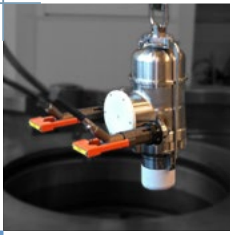
Forskningsrådet

Raising energy efficiency and reducing greenhouse gas emissions

An analysis of publicly funded petroleum research 2015–2018

Programmes

PETROMAKS 2 / DEMO 2000



About the programmes
PETROMAKS 2/DEMO 2000

Large-scale programme for petroleum research – PETROMAKS 2

The PETROMAKS 2 programme has overall responsibility for research to promote responsible and optimum management of Norway's petroleum resources, as well as future-oriented industrial development in the sector.

The scope of the programme is limited to upstream activities, and all research projects must clearly address research questions related to petroleum resources on the Norwegian continental shelf.

The primary objective of the programme is to generate new knowledge and technology to facilitate optimal utilisation of Norwegian petroleum resources and enhance the competitiveness of the Norwegian continental shelf compared with other petroleum provinces in terms of costs, greenhouse gas emissions and the environment.

www.forskningsradet.no/petromaks2

Pilot and demonstration programme – DEMO 2000

The DEMO 2000 programme seeks to ensure long-term competitiveness in the oil and gas industry and continued profitable and sustainable recovery of petroleum resources on the Norwegian continental shelf.

The aim of DEMO 2000 is to demonstrate and qualify innovative products and systems through close collaboration between the supplier industry, petroleum companies and research institutes. Demonstration and qualification activities are to be carried out under realistic offshore conditions or in suitable onshore facilities.

www.forskningsradet.no/demo2000

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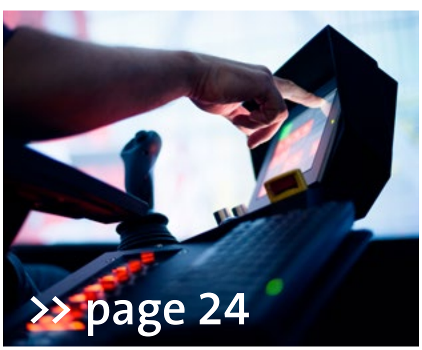


Photo: Ole Jørgen Bratland/Equinor

MHWirth will streamline drilling operations with smart digital solutions.

Photo: Aker Solutions

Aker Solutions develops safe and energy-efficient electrical shutdown of subsea production wells.

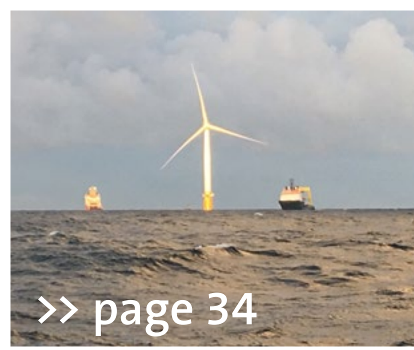


Photo: Stian Lein

TechnipFMC is developing solutions for CO_2-free and stable energy supply through ocean-based hydrogen technology.

Photo: Sverre Chr. Jarild

Preface

The changes expected to take place in the global energy system by 2040 are described in the report «World Energy Outlook 2017», published by the International Energy Agency IEA. The prognosis indicates that global energy needs are growing more slowly than before, but that they will nonetheless increase by 30 per cent in relation to current needs by 2040 given that energy efficiency measures are implemented. It is therefore likely that there will also be an increase in the demand for oil and gas, as well as the growing need for renewable energy.

As a signatory to the Paris Agreement, Norway has pledged to cut its greenhouse gas emissions by 40 per cent by 2030. This goal is enshrined in the Climate Change Act, as is Norway's goal to become a low-emission society by 2050. The activities on the Norwegian continental shelf must contribute to realising the Government's goal of reducing Norway's total greenhouse gas emissions. The development of more energy-efficient technologies and production methods for the petroleum industry will make an important contribution to reaching these goals. They are described in the Government's white paper on Norway's new emissions commitment for 2030 – a joint solution with the EU (Report to the Storting No 41, 2016–2017).

The petroleum activities on the Norwegian shelf make a major contribution to Norway's economy and they will continue to do so for decades to come, through central government revenue, industrial activity, employment and technological developments. Research-based knowledge about the significance of these activities is therefore important, both now and in the future, including the many opportunities to minimise the environmental footprint. The sector is one of the biggest sources of greenhouse gas emissions from Norwegian territory, and research and technology developments that lead to reduced emissions to air is an important precondition for resource management on the Norwegian shelf and for reaching the Government's climate goals.

An important goal of publicly funded petroleum research is to generate new knowledge and technology to maintain Norway's position as the oil and gas province with the highest energy efficiency, lowest level of emissions to air and the lowest level of harmful discharges to sea per produced unit. In order to reach the goal, it is essential and necessary to reduce, as much as possible, the time from the research is carried out until it is taken into use, in the interests of both the sector and the environment.

The analysis for this brochure shows that the Research Council's two programmes PETROMAKS 2 and DEMO 2000 have provided funding to more than 100 projects between 2015 and 2018, to the research communities and private industry, which will have positive effects for the environment if they are taken into use. Many of the research results will help to reduce emissions of greenhouse gases to air, both directly, by reducing the number of tonnes of CO_2 produced from an emission source, and indirectly by implementing more energy-efficient processes. We present some of the projects in this report.
A complete overview of the projects that have confirmed that they will be able to contribute to energy efficiency and reduce greenhouse gas emissions are listed at the back of this report, which is now in its third edition. Similar analyses were conducted in 2012 and 2015.

Happy reading!

Siri Helle Friedemann
Director, Department for Petroleum Research
Division for Resource Industries and the Environment

Photo: T. Keilman, Forskningsrådet

Towards a low-emission society

The Paris Agreement sets out targets for big cuts in emissions. Norway has pledged to cut its greenhouse gas emissions by 40 per cent by 2030, and to have become a low-emission society in 2050. These goals are enshrined in the Climate Change Act. The petroleum industry has a key role to play in reaching these goals. «The Roadmap for the Norwegian Continental Shelf» describes how they are to be achieved.

Photo: Thor Nielsen/SINTEF

Maria Barrio and Marita Wolden at SINTEF's multiphase laboratory at Tiller.

Norway's climate goals

The Paris Agreement is the first legally binding climate treaty with wide global participation. Every country pledges to set emission goals and to report on them. The agreement will facilitate greater efforts to secure emission cuts and adapt to climate change. It sets out a clear direction for future climate work and contains provisions to strengthen efforts over time.[1] The agreement was adopted in December 2015 and entered into force on 4 November 2016.

The Government's white paper on Norway's new emissions commitment for 2030 – a joint solution with the EU (Report to the Storting No 41, 2016–2017) describes how Norway, by 2020, will cut global emissions of greenhouse gases corresponding to 30 per cent of Norway's emissions in 1990, and that Norway has made a conditional commitment to cut its emissions by at least 40 per cent by 2030 compared with 1990. Norway's goal for 2020 is followed up under the Kyoto Protocol, while the 40 per cent goal for 2030 is reported to the UN as Norway's contribution under the Paris Agreement and is enshrined in the Climate Change Act.[2]

Under the EEA Agreement, Norway already cooperates with the EU on reducing emissions in sectors covered by the EU Emissions Trading System (EU ETS). Under an agreement on joint fulfilment of the climate commitments for 2030, Norway and the EU will also cooperate on cutting emissions in sectors not covered by EU ETS from 1 January 2021 (see figure). These are mainly emissions from transport and agriculture, but also emissions from the construction industry, waste industry, energy supply and downstream petroleum activities. The Norwegian Environment Agency has estimated that there is a potential for reducing emissions from sectors not covered by EU ETS by 18 million tonnes of CO_2 equivalents, including transport, agriculture, industry and the petroleum sector (Report to the Storting No 41, 2016–2017). The petroleum industry will thus play an important role in realising the Government's goal of cutting total emissions in Norway through increased knowledge and new technology.

