.2015 – 21:55

*Riksrevisjonens undersøkelse av myndighetenes arbeid for økt oljeutvinning fra modne områder på norsk kontinentalsokkel (April 2015)
Source: Rystad Energy research and analysis

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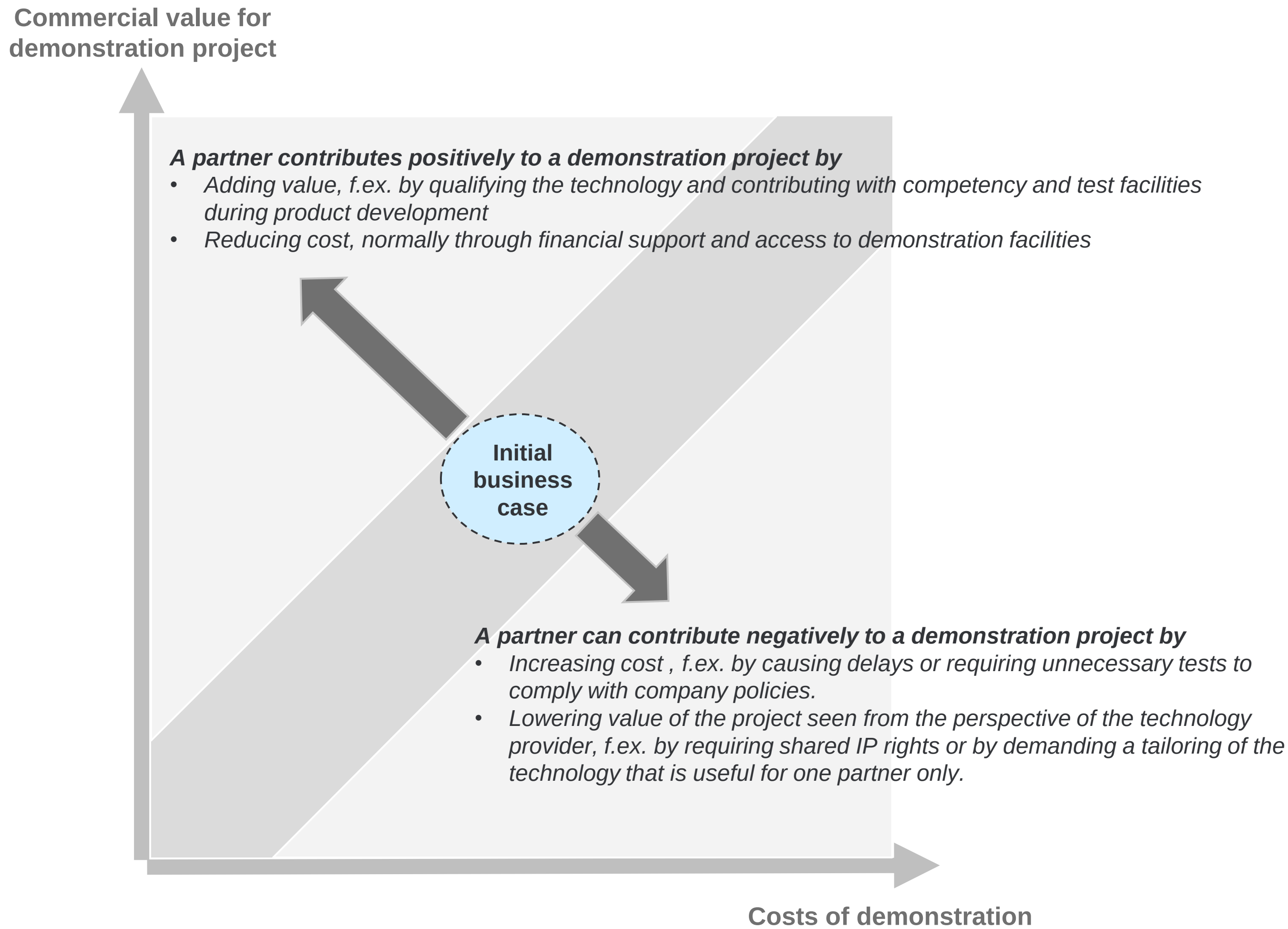
2 Getting the right partners by considering how they can contribute to the project

The sketch illustrates how a potential partner can contribute both negatively and positively to a technology demonstration project.

When designing the partnership, it will be important to consider the partners' potential net contribution to the project by weighing value-adding or cost sharing capabilities against possibly negative impacts.