Green competitiveness

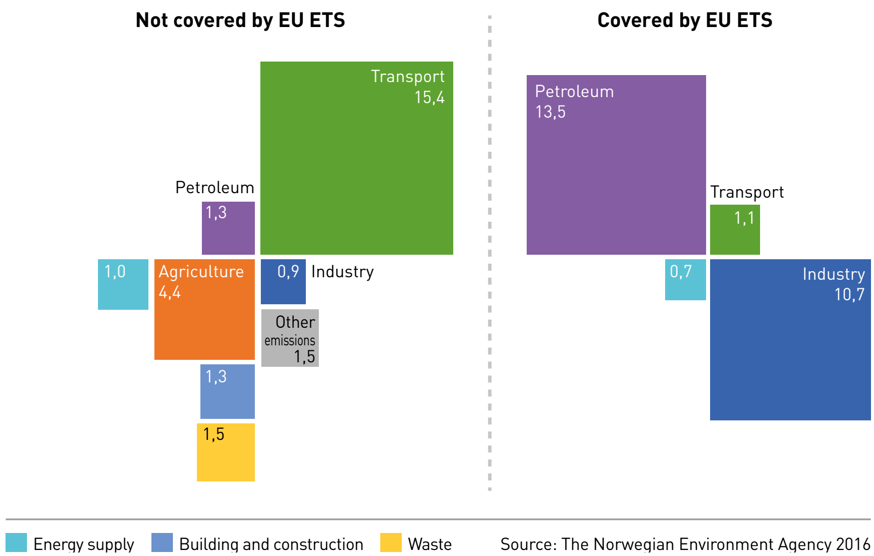
In order to reach the goals for emission cuts, the Government has devised the strategy «Better growth, lower emissions – the Norwegian Government's strategy for green competitiveness.»[3] The strategy intends to provide a predictable framework for the green transformation of Norway, and help the

1 www.regjeringen.no/no/aktuelt/paris-avtalen-om-klima-vedtatt/id2467187/

2 lovdata.no/dokument/NL/lov/2017-06-16-60

3 www.gronnkonkurransekraft.no/files/2016/10/Strategi-for-grønn-konkurransekraft.pdf

Norway's greenhouse gas emissions in 2014
Million tonnes of CO_2 equivalents



Overview of Norwegian greenhouse gas emissions 2014.[5]

country reach its climate goals for 2030 and 2050. This transformation will take place in dialogue with business and industry, and 14 roadmaps have been developed for different business sectors.

«The Roadmap for the Norwegian Continental Shelf» has been developed by the Norwegian Oil and Gas Association and the Federation of Norwegian Industries through the KonKraft collaboration.[4] The roadmap mainly covers the value chain from drilling to field abandonment, and highlights a number of instruments that have made «Norwegian petroleum production the world leader in low greenhouse gas emissions». The roadmap highlights technologies that contribute to more energy-efficient operations and lower greenhouse gas emissions, such as multiphase transport over long distances, horizontal drilling, subsea processing and more efficient water treatment.

The roadmap identifies several technology areas with a potential to reduce greenhouse gas emissions. Up until 2030, there is a potential for further energy efficiency measures to be implemented on existing installations. This includes areas such as power generation, drilling and operation, logistics, base operations and support vessels. New field developments that will continue to produce towards 2050 should include value chains for technology developments and conceptual choices for all phases of the field's lifetime. Power solutions with low emissions must be studied and implemented, and production strategies must be optimised with regard to greenhouse gas emissions. The industry should also investigate possible new value chains, for example hydrogen production. Carbon capture and storage (CCS) is also highlighted as an important focus area.

The roadmap recommends boosting publicly funded research efforts, by increasing allocations to research, development and demonstration of low-emission solutions for the petroleum industry, and by establishing a national centre for low-emission technology for the petroleum industry.

The roadmap explicitly describes the need for substantial and sustained research efforts and development of knowledge and new technology for the Norwegian continental shelf in the years to come. It also emphasises the need to intensify public and industrial research efforts to promote technology that reduces greenhouse gas emissions.

>> Research and technology development can help reduce emissions to air, both directly, for example by reducing the number of tonnes of CO_2 produced from an emissions source, and indirectly through more energy-efficient processes. Public research will be an important contribution in achieving this.

4 www.norskoljeoggass.no/contentassets/992dcd6ed1414f5fa6eecaf763b6da25/klimaveikart_rapport.pdf

5 www.gronnkonkurransekraft.no/files/2016/10/Strategi-for-grønn-konkurransekraft.pdf

Objectives and priorities in petroleum research

The global need for clean energy is growing. Fossil fuels will, however, continue to be an important part of the world's energy systems for a long time. Research and technology development to reduce greenhouse gas emissions are important preconditions for resource management on the Norwegian continental shelf and represent significant contributions to realising the Government's climate goals.

Photo: Minox Technology AS

The long-term plan for research and higher education

Less than half the estimated oil and gas resources on the Norwegian continental shelf have been recovered. The Government's «Long-term plan for research and higher education 2015–2024» emphasises that new knowledge and technology are still needed to be able to utilise the remaining petroleum resources on the shelf in an optimal manner. One goal in the long-term plan is that Norway shall continue to be a world leader in technology development relating to the recovery of offshore oil and gas resources, and that a further cost efficient and sustainable utilisation of the petroleum resources on the Norwegian continental shelf will require further investment in research, development and competence.

OG21 sets the course

Norway's technology strategy for the petroleum sector (OG21) was established by the Ministry of Petroleum and Energy in 2001 to identify technological priorities for efficient and environmentally friendly petroleum activities on the Norwegian continental shelf. OG21 is a collaboration between oil companies, universities, research institutions, suppliers and public authorities, set up to develop a national technology strategy for the Norwegian petroleum sector. OG21 points out that public funding of petroleum research generates a high return for society and that research and development of technology are increasingly important as the technological challenges on the Norwegian continental shelf increase in complexity. OG21 revised the strategy in 2016.[6]

The key priorities are reflected in four technology areas:

1. Energy efficiency and the environment
2. Exploration and increased recovery
3. Drilling, completion and intervention
4. Production, processing and transport

6 www.og21.no

In addition to this, energy efficiency and lower gas emissions is a cross-cutting priority that shall be included in all areas of research and technology development for the activities on the Norwegian continental shelf.

OG21 points out that up until 2030 the existing infrastructure on the Norwegian shelf will dominate Norwegian petroleum production, and emphasises that low-emission technologies adapted to these platforms will therefore have an important role in reducing total

Illustration: ABB

ABB Subsea substation - next generation subsea electrical power system.

Photo: Minox Technology AS

greenhouse gas emissions from the petroleum sector. For such platforms, the reduction of emissions from power generation, which is currently largely done using turbines, as well as achieving more energy-efficient operations is particularly important.

The Research Council's petroleum programmes follow up

The recommendations in the OG21 strategy have been incorporated into the programmes' plans. Reduction of emissions to sea and air has for many years been in focus as part of the calls for proposals under PETROMAKS 2 and DEMO 2000. Part of the solution to achieving lower emissions is through greater integration between energy and petroleum. Since 2015, PETROMAKS 2 has collaborated with other Research Council programmes on calls for proposals in the field of ocean technology, involving cooperation between representatives of different sectors. In the ocean technology area, several ongoing projects are now developing solutions to integrate renewable energy in offshore energy systems.

The first two petroleum research centres (PETROSENTER) were established in 2013. Long-term funding was provided in response to important national research needs. The two industry-oriented research centres focus on petroleum activities in the High North and in the Arctic, and improved recovery. The recommendations in OG21 and the Roadmap for the Norwegian Continental Shelf were followed up with a call for proposals for a further petroleum research centre in 2018. The centre will focus on low-emission technology for petroleum activities on the Norwegian continental shelf.

Since 2010, the Research Council has been instructed in the allocation letter from OED to set aside at least NOK 25 million for research into energy efficiency and reduction of greenhouse gas emissions from oil and gas production on the Norwegian shelf. The Research Council has conducted a survey to map petroleum-related research projects for the purpose of gaining an overview of projects that could increase energy efficiency and/or reduce emissions to air through making use of new technology. The results show that extensive additional funding has been granted to projects with a potential for improving energy efficiency and reducing emissions to air. The projects that have confirmed relevance to energy efficiency and/or reduced emissions to air are listed at the back of this brochure.

Projects offering new opportunities

Publicly funded petroleum research contributes to Norway realising its part of the global climate goals. An analysis of publicly funded petroleum research shows that 60 per cent of the projects develop knowledge and technology that can be used to reduce greenhouse gas emissions with the aid of new technology and competence, and energy efficiency measures on existing and new installations on the Norwegian continental shelf.

The analysis is based on all the petroleum projects comprised by the Research Council's PETROMAKS 2 and DEMO 2000 programmes that started up between 2015 and 2018. All 187projects have been contacted and 176 projects have responded, corresponding to a response rate of over 90 per cent. The analysis is based on figures provided by the projects. Projects that failed to respond are not included in the analysis. Similar analyses were conducted in 2012 and 2015.