Conceptual sketch of partner contribution to a technology demonstration project



Source: Rystad Energy research and analysis

2 Overview of partner contribution to a technology demonstration project

Partner type		Positive contributions to business case	Potential downsides to business case
	***E&P company Technical / R&D***	• *Financial support* • *In kind contributions such as research personnel with relevant knowledge or own research results* • *Internal promotion of new technology*	• *Disconnect or disagreement between technical and operational department might slow down or prevent field tests or final qualification (increased demonstration costs)* • *Could be a "**sleeping pillow**" as commercial sale is not necessarily a natural follow-up. As a consequence, the commercial value of the technology could be overestimated.*
	***E&P company Operational / Licenses***	• *Financial support* • *Commercial evaluation of business case* • *Access to test facilities* • *Access to field test* • *«Quality stamp» of new technology*	*Increased demonstration cost due to* • *A desire to acquire IP rights* • *General cost focus might slow down commercial negotiations* • *Missing quality systems might reduce possibility for measuring outcome of demonstration project* • *Having only one E&P partner adds risk of project being stopped due to change in E&P company policy*
	***Oilfield Service Provider***	*Equipment providers* • *Understanding of necessary steps towards industrialization of technology* • *Often supportive in order to stay on-top of technological development* *Service providers* • *Good access to full scale test environment* • *High level of trust from most operators* • *Easier commercial deployment of new technology if an OFS provider knows the technology*	*Equipment providers* • *Some of the largest OSPs have production-optimized organizations with reduced innovative power* *Service providers* • *Day rate driven OFPs could have incentives to slow down development of new technology that cannibalizes current product lines and revenue streams*
	***Government***	• *Financial support up to a certain level* • *Quality stamp of scientific content and relevance for NCS* • *Increased awareness of demonstration project* • *Possible support from NPD through PDO processes and follow up of production licenses*	• *Limited duration of support period increases fund-raising workload* • *Reporting requirements reduces project flexibility*

Source: Rystad Energy research and analysis

2

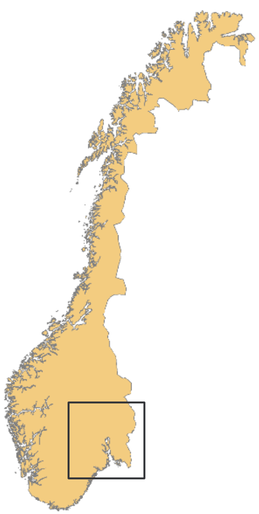
Partnerships in case studies

Case	Main business case for partners	Partners	1. Improvements of original business case	2. Partner contribution and influence
MudCube	Mainly HSE, but also efficiency gains	*Initially: Statoil Research Demo 2000* *Currently: Dong, Talisman, Maersk Drilling, Saipem*	Cubility personnel present during offshore installation and testing reduces risk	Financial support of building proprietary test center. Got the "field approval stamp" from Statoil. However further operational testing was not possible in Statoil. Current partners are first commercial clients
Continuous Motion Rig	Reduction of drilling costs	*Statoil, Shell, ConocoPhillips* *Demo 2000*	Investments of 25 million NOK in a «virtual demonstration» in RobotStudio to demonstrate ability to design a working solution	Financial support. Possibly field demonstration at a later stage
Badger Explorer	Significant reduction of exploration costs	*ExxonMobil, Statoil, Chevron, Wintershall, CNPC – DR,* *Demo 2000*	Right to first use and price discounts on final commercial solution. Attempted to harvest early low hanging fruit of sensor placement at 200 meter depth in Canadian oil sands	Financial support and in-kind contribution with drilling and geology expertise. Potential onshore testing in China at a later stage
Enhanced Drilling	Mainly reduction of drilling cost and ability to drill ''un-drillable'' wells. Required for mature and depleted subsea fields. Increased recovery.	*Statoil* *Demo 2000* *Innovation Norway*	By satisfying NCS and Statoil requirements, it will be easier for to get acceptance internationally	Financial support and access to field pilot testing at Troll. On the downside, time consuming negotiations on IP rights and service rates as this was also a commercial project.
Reelwell Drilling Method	Reduce drilling costs	*Total* *DEA* *Petrobras* *Haliburton/Sperry* *Demo 2000*	Partners granted first purchase rights and discounts	Financial support, expertise and access to field test facilities. Upcoming drilling trial to validate extreme ERD in Canada March 2016
Subsea Water Intake and Treatment (SWIT)	Increased production. Reduced costs. HSE	*SOCAR (NOC, Azerbaijan)* *Suncor* *Wintershall* *ExxonMobil* *Chevron* *Demo2000*	First purchase rights and discounts Scope extended with production of additional water qualities like low salinity and low sulphate water. Test location placed close to NIVA facilities allowing accurate and cost efficient measurements	Financial support. Field direct use or demonstration at a later stage
Deep Penetrating Anchor (DPA)	Cost reduction through faster anchoring during floater (platform or rig) installation.	*Statoil*	Statoil acquired ownership in Deep Sea Anchors	Financial support and access to field tests at Troll and demonstration at Gjøa. Field qualified "stamp" from Statoil. However, having Statoil as a partner and investor can be too comforting – still a need to work on the next step – first commercial sales. This has proven difficult due to missing involvement from installation companies and that Statoil Technology Invest has no influence over field development decisions

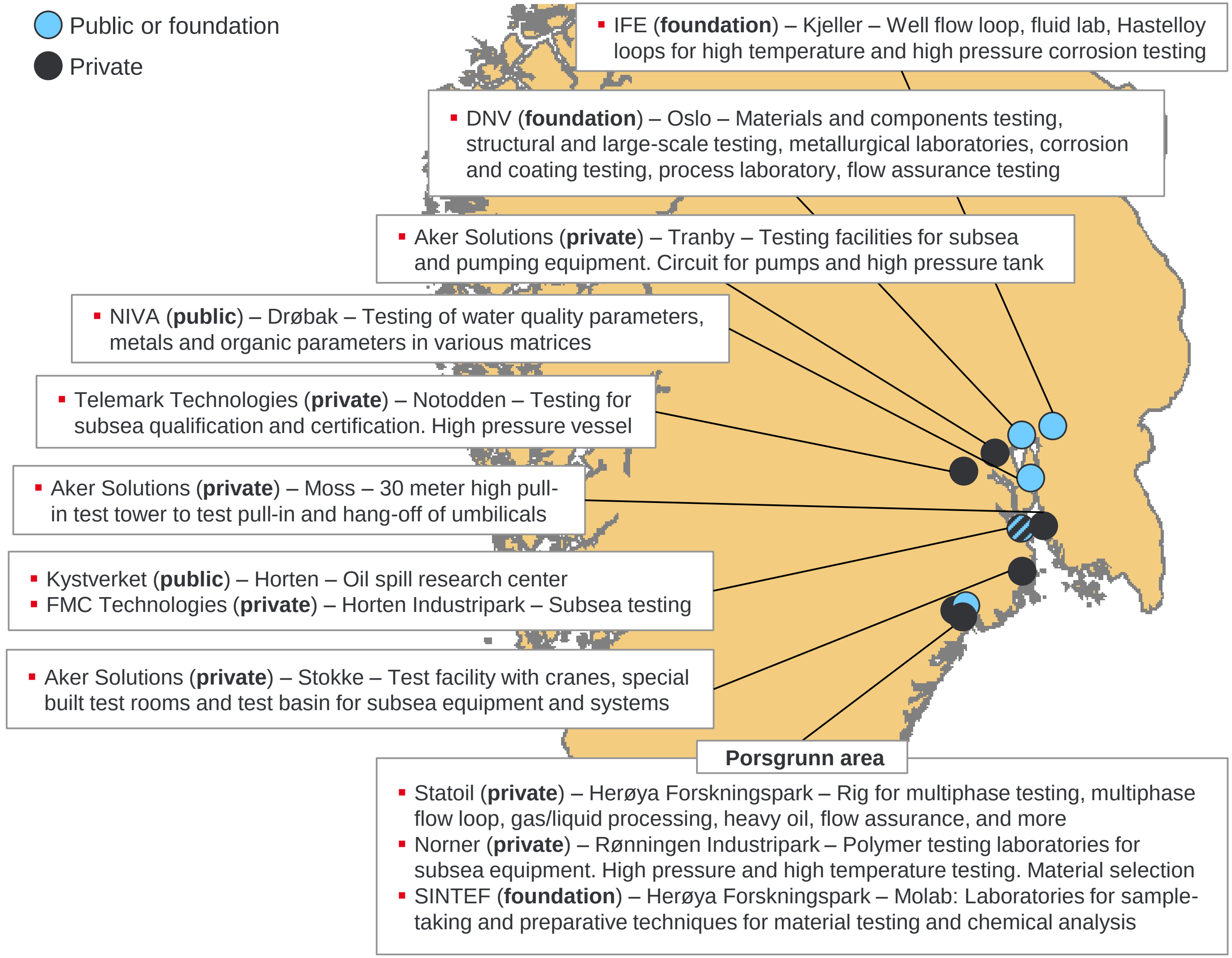
Source: Interviews; Rystad Energy research and analysis

Overview of Norwegian test facilities

The test facilities in Norway fall into two categories: public or foundation based, and private test centers. Interestingly there are smaller technology companies that have built their own test centers that are also open and available to rent. 2TD Drilling, Telemark Technologies and Cubility have their test centers open to others.