The analysis shows that 60 per cent of the projects under PETROMAKS 2 and DEMO 2000 have the potential to increase energy efficiency and/or reduce emissions to air. Research and technology development can help to reduce emissions to air, both directly – for example by reducing the number of tonnes of CO_2 produced from an emissions source, or indirectly by implementing more energy-efficient production processes. The analysis also looks into whether the projects are targeted or are of relevance to energy efficiency. The targeted projects have greater energy efficiency and/or lower CO_2 emissions as their main goal. The analysis shows that 7 per cent of the projects are directly targeted, while 53 per cent of the projects are of relevance if the technology is put to use. Energy efficiency is not a primary goal in these latter projects, but is triggered by research and innovations that were initially intended for completely different purposes such as robotisation, automation and optimisation of methods and processes.

The projects' own classification of environmental potential

The table gives an overview of how the projects classified their environmental potential. Of a total of 176 respondents, 105 confirmed that their projects have potential for energy efficiency and/or reduced emissions to air. This corresponds to 60 per cent of the portfolio.

The projects' own classification of environmental potential	Number of projects	Percentage breakdown of environmental potential	Percentage of whole portfolio
Energy efficiency	94	90	53
Lower emissions to air	52	50	30
Electrification	19	18	11
Other (such as discharges to sea/renewable energy)	42	34	20
Total projects with a potential for energy efficiency and/or reduced emissions to air	**105**	**100**	**60**

Overview of the projects' own responses. Number of responses/projects included in the analysis: 176

A large majority of the projects (94 of a total of 105), has confirmed potential for energy efficiency. This represents 90 per cent of the 105 projects. Compared with all projects initiated between 2015 and 2018, 53 per cent of the portfolio report a potential for energy efficiency and 30 per cent a potential for less emissions to air – across all project types and discipline areas. This indicates that new technology generally contributes to both energy efficiency and lower greenhouse gas emissions. In addition, 11 per cent reported relevance to electrification and 20 per cent also reported a potential for other environmental benefits, such as reduced emissions to sea, carbon capture and storage, less use of chemicals and renewable energy. Note that many of the projects have a potential for several environmental benefits, so that the total number indicated per topic is greater than the number of responses.

The projects that have confirmed relevance to energy efficiency and/or reducing emissions to air are listed at the back of this brochure.

Research targeting environmental exploitation of petroleum resources

In 2016, emissions from the petroleum activities represented approximately a quarter of Norway's total greenhouse gas emissions. Just over 80 per cent of the CO_2 emissions from the petroleum activities were from gas turbines used for local power production offshore. Large amounts of power are needed for offshore operations, and it is therefore important to continue to develop competence and technology of relevance to new and/or better ways of generating power. Possible examples are more efficient gas turbines, further development of combined power plants (heat recovery units and steam turbines), hybrid power solutions for supplying offshore infrastructure (offshore wind, battery solutions, fuel cells, wave power etc.), hydrogen for blending with natural gas and combustion of other gases that emit lower or no greenhouse gases. Greater energy efficiency in power production is one of the most important and environmentally friendly means of saving energy and reducing emissions.

7 per cent of the projects in the petroleum portfolio that started up between 2015 and 2018 directly targeted the development of technologies for energy efficiency and/or lower greenhouse gas emissions. The majority of these address power generation with reduced emissions to air, electrification using offshore wind farms and electrification of subsea installations. These targeted projects have a particular focus on hybrid power solutions, further development of combined power plants and hydrogen for blending with natural gas. The implementation of new, environmentally friendly technology will result in more efficient power production and thus reduced CO_2 emissions.

▶▶ At present, electricity and heat for the installations on the Norwegian shelf are largely produced by gas turbines. At the same time, Norway has a great unexploited potential in offshore wind power. Prototech AS aims to combine the two systems with an energy storage concept and develop an overall hybrid concept. The energy storage concept includes a reversible fuel cell system. On windy days, the fuel cell system can store surplus energy by producing hydrogen. During peak periods of power consumption, the fuel cell system can use hydrogen to produce electricity. The fuel cell system will thus function as a backup power supply system, and the renewable energy source is fully utilised. The hydrogen can also be used to fuel the gas turbines and thereby reduce the consumption of natural gas. This gives a cleaner fuel with lower greenhouse gas emissions.

▶▶ SINTEF will facilitate more efficient energy use on the Norwegian shelf. Gas turbines placed on deck are responsible for eight out of every ten kilogrammes of CO_2 emissions from the platforms. They supply power to the platforms, but much valuable heat is discharged with the exhaust gases. By attaching a steam turbine that can utilise the residual heat, the combined power plant can produce power twice from the combustion heat. The plant is part of a bottoming cycle, a combined plant that uses exhaust gases from offshore gas turbines to generate power. Expected potential reductions in CO_2 emissions from offshore turbines are 17 and 21 per cent, respectively, on implementing lightweight 12 MW and 16 MW bottoming cycles. In practice, this can be done by reducing the number of gas turbines and replacing them with bottoming cycles connected to the remaining gas turbines.

Great potential for environmental benefits in several technology areas

The majority of the projects that reported a potential for energy efficiency and/or reducing emissions to air, do not have reduction of greenhouse gas emissions as their primary objective. This shows that research and technology development in the petroleum sector often can contribute to reducing emissions to air, even if the research is aimed at solving completely different technology and knowledge needs for the

Photo: Calora Subsea AS

Norwegian shelf. Process simplification and automation, increased knowledge for better decision support and more optimal operations are examples of this. Energy efficiency is not the primary objective of these projects, but is triggered when using knowledge and technology aimed at innovations that were primarily created for completely different purposes.

An indirect way of achieving lower emissions to air is by making processes more efficient so they can be carried out more quickly. When an operation takes less time, it also produces less emissions to air. Many offshore operations can only be performed using support vessels or rigs. Reducing the time spent on such operations, or reducing the size of support vessels, will significantly reduce fuel consumption and thus emissions of greenhouse gases from fuel combustion. The analysis also shows that, even if the contribution from each individual project may be modest, when combined, they can potentially trigger major changes in the petroleum industry. Furthermore, the projects emphasise safety that decrease the potential for undesirable incidents. The majority of these projects relate to drilling and well technology, multiphase transport, subsea solutions and optimised production strategies.

Drilling and well technology

The development of drilling and well technology has long been a priority area because of low oil prices and high costs. In order to cut costs, the operators want research and technology that can make the operations more cost-efficient. Among other things, energy efficiency can be achieved through faster and smarter performance of drilling and well operations, through moving some operations from big drilling rigs to lighter vessels or through reducing the need for support vessels. Robotisation and automation will reduce the total time spent on operations, thus reducing total energy consumption and CO_2 emissions per unit of oil produced. In addition, research provides increased understanding of the complexity of the operations and provides better decision support, so that the operations can be made safer and more energy-efficient. The potential for greater energy efficiency and lower emissions of greenhouse gases in drilling and well technology is primarily realised through implementing new technology such as robotisation, optimisation and automation to simplify processes, faster drilling and safer well intervention.

▶▶ West Drilling Product AS is developing Continuous Motion Rig (CMR), a new and revolutionary method of performing a continuous drilling process without stopping for connections. CMR can potentially cut drilling time by half, with corresponding cuts in energy consumption and emissions. All tasks are carried out by electrical robots working together as an autonomous unit. The technology also opens for drilling longer wells. The extended reach can increase recoverable resources and make the recovery of neighbouring small discoveries commercially viable. This will entail significant energy savings and reduced emissions. The method can potentially cut back the time from when a drilling vessel arrives at the destination until it leaves the location by 30 to 50 per cent. This entails corresponding reductions in energy needs and emissions compared with conventional drilling technology. The technology is adapted for electrification from shore. It is equipped with electrical systems that are capable of delivering power back to the network, and is facilitated for connection to efficient hybrid plants.

▶▶ Aarbakke Innovation AS is developing a well intervention tool to enable substantial energy and cost savings in plugging and abandonment (P&A) of offshore wells. P&A operations in the oil and gas industry are costly. At present, necessary operations to remove production tubing and injection lines require mobilisation and use of a costly and energy-consuming drilling rig.

Aarbakke Innovation AS is developing Micro-Tube Removal tool (MTR), which makes P&A possible without pulling the production tubing. This entails significantly lower emissions than the methods used today. On platforms, the work can be carried out using electrically powered well intervention methods, referred to as light well interventions, instead of large drilling rigs. By leaving the production tubing in the well, the transportation of large volumes of pipe by supply vessels, and subsequently by truck, is avoided and emissions are significantly reduced. The process of having to handle somewhere around 700 tonnes of production tubing per well is avoided, and the use of smaller vessels entails lower emissions.