List of identified demonstration facilities in East Norway



Source: Interviews, Rystad Energy research and analysis

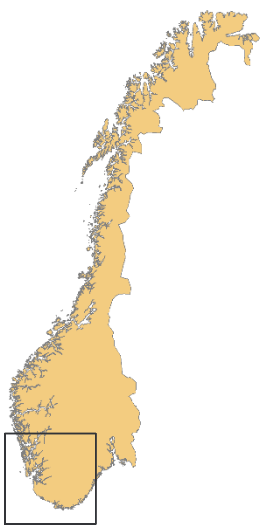
Overview of Norwegian test facilities

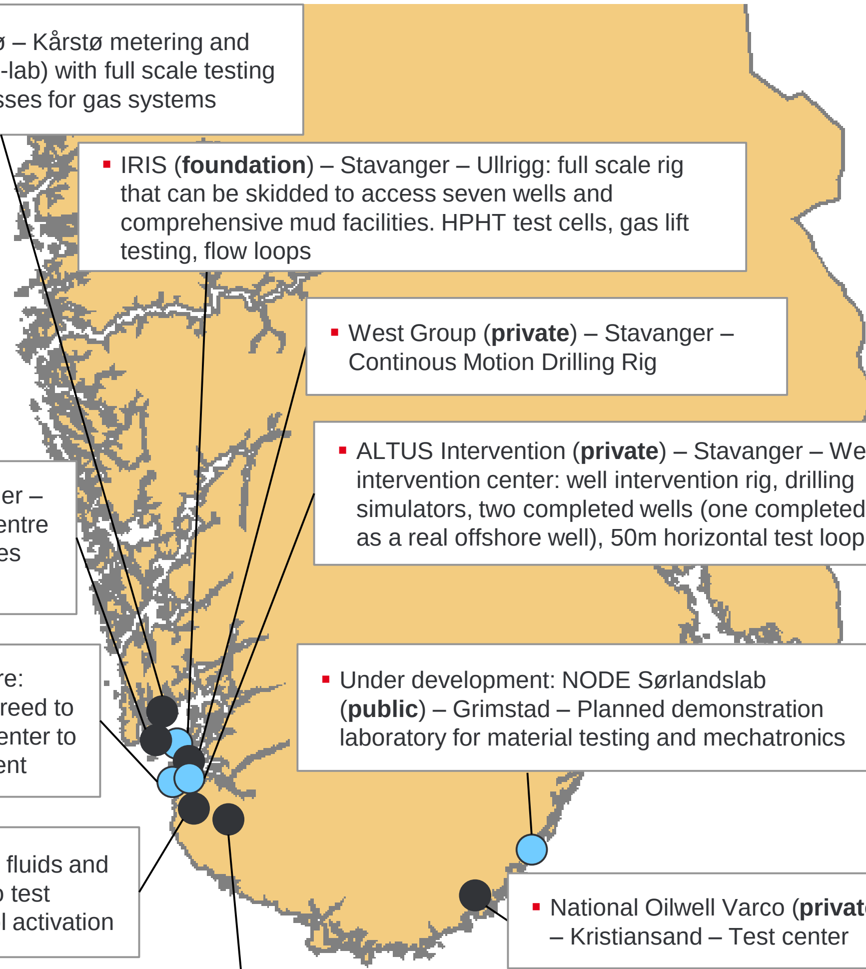
List of identified demonstration facilities in Southwest Norway

- Public or foundation
- Private

Offshore/field testing

- Norsk Oljevernforening For Operatørselskap (NOFO) (**public**) – Frigg-field – ”Oil spill response”: yearly oil spill simulation offshore to improve and develop new oil spill technology. Companies can apply to participate





- Statoil (**private**) – Kårstø – Kårstø metering and technology laboratory (K-lab) with full scale testing of equipment and processes for gas systems
- IRIS (**foundation**) – Stavanger – Ullrigg: full scale rig that can be skidded to access seven wells and comprehensive mud facilities. HPHT test cells, gas lift testing, flow loops
- West Group (**private**) – Stavanger – Continous Motion Drilling Rig
- ALTUS Intervention (**private**) – Stavanger – Well intervention center: well intervention rig, drilling simulators, two completed wells (one completed as a real offshore well), 50m horizontal test loop
- Marine Energy Test Centre (**private**) – Stavanger – Test center for offshore wind energy. The Metcentre provides concessions, infrastructure and services required for testing in shallow and deep waters
- Shell (**public**) – Risavika – Risavika Gas Centre: Shell, IRIS and University of Stavanger has agreed to reopen the gas center. It has a full scale test center to develop technologies to use of gas more efficient
- Under development: NODE Sørlandslab (**public**) – Grimstad – Planned demonstration laboratory for material testing and mechatronics
- Cubility (**private**) – Sandnes – Full scale fluids and solids control testing. The facility has two test cabins and a control room remote control activation
- National Oilwell Varco (**private**) – Kristiansand – Test center
- 2TD Drilling (**private**) – Ålgård – 2TD Technology Center: test equipment to simulate drilling conditions based on a custom-made horizontal drilling rig

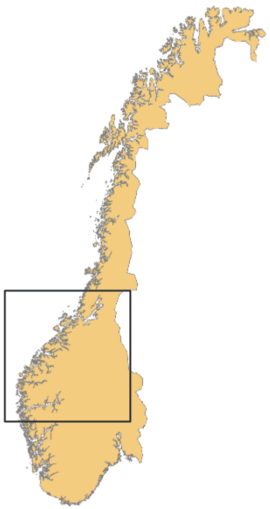
Source: Interviews, Rystad Energy research and analysis

Overview of Norwegian test facilities

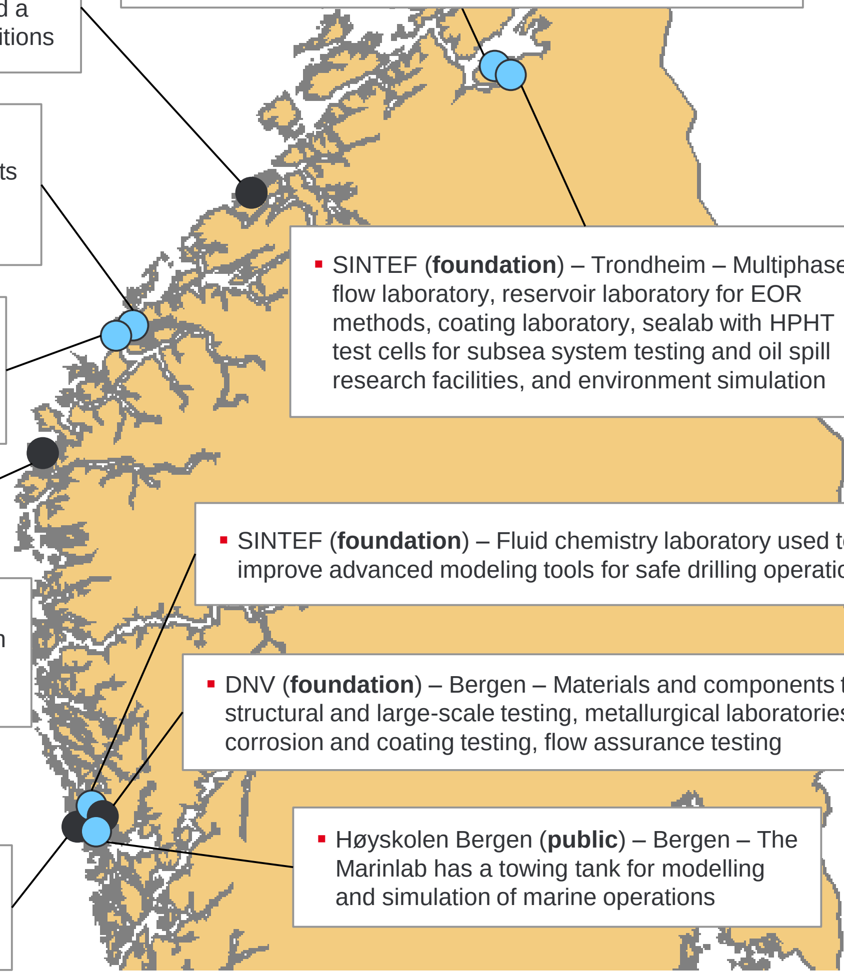
List of identified demonstration facilities in Western-Mid Norway