Multiphase technology

Challenges associated with the recovery of oil and gas on the Norwegian shelf include limiting the costs of investment and energy consumption. Potential cost drivers when developing new oil and gas deposits include the construction and operation of new oil platforms. It is therefore desirable to make use of existing infrastructure, rather than constructing new. In many cases this entails that raw oil, water and gas must be transported together over long distances (multiphase transport), either to shore or to existing platforms on other fields. Multiphase technology addresses the transportation of several phases in the same pipeline. Multiphase transport can pose various challenges, such as precipitation of solids, scale and corrosion inside the pipe, caused by different substances present in the liquid/gas being transported. There is also a risk of gas and fluid arriving by turns in the processing plant so that the receiving system is flooded. Furthermore, the pressure required to transport more phases at the same time can be difficult to predict. These challenges are addressed using simulation tools in order to provide a better decision support basis for the choice of technical solutions. The costs of different solutions will vary widely, and more accurate predictions enable considerable savings to be made in terms of both investment costs and energy consumption.

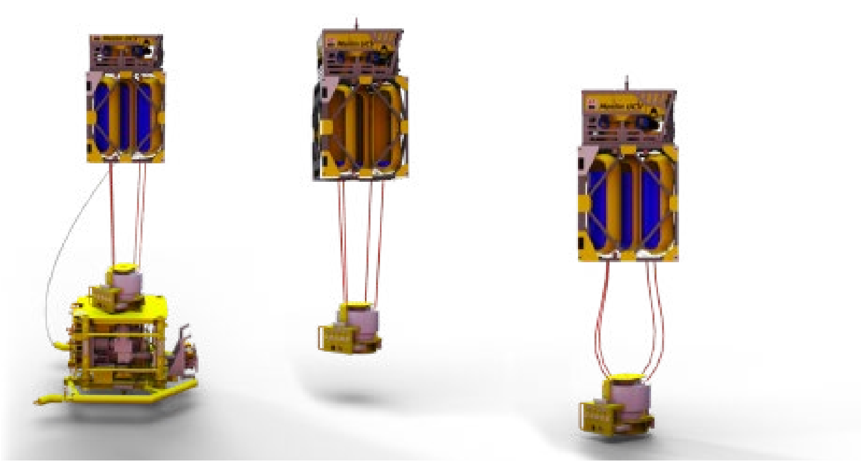
Current flow simulation tools have challenges when oil, water and gas are present at the same time. When these fluids are transported over many tens of kilometres, even moderate differences between the data and the predictions can have major consequence for the choice of solution and hence also for the costs of development. That the simulation tools are as accurate as possible is therefore important for field design and operational decision-making. A majority of the projects look at how multiphase transport can be optimised based on increasing know-how about multiphase blends, better modelling of multiphase transport over long distances, materials for safe multiphase transport and reducing the use of chemicals.

Photo: Ludvig Killingberg/SINTEF

SINTEF's multiphase laboratory at Tiller outside Trondheim has recently been upgraded with funding from the Research Council of Norway. Here, unique experimental data are generated, and these are used, among other, for the development of new models for multiphase simulators.

▶▶ Petroleum is an emulsion – a liquid-liquid mixture composed of two, or more, immiscible components, just like mayonnaise. If the mayonnaise separates, some effort is required to restore it to its original emulsion state. Correspondingly, there are significant problems involved in extraction and transport of petroleum emulsions once the mixture has broken (separated). The process is complex to control, and it is difficult to predict how the emulsion will behave because of the many variants of petroleum types and treatment conditions. NTNU will study the region between two liquid drops immersed in another liquid (for example, two oil drops in water) in the presence of soaps (surfactants) and other components. The purpose is to be able to describe the droplet-droplet merging (usually referred to as coalescence). Understanding this phenomenon can potentially lead to significantly higher energy efficiency in the production and transport of oil and gas.

▶▶ In all petroleum fields, the pressure gradually decreases as the gas and oil are recovered – just as when the air goes out of a balloon. The pressure is the gas's driving force. This means that the gas flow rate is reduced the longer the recovery from the gas field has taken place. Some of the gas will be converted to liquid on the way up the well, and it is therefore important that the gas velocity is high enough for the liquid to be entrained in the flow. If the gas velocity is too low, the liquid will remain in the well and choke it, so that the well stops producing. Recent measurements carried out in SINTEF's multiphase laboratory in collaboration with LedaFlow, show that the gas does not need to flow as fast as previously assumed in order to entrain the oil. The results are important to be able to design future gas wells so that they can be operated in an optimal manner, save operating costs and consume less energy.



A ROV (Remote Operated Vehicle) operates the IKM Variable Buoyancy System (VBS) to lift and move components (Tree Cap) subsea. Water is pumped out of the VBS tanks to lift and into the VBS tanks to lower them to the seabed.

Subsea technology

Moving the oil and gas production from topside plants to subsea systems has favourable consequences for the platform's energy efficiency. This is due to effects such as major savings on materials (platform construction), reduction in operating personnel and more energy-efficient processing and transport of multiphase flow. Performing parts of the oil and water separation on the seabed helps to achieve a more energy-efficient production. Reinjecting the water back into the oil well frees space in the risers to the platform. Much energy is saved by not having to pump the water several hundred metres up to the platform before it is separated and sent back down again. In addition, the ambient pressure is much higher on the seabed than on the surface, which further reduces the energy required for pumping oil, gas and water. On the other hand, equipment placed on the seabed is inaccessible and needs to be robust and operationally reliable. These projects study process equipment and materials adapted for subsea operation, such as pumps, valves, dehydrators, CO_2 removal components, coolers and subsea vessels as well as power supply and distribution.

▶▶ Pumps can increase the recovery from existing fields by 10-30 per cent and are an excellent tool for increasing income with minimum impact on the environmental footprint. For example: One per cent improved recovery from a field on the Norwegian shelf will increase Norway's income by NOK 100 billion (based on an oil price of only USD 30 per barrel). Nonetheless, this type of equipment has only been installed on 18 of a total of around

1,600 fields. The greatest obstacles to more extensive use of pumps are equipment and installation costs combined with sub-optimal reliability. Fuglesang Subsea AS is developing an autonomous subsea pump; Omnirise Booster. Placing the pump on the seabed will remove the need for several hundred tonnes of topside equipment and an expensive hydraulic umbilical. The technology enables longer step-outs and can be operated from fully electrified onshore infrastructure. Less need for materials in addition to major weight reduction on the platforms gives a high potential for CO_2 reductions. The pump system can be operated without the traditional frequency converter and without a barrier fluid system. Omnirise is also the world's first green subsea pump module to have hermetically sealed barriers against the sea, which minimises the risk of spills.

Photo: Calora Subsea AS

▶▶ Subsea petroleum plants are being developed for deeper, colder and more remote areas, and it would be ideal if the next generation of unmanned underwater vehicles (UUV) could «live» next to such subsea facilities. SINTEF is conducting a project to enable UUVs to understand their environment and operate at the correct level of autonomy while keeping the operator in «the loop». This will be achieved by using subsea 3D sensors to generate 3-dimensional data about the UUVs' environment and new methods whereby the UUVs can use the data to understand their seabed environment. SINTEF is also developing techniques for automation of the planning process, so that the UUVs can plan operations of their own accord, based on their understanding of the environment they operate in. The results can be conducive to increasing the efficiency and safety of offshore operations, and increase the use of underwater vehicles that «live» on the seabed by the subsea facilities. Such solutions will help reduce the need for sending personnel offshore and reduce the use of surface vessels in connection with the operation of underwater vehicles. This will make it possible to reduce total energy consumption in offshore operations and emissions to air.

Production optimisation and integrity monitoring

An indirect way to achieve lower emissions is by rationalising processes, so that a task can be performed faster or that a task can be performed using less energy. Reduced implementation time for energy-intensive processes and improved work processes relating to production and operation, thus lowering the costs and increasing production, are examples of this. Optimisation through integrity monitoring, better utilisation of production data and automation of processes will result in more efficient oil and gas production. In turn, this means that less energy is needed for process implementation. An important consideration in these projects is reduced risk of undesirable incidents. This will in turn lead to greater operational reliability, less flaring, lower risk of leakages and a safer working environment.