Public or foundation

Private



- Shell (**private**) – Nyhamna – Ormen Lange Land: Test basin for full scale subsea compression and a process module that can simulate seafloor conditions
- SINTEF/MARINTEK (**foundation**) – Trondheim – Ocean laboratory with towing tanks to simulate marine conditions
- Høyskolen Ålesund (**public**) – Ålesund – The offshore simulation center offers simulator products for anchor handling operations, PSV operations, subsea- rig- and ship crane/lifting operations
- SINTEF (**foundation**) – Trondheim – Multiphase flow laboratory, reservoir laboratory for EOR methods, coating laboratory, sealab with HPHT test cells for subsea system testing and oil spill research facilities, and environment simulation
- Runde Environmental Centre (**public**) – Runde – Infrastructure for monitoring to conduct research on the environment and to promote sustainable technology for fisheries and energy production
- SINTEF (**foundation**) – Fluid chemistry laboratory used to improve advanced modeling tools for safe drilling operations
- Stadt Towing Tank (**private**) – The test laboratory consists of a large water basin (185m long) and the equipment needed to perform the experimental tests
- DNV (**foundation**) – Bergen – Materials and components testing, structural and large-scale testing, metallurgical laboratories, corrosion and coating testing, flow assurance testing
- Høyskolen Bergen (**public**) – Bergen – The Marinlab has a towing tank for modelling and simulation of marine operations
- FMC Technologies (**private**) – Ågotnes – Three test basins for test of subsea systems with pressures up to 1,400 bar



Source: Interviews, Rystad Energy research and analysis

Good coverage of test centres needed to close technology gaps in OG21 strategy

TTA	Technology gap Identified in OG21 strategy	Coverage
TTA 1 Safety and environment	Oil spill response technologies Drilling technologies Produced water technology Remote sensing technologies Leak detection Environmental monitoring Understanding the natural environment … Energy efficiency Technology for seismic operations Modelling tools	*Good coverage where relevant by public test centres. Also some private coverage*
TTA 2 Exploration	Chalk specific technology Special arctic exploration technology Improved volumetric sweep Geophysical acquisition, processing, imaging … Basin & play scale integrated geological P&M Mapping, release and transport of "immobile" oil Enhanced oil recovery	*In large, full scale tests of TTA2-specific technology must be executed in or at field*
TTA 3 Drilling and well	Drilling automation Extended reach drilling Drilling trouble avoidance Low-cost drainage points Low-cost well intervention technology Faster drilling Methods to prevent loss of well integrity Reliable, low-cost smart completions Technology for capping and containment New NCS development concepts	*Very good coverage both in the public sector with Ullrigg and in the private sector*
TTA 4 Production	Flow modelling and flow assurance Integrity management and risk reduction New field development concepts Subsea and in-well processing Power supply and distribution-subsea Subsea technology Leakage prevention and detection Gas processing and LNG Increased production efficiency Automation, unmanned facilities Condition monitoring - sensor technology	*Good coverage with a mix of public and private centres. Most subsea technology can only be tested at private test facilities. However, the subsea companies tend to be open for cooperation with smaller technology providers. Potential for an open, public test facility*

Demonstration projects related to technology gaps in grey are likely to be done in/at field. It is therefore not relevant to discuss test center coverage

Source: OG21 strategi; Rystad Energy research

Overview of test center coverage versus OG21 identified technology gaps

	Technology gap Identified in OG21 strategy	**Public test centres***	**Private test centres***
TTA 1 Safety and environment	Oil spill response technologies	Oil spill research center (Horten) / Arctic oil spill testing, Svalbard	
	Drilling technologies	Ullrigg, Stavanger	Cubility, Stavanger / NOV Kristiansand / SINTEF Bergen
	Produced water technology	NIVA, Oslo	
	Remote sensing technologies	Runde Environmental Centre	
	Leak detection	DNV, Oslo/Bergen	K-lab, Kårstø / Shell Risavika
	Environmental monitoring	N.A.	N.A.
	Understanding the natural environment …		
	Energy efficiency		
	Technology for seismic operations		
	Modelling tools		
TTA 2 Exploration and increased recovery	Chalk specific technology	N.A.	N.A.
	Special arctic exploration technology		
	Improved volumetric sweep		
	Geophysical acquisition, processing, imaging …		
	Basin & play scale integrated geological P&M		
	Mapping, release and transport of "immobile" oil		
	Enhanced oil recovery		
TTA 3 Drilling and well	Drilling automation		CMR Rig, Ullanhaug, Stavanger/ NOV Kristiansand
	Extended reach drilling	Ullrigg, Stavanger	NOV Kristiansand
	Drilling trouble avoidance	Ullrigg, Stavanger	NOV Kristiansand / SINTEF Bergen
	Low-cost drainage points	Ullrigg, Stavanger	NOV Kristiansand
	Low-cost well intervention technology	Ullrigg, Stavanger	NOV Kristiansand / ALTUS Intervention, Stavanger
	Faster drilling	Ullrigg, Stavanger / NODE Sørlandslab (planned)	NOV Kristiansand / 2TD Technology Center
	Methods to prevent loss of well integrity	Ullrigg, Stavanger	NOV Kristiansand / 2TD Technology Center
	Reliable, low-cost smart completions	Ullrigg, Stavanger	NOV Kristiansand / 2TD Technology Center
	Technology for capping and containment		
	New NCS development concepts		
TTA 4 Production	Flow modelling and flow assurance	IFE, Kjeller / SINTEF Trondheim	Statoil heavy oil, Porsgrunn
	Integrity management and risk reduction	DNV, Oslo/Bergen	
	New field development concepts	DNV, Oslo/Bergen	
	Subsea and in-well processing		Ormen Lange Pit
	Power supply and distribution-subsea		Ormen Lange, Aker Solutions/FMC centres, Telemark T.
	Subsea technology		Ormen Lange, Aker Solutions/FMC centres, Telemark T.
	Leakage prevention and detection		K-lab, Kårstø / Shell Risavika
	Gas processing and LNG		K-lab, Kårstø / Shell Risavika
	Increased production efficiency	N.A.	N.A.
	Automation, unmanned facilities		
	Condition monitoring - sensor technology		

*full or parts of demonstration can be done at test facility
Source: OG21 strategi; Rystad Energy research

Internationally test centers in which demonstrations have taken place

Several international test centers have been mentioned during the interviews. Specific centers mentioned are Petrobras' facilities in Brazil, ice tanks in Canada and Germany, Mont Terri Rock Laboratory in Switzerland and the large oil service companies' test centers.

In addition, the interviewed technology companies have had onshore field demonstrations in Indonesia, Germany, the United States and Saudi Arabia.

Examples of demonstration facilities and field sites internationally

Test type	Country	Location	Owner	Test facility
Test center	Brazil	Atalaia	Petrobras	Multiphase flow loop, gas lift valve dynamic test loop, etc.
Test center	Brazil	Rio de Janeiro	Universidad Federal do Rio de Janeiro	Towing tanks, multiphase flow laboratory, etc.
Test center	Canada	St John	NRC	Ice tank
Test center	Finland	Helsinki	Aker Arctic Technology	Ice tank
Test center	France	Pau	Total's Centre Scientifique et Technique Jean Féger (CSTJF)	Headquarters for E&P research. Laboratory space and computing power
Test center	Germany	Hamburg	Hamburg Ship Model Basin	Ice tank and towing tank
Test center	Switzerland	Mont Terri	Swiss Federal Nuclear Safety Inspectorate ENSI	Nuclear waste seals
Test center	United States	New Jersey	Bureau of Safety and Environmental Enforcement	Onshore oil spill response research centre
Test center		Globally	Schlumberger	
Test center		Globally	Halliburton	Multiple and multipurpose test facilities
Test center		Globally	Baker Hughes	
Onshore field	Indonesia			
Onshore field	Germany			Onshore fields and drilling rigs used for demonstration of technology
Onshore field	United States			
Onshore field	Saudi Arabia			