▶▶ The well pressure is sometimes too low to push the wellstream up through the riser to the platform. By injecting gas into the production tubing below the riser (gas lift), the oil column becomes lighter and this facilitates uninterrupted production. Approximately 80 per cent of all wells on the Norwegian continental shelf are gas-lift wells. Hence, better utilisation of the injected gas with distribution between producing wells, and less energy spent on handling the lift gas, represent a significant potential for reducing energy consumption per produced oil equivalent. Scanwell Technology AS will test and pilot a unit with sensors for measuring pressure, flow rate and propagation of tracer gas in wells in a completely new way. Sensors placed on the X-mas tree or wellhead and connected to software that describes the propagation of tracer gas based on process conditions and annular geometry, will enable production monitoring and detection of leakages, both in real time and over periods of time. This information will furnish the operator with a new tool to increase production from gas-lift wells, prevent killing of «healthy» wells, reduce the risk of leakages and monitor wells that are ready for plugging and abandonment (P&A). The project's own calculations show a potential reduction in CO_2 emissions per produced oil equivalent (based on gas turbine operation) of 30-60 per cent compared with today's technology

▶▶ The control room operator is completely dependent on understanding the underlying causes and consequences of extraordinary events in order to respond in a correct and timely manner. In its AlarmTracker project, Eldor Technology AS wishes to contribute to better decision-making through digitalisation. The project aims to make production more efficient and reduce downtime on oil and gas installations through greater situational awareness and real-time decision support by offering operators web-based causal analyses. The overall objective is to handle «abnormal» situations in the best possible manner in order to limit their consequences for production, avoid production losses, minimise flaring and reduce the load on safety equipment.

Electrification is more than power from shore

As the subsea industry is being developed for ever greater depths, further from shore and in harsh and Arctic environments, there is a growing need to develop and introduce new technology to meet environmental requirements and reduce costs. For example: Current subsea systems use a water-based hydraulic fluid when operating valves on the seabed, and there is a risk of some of this fluid leaking into the sea. By introducing fully electrified subsea installations and removing the hydraulics, this risk can be eliminated completely.

11 per cent of the projects initiated between 2015 and 2018 report relevance to electrification. Electrification of the Norwegian shelf is often understood to mean being supplied with electricity from shore, but most of these projects address electrification of subsea installations, including fully electrified subsea systems, and supplying platforms with power from other energy sources (such as renewable energy), in addition to offshore energy systems and energy management (more efficient control/use of energy). This is a new direction compared with previous years. The projects relating to electrification of subsea installations comprise new technology, including replacement of hydraulic systems, as well as improvements to already existing electrical systems with a view to safer and more efficient operation. These projects will contribute to the electrification of subsea installations, such as power systems, control systems for data and electricity transmission, easier connection of subsea installations, charging stations for autonomous underwater vehicles (AUV) and non-hydraulic valves.

▶▶ ABB with Equinor and partners will develop and build the next generation of subsea electrical power systems. The equipment must be highly reliable and safe, as it will be lowered to seabed depths of 3,000 metres and operated for 30 years with a minimum of interruptions and maintenance. This can be compared with sending a satellite into space; once it is done, the satellite is almost inaccessible. The technology is expected to improve oil recovery and reduce the CO_2 footprint per barrel through use of power from shore. It also entails a potential for the reduction or removal of topside installations, which can give significant emission cuts.

▶▶ Wisub AS has developed a technology that enables wireless transmission of power and data under water based on induction and microwaves. Established technology has depended on metal pins to transmit power, just like plugging into a socket to get electricity at home. On the seabed, the risk that the metal pins will corrode is great, and short-circuiting can often result from contact between metal conductors and saline water. WISUB intends to eliminate these problems by removing the metal pins. This will simplify and optimise subsea operations and can potentially reduce greenhouse gas emissions though more efficient service operations. An underwater robot (ROV – remotely operated vehicle) weighing several tonnes is currently used to replace big components, which can easily damage the metal pins in the traditional connections. When subsea connections are made

Photo: Thor Nielsen / SINTEF

easier and faster, the operating time of the vessel controlling the operation are reduced along with the need for fuel, thereby reducing CO_2 emissions.

Mature fields have greater energy needs

Based on current production plans, more than half the proven oil resources are left in the subsurface. The ambition is to increase the recovery factor. Injection of water, gas or other fluids is important in order to recover the remaining oil, but this requires more energy. The projects are studying how the injected fluids move through the reservoir to optimise the recovery efficiency. Many fields on the Norwegian shelf depend on water injection to maintain the reservoir pressure. Water injection is very costly and the energy consumed is a source of CO_2 emissions. The handling and cleaning of produced water is likewise an energy-intensive process.

▶▶ The National IOR Centre at the University of Stavanger, a petroleum research centre, develops, among other things, methods which will enable reduction of the volumes of injected and produced water, thus contributing to greater energy efficiency. The research centre is developing new models and uncertainty quantification of the reservoir and the chemical and physical processes that take place when it is being drained. This is very important in order to plan, develop and optimise energy-efficient recovery. It includes planning

SINTEF's multiphase laboratory is the largest of its kind in the world and is used for the development of technology for cost and energy efficient transport of oil and gas.

of new wells, control of injection and production rates and better understanding and modelling of methods for improved recovery.

▶▶ To increase production and the recovery factor, it is important to prevent the adverse effect of gas and/or water breakthroughs in the well. As the breakthrough increases, the production needs to be choked back if the oil produced is accompanied by large amounts of unwanted gas and water. Inflowcontrol AS has developed an Autonomous Inflow Control Valve (AICV), a new advanced well concept. These wells have a large number of inflow control valves (typically 250) placed at defined intervals along the horizontal length of the well. The valves are left in open position while the oil is being drained, but they close automatically in the event of gas and/or water breakthroughs. Such valves should preferably be autonomous (self-adjusting). The new AICV technology is the only technology on the global market that enables almost complete shut-in of gas and water locally in the well. This means that much less gas and water is produced from the oil wells and much less energy (with related CO_2 emissions) is needed. This applies to production as well as water and gas injection and is expected to reduce energy consumption by up to 40 per cent.

Improved recovery using natural gas and CO_2

In addition to water injection, injection of natural gas is used as a method to increase the recovery factor on the Norwegian shelf. It may also be possible to use CO_2 instead of natural gas, when CO_2 is available in sufficient quantities.

Photo: Tomm Erichsen/Bigwig

Prototype of AlarmTracker, a development project by Eldor Technology AS. The technology will increase production by helping the operator to make the right decision under abnormal situations.

▶▶ A project at IRIS aims to increase knowledge about how three fluids (water, oil and gas) move through porous rock. In order to achieve this, the project is developing improved methods of pore-scale modelling, which are used directly in 3D simulations of pore geometry based on images of the rock (digital rock physics technology).

▶▶ The combined injection of CO_2 and a surfactant (soap) produces a foam that is far more viscous than the oil in the reservoir. This can increase the recovery factor. A project at the University of Bergen aims to establish attractive industrial solutions to reduce carbon footprints through combined CO_2 storage and improved oil recovery from mature fields by use of nanotechnology to stabilise CO_2 foam.

Exploration

A large part of the remaining petroleum resources has yet to be discovered. Exploration activities on the Norwegian shelf are important for sustaining petroleum activities in the long term. Projects with a focus on exploration seek to increase the likelihood of boreholes hitting targets, improve image quality and gain more knowledge and understanding relating to the development of relevant exploration models for the Norwegian shelf.

▶▶ At present, many geologists spend most of their time interpreting seismic data. Some of this work can be automated using artificial intelligence. Technology being developed by Earth Science Analytics AS will be able to identify geological formations, faults, horizons and three-dimensional bodies such as salt bodies, channels and other stratigraphic features. Use of deep

Fotograf: Marit Hommedal, Bilderettigheter: Xsens AS

Xsens flow meter for energy and emission reduction. Xsens clamp-on flow meter technology for safe and accurate process measurement in the oil industry, as well as emission reporting and fuel reduction on ships. Magne Husebø, Remi Kippersund, Kjell-RuneToftevåg (all Xsens AS).

neural networks will also enable automatic identification of rock and fluid characteristics based on seismic data. This is currently being done using complicated seismic intervention techniques and rock-physics methods. The project will help to achieve greater precision in predicting hydrocarbon deposits. This will reduce the number of wells that need to be drilled and thus reduce emissions from drilling operations.

Other environmental effects

20 per cent of the projects are relevant to other positive environmental benefits, in addition to energy efficiency and/or lower emissions to air. The majority of these projects can result in reduced discharges to sea and less use of chemicals. Furthermore, several projects report relevance to carbon capture (CCS) and renewable energy. The example below shows a great potential for cutting back on the use of chemicals and materials, in addition to very energy-efficient multiphase transport over long distances.

▶▶ The current methods of transporting hydrocarbons from the well for further processing are based on keeping the pipe flow warm and using chemical inhibitors to prevent wax and hydrate formation (ice-like crystals). This entails using large quantities of chemicals and supplying a lot of energy for physical heating and/or a thick layer of insulation on all production tubing. Through a new method for handling both wax and hydrates in a cold regime, Empig AS aims to make multiphase transport possible at ambient temperatures (cold-flow) and thus remove the need for chemicals, energy for heating and large quantities of insulation materials. The technology can thus have major environmental benefits.

Relevance to other industries, including renewable energy

Technologies from the oil and gas industry can be utilised for much more

Photo: Johan Wildhagen

than their original purpose. The innovations are often transferred to other parts of society.[7] Examples of this are large aquaculture facilities far from shore, seawater purifiers that can produce drinking water in hot climates, sensors for subsea installations adapted for satellite use (ESA) and a modelling tool for fluid flows in oil reservoirs that can be used to examine how cancer spreads in the human body.

Many of the PETROMAKS 2 and DEMO 2000 projects are also of relevance to technology transfer to other industries.

For example, 8 per cent of the projects have reported that their projects are of relevance to renewable energy, like offshore wind, geothermal energy, hydrogen recovery and wave power, in addition to energy efficiency and/or lower emissions of greenhouse gases. This shows that much of the research carried out in the petroleum programmes has good transfer value to other key areas for energy security for the future.

In order to promote green growth, technology development and transfer of knowledge across the ocean-based industries, the Research Council has issued several calls for proposals in the field of ocean technology. A presentation of three of these projects is given under «Project examples from the portfolio» later on in this brochure. Two of the projects concern integration of offshore wind on oil and gas installations, while one of them looks at CO_2-free, hydrogen-based offshore energy production for offshore installations and the maritime sector.

Public funding and supplemental financing to petroleum research with potential for energy efficiency and/or reduced emissions to air

The Research Council has awarded a total of NOK 1.513 billion to the 187 petroleum projects under PETROMAKS 2 and DEMO 2000 initiated between 2015 and 2018. These allocations have in turn trig-

7 norskoljeoggass.no/naringspolitikk/publikasjoner/teknologioverforings-rapporten-2017/

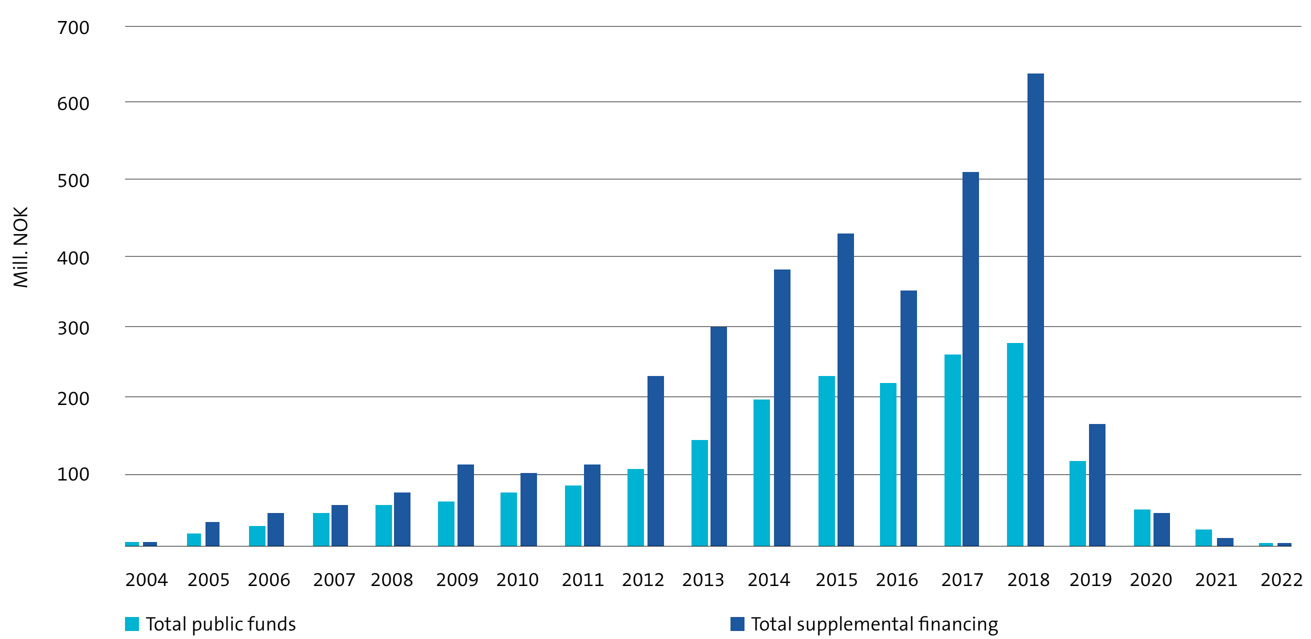
gered an additional NOK 2.726 billion in cash financing and in-kind support from the projects and their partners. As many as 105 of these projects have reported a potential for energy efficiency and/or lower emissions to air if the technology is implemented. These projects have received NOK 819 million in public funds. In addition, these projects have triggered NOK 1.677 billion from other sources. The total budget used for research with a potential for energy efficiency and/or reduced emissions to air on the Norwegian shelf for projects granted the past three years is therefore NOK 2.492 billion.

Three sets of analyses (2012, 2015 and 2018) show that, since 2004, more than 250 projects with a potential for energy efficiency and/or reduced emissions of greenhouse gases have been awarded funds under the PETROMAKS / PETROMAKS 2 and DEMO 2000 programmes. The graph shows an overview of public funding and supplemental financing of projects that contribute environmental benefits granted during the period 2004–2018. The graph extends to 2020, as the projects extend over several years. During this period, NOK 2.020 billion has been awarded under the programmes to projects with a potential for increasing energy efficiency and/or reducing emissions to air from the petroleum sector. This funding has in turn triggered NOK 3.598 billion in cash contributions and own efforts on the part of the projects and their partners, so that a total of more than NOK 5.6. billion has been spent on research of relevance to the climate settlement *(klimaforliket)*.

An overview of the projects with a potential for energy efficiency and/or reducing emissions of greenhouse gases are listed at the back of this brochure. Only projects that have confirmed such a potential are included on the list.

>> Over NOK 5.6 billion has been invested in research relevant to the climate settlement through PETROMAKS / PETROMAKS 2 and DEMO 2000 projects.

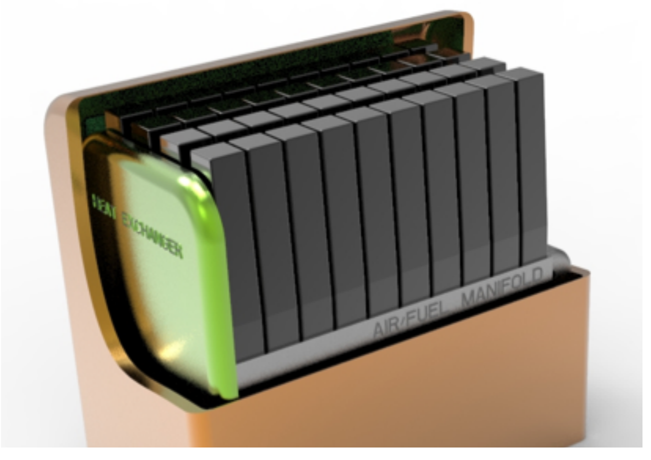
Public funding and supplemental financing for petroleum research with a potential for energy efficiency and/or reduced greenhouse gas emissions to air



Fuel cells for offshore power

Nearly all offshore power production is currently based on gas turbines, and they are responsible for between 80 and 90 per cent of CO_2 emissions from the Norwegian continental shelf. **Prototech AS** aims to replace today's gas turbines with fuel cell technology. This will increase efficiency and thus reduce emissions.

Photo: CMR Prototech



▶ Today's gas turbines have limited efficiency, normally around 30 per cent, though slightly higher when operated optimally. Use of fuel cell technology instead of today's gas turbines can significantly increase efficiency and thus reduce emissions. At the same time, requirements for reliability must be met without notably increasing the weight or volume. The plan is to achieve this by integrating several technologies into one system giving an optimal combination of size, efficiency and cost. The new Clean Highly Efficient Offshore Power (CHEOP) system includes two fuel cell types (SOFC and PEM), steam reformation and hydrogen membranes closely integrated and with heat transfer between the processes.