Source: Interviews, Rystad Energy research and analysis

Appendix

Interviews

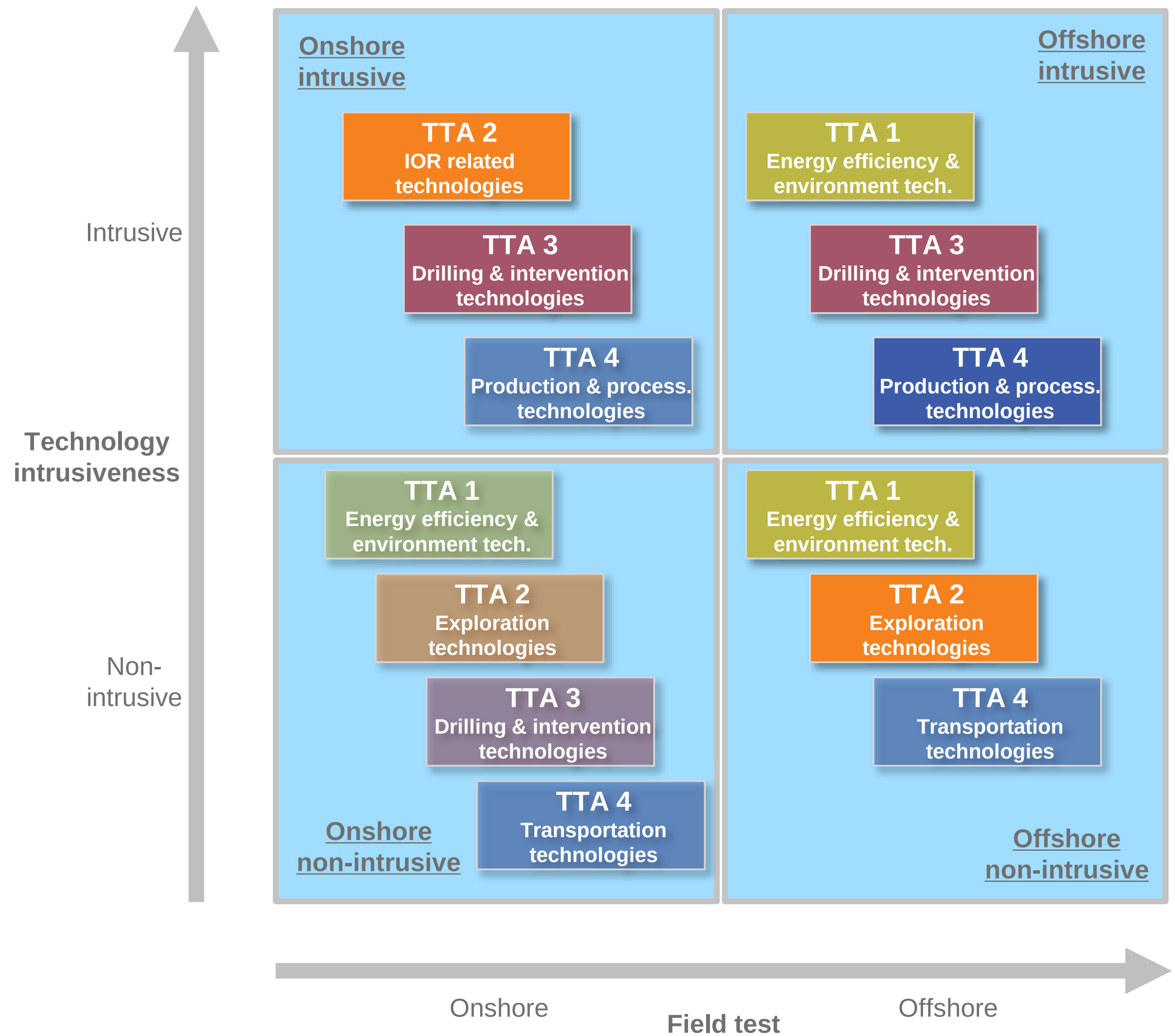
Type	Company	Name	Transcript
Technology	Cubility	Even Gjesdal	Yes
Technology	Enhanced Drilling	Børre Fossli	Yes
Technology	Seabox	Helge Lunde	Yes
Technology	West Group	Odd Skjærseth	Yes
Technology	NLI Offshore and Marine Products	Anders Tørud	Yes
Technology	Badger Explorer	Øystein Larsen	Yes
Technology	Fishbones	Rune Freyer	Yes
Technology	UiS/ReelWell	Arnfinn Nergaard	Yes
Research	IRIS	Oddvar Skjæveland	Yes
Research	IRIS	Sigmund Stokka	Yes
Research	The Research Council of Norway	Anders Steensen	No
Research	OG21	Gunnar Lille	No
Research	The Research Council of Norway	Øyvind Veddeng Salvesen	No
Operator	Lundin	Kristian Kolbjørnsen	Yes
Operator	Statoil	Kjetil Skaugset	Yes
Operator	Statoil	Øivind Fevang	Yes
Industry	Norsk Industri	Runar Rugtvedt	No
Government	Norwegian Petroleum Directorate	Kirsti Veggeland	Yes

The technology target areas (TTA) in OG21 have different demonstration characteristics

Not all technologies can be strictly put into one group but the segmentation can facilitate a discussion around the arguments and reasoning behind the selection of various demonstration strategies by previous ventures and how new technology ventures can learn from their experiences.

Based on the TTA focus areas, the illustration categorize these technology groups in the four demonstration groups.

Technology demonstration characteristic for technologies to be used on NCS (offshore)



Source: Rystad Energy research and analysis