Solid Oxide Fuel Cells (SOFC) with an operating temperature of approximately 800°C convert natural gas to electricity very efficiently. A SOFC is fuel flexible, allowing it to utilise the natural gas resources available on the platforms. The drawback is that a SOFC plant is too big and heavy for offshore use. Low-temperature fuel cells (PEM/HT-PEM), developed for use in private cars, depend on pure hydrogen fuel, but are much more compact (only 10 per cent of the size of a SOFC). The CHEOP technology developed by Prototech AS reduces the weight of the fuel cell system to one quarter of the baseline SOFC system. This can be achieved by first reforming the natural gas to hydrogen and CO_2, using a palladium-based hydrogen membrane to separate out most of the hydrogen. This hydrogen is then converted in the PEM fuel cells, while the SOFC is used for post-combustion of residual fuel from the membrane separation. The SOFC is also used as a source of heat for the reformation, which ensures a high total efficiency of almost 60 per cent. Hence, the project has a potential for cutting CO_2 emissions from the Norwegian shelf by almost half.

The project is headed by Prototech AS in collaboration with the University of Bergen, the Western University of Applied Sciences, Equinor and Shell Norge.

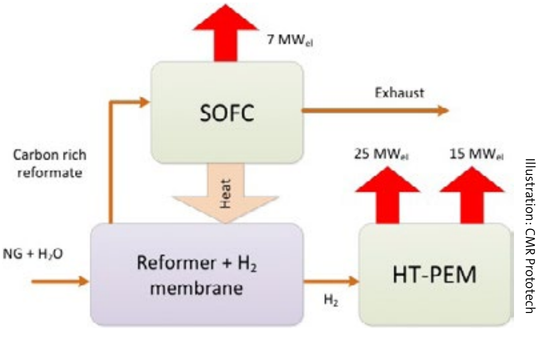


Illustration: CMR Prototech

Photo: CMR Prototech

Mounting of SOFC fuel cell.

Wind power for offshore installations

While electricity consumption on the Norwegian mainland is almost entirely based on renewable energy, mainly hydropower, oil and gas production on the Norwegian continental shelf largely uses fossil fuels with significant greenhouse gas emissions. There is a great need for new energy solutions to increase energy efficiency and reduce CO_2 emissions from the Norwegian continental shelf. One renewable energy solution is to install floating wind turbines near offshore installations.

Photo: Jan Arne Wold, Woldcam/Equinor

Dudgeon Offshore Wind Farm

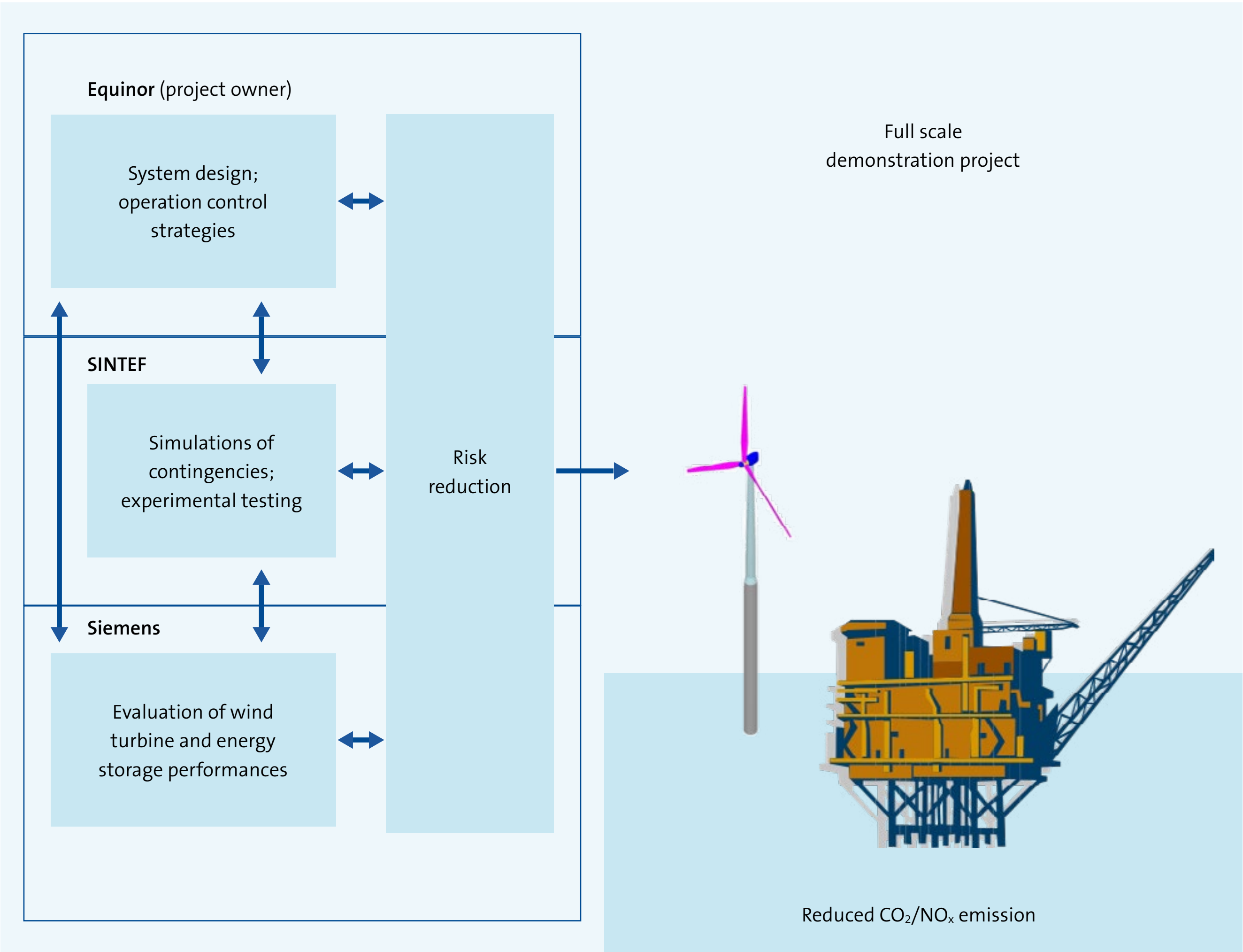
The main objective of the project «VIKINGS: Offshore Wind Integration within the Stand-alone Electric Grid of Oil and Gas Offshore Installations» is to reduce the risks associated with integrating a floating wind farm into the energy system for oil and gas installations to reduce CO_2 and NOX emissions. However, connecting floating wind turbines to an existing electricity network on an offshore installation poses many challenges.

In this project **Equinor**, SINTEF Energi and Siemens will identify technical challenges relating to reliability associated with the integration of renewable energy into installations in the North Sea. The aim is to identify the bottlenecks of integrating offshore wind farms with the electric grid for offshore oil and gas installations. Simulations in combination with laboratory experiments will be used to examine the stability.

The technology will reduce the need for fossil fuels offshore, as well as the need to install further gas turbines on installations that need more power. A study has shown that NO_X and CO_2 emissions can potentially be reduced by 40 per cent, though this will vary from one field to the next. There are great climate benefits from using floating wind turbines to reduce CO_2 and NO_X emissions from oil and gas installations on the Norwegian continental shelf.

The project is part of the Research Council's ocean technology initiative.

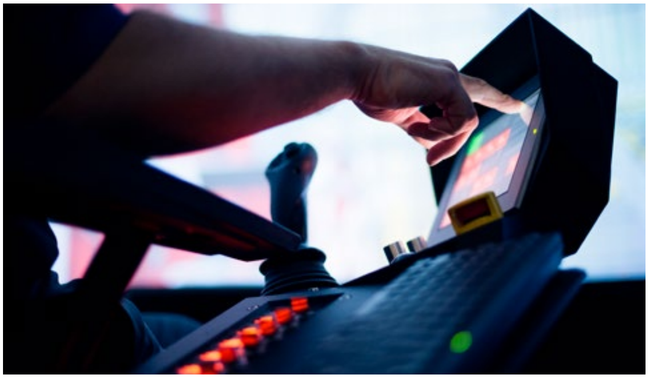
Illustration: Equinor



Efficient drilling operations using digital solutions

Offshore drilling is both costly and time consuming, and the process can lead to large emissions. The solution is smart data modules. Drilling operations are made more efficient, and, with greater speed and safety, both emissions and costs are reduced.

Photo: Ole Jørgen Bratland/Equinor



When exploring and developing oil and gas fields, the costs of drilling represent a significant part of the total project cost. Statistics Norway (SSB) has estimated that drilling costs amount to approximately half the investments made on the Norwegian shelf. Imagine if the time it takes to drill an offshore well can be cut by 20 per cent, at the same time as it is safer, more accurate and with less emissions and fuel needs.

To automate and streamline drilling operations using digital solutions was the main goal when **MHWirth**, Sekal and Equinor started work on developing an open digital solution with different smart modules in a kind of app store. Even though drilling operations have become more efficient in recent years, 20-25 per cent of the time is still designated as downtime. However, efficiency cannot be increased by simply stepping on the accelerator. Monitoring the drilling operation, repeating the same minor and major steps of the process, changing and optimising the correct drilling parameters, while continuously analysing possible outcomes, require super-human brain capacity. That is why drilling takes longer than what is physically possible. Even if the drilling grinds to a halt, the meter keeps running with respect to both rig and fuel costs. A pilot project on the Songa Enabler rig has shown that by automating operations through an open interface solution named DEAL and smart modules, it took less time to drill the well, there was less room for human error and easier to prepare for the next operation.

Automation helps the drilling operator to detect anomalies before they become faults, so that measures can be initiated or the operation halted before the situation requires extensive downtime. MHWirth and its partners, Sekal and Equinor, believe that it is realistic to reduce downtime by nearly 20 per cent by using DEAL and the various smart modules. Fuel consumption can, in turn, be reduced correspondingly, entailing less emissions and lower costs.

Each of the companies has already reaped benefits from much of the technology individually, but the full potential is utilised by connecting the various software programs and analysis tools. The result is a real-time monitoring of downhole events at any time, and a system that will stop of its own accord on detecting a fault that is about to occur. Based on a cautious estimate of USD 200,000 per day in rig hire and a drilling operation of 45 days' duration, 20 per cent downtime amounts to USD 1.2 million for just a single well. And that is for rig hire alone. In addition, the oil companies' own costs of operation are roughly as high, and production start is delayed.

The project started by addressing the efficiency of well operations, but the ripple effects have proved to be great. The operations are perceived as safer and more accurate and have resulted in less emissions and significant reduction in costs.

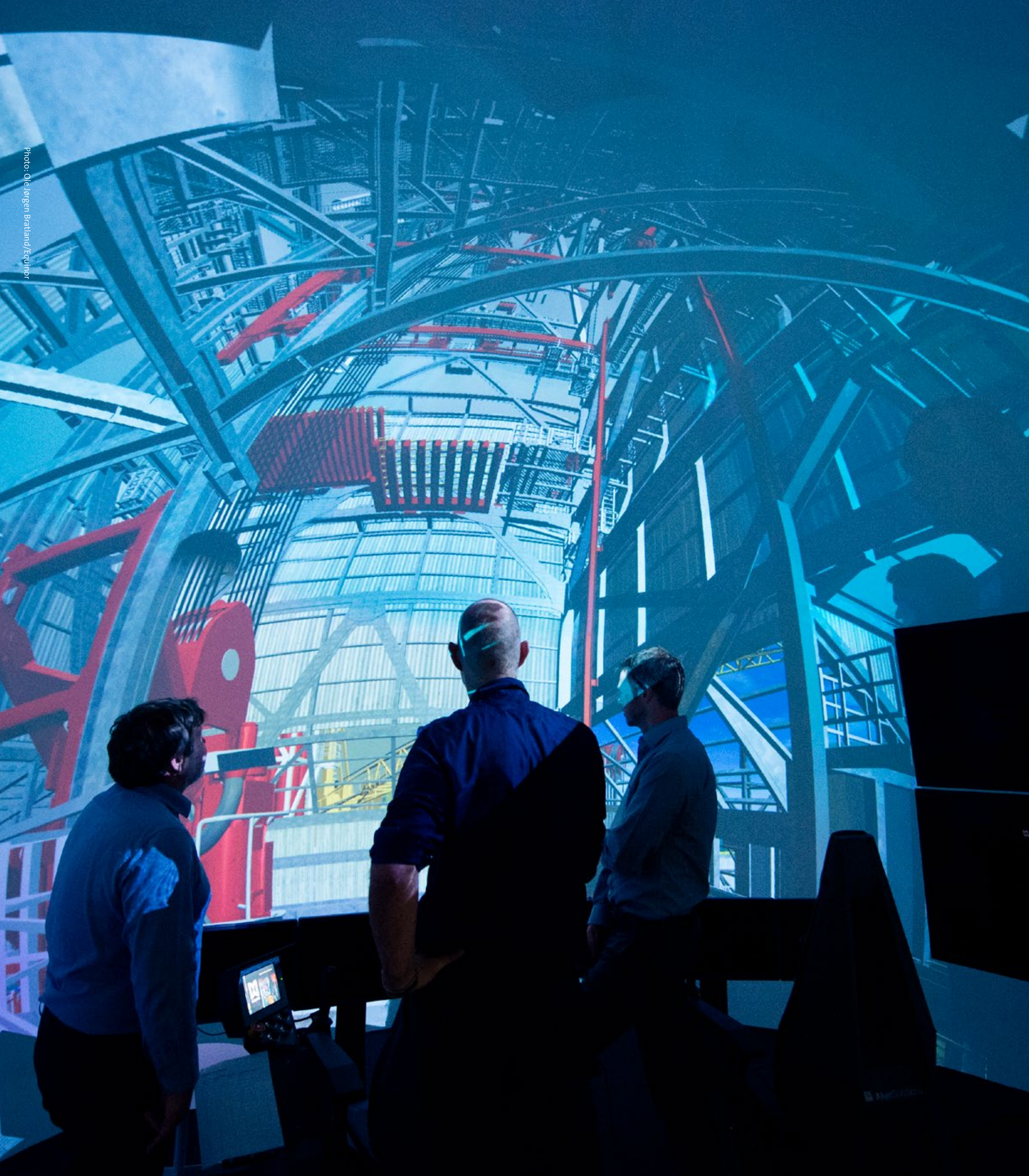


Photo: Ole Jørgen Bratland/Equinor

Wind-powered water injection

An integration of the renewable energy industry and the petroleum industry, whereby renewable energy sources power offshore oil and gas operations, has a great potential for reducing both costs and CO_2 emissions. The WIN WIN project shows how floating wind turbines can provide an environmentally friendly, reliable and cost-efficient alternative power source for offshore water injection systems.

▶ The WIN WIN (WINd-powered Water INjection) project is developing a wind-powered water injection system that will meet the technical, functional and commercial requirements of the industry, and represents a realistic alternative with unique advantages.

The WIN WIN project combines known and tested technology in a new way, and will improve oil recovery, using water injection powered by renewable energy. During the first phase of the project, no technical barriers were identified, and it was concluded that it is technically feasible to use a floating wind turbine to power a water injection process. Such a solution meets performance objectives and can compete with conventional solutions. The autonomous system is anchored close to the injection well. In addition to offering oil and gas operators a flexible alternative to reduce costs, a WIN WIN unit is expected to reduce annual CO_2 emissions by 9,000 tonnes.

The second phase of the WIN WIN project was initiated at the beginning of 2017. The project is headed by **DNV GL**, with participation from Exxon Mobil and Eni Norge. The project aims to validate the electrical system and increase the understanding of the operation of an autonomous micro-network with large and varying loads. The main activities during phase two of the WIN WIN project are simulation and experimental testing of the micro-network. The experimental testing, referred to as «power-hardware-in-the-loop» (PHIL), is being carried out in DNV GL's laboratory in Arnhem in the Netherlands. The testing aims to validate the stability of the micro-network during different operational phases.

Phase two of the project will be completed at the turn of the year 2018–2019. One of the main deliverables is a guideline document for design, installation and operation of the WIN WIN-installation.

The project is part of the Research Council's ocean technology initiative.

Artificial intelligence contributes to optimal production

ProductionCompass AI will enable production engineers and operators to increase production from an oil field by 1-3 per cent by making better use of bottlenecks in the production system. Many of the fields on which this decision support system is implemented can expect the additional production to be more energy-efficient, thereby reducing emissions to air per barrel of oil produced.

▶ Data from an oil field are continually being generated by a vast number of sensors. Operators therefore need good algorithms and analysis tools in order to utilise all these data. By combining data processing, computer learning, artificial intelligence and visualisation into a real-time, automated and data-driven decision support system for daily production optimisation, the process is made more efficient.

Solution Seeker has developed the first artificial intelligence for upstream optimisation of oil and gas production, which uses big-data and computer learning techniques to solve the dynamic stochastic optimisation problem. ProductionCompass will provide operators and production engineers with automatically generated alternatives for adjustment of for example well valves, to increase oil production, without violating for example the gas compression capacity.

The system is being developed as a software product called ProductionCompass AI. At present, the software has been installed on five fields in the North Sea and the Norwegian Sea, by the oil companies ConocoPhillips, Aker BP, Neptune, Wintershall and Lundin. Solution Seeker is planning to offer ProductionCompass AI as a commercial product towards the end of 2018.

Solution Seeker is a spin-off company from NTNU and develops artificial intelligence that will contribute to optimal production of oil and gas.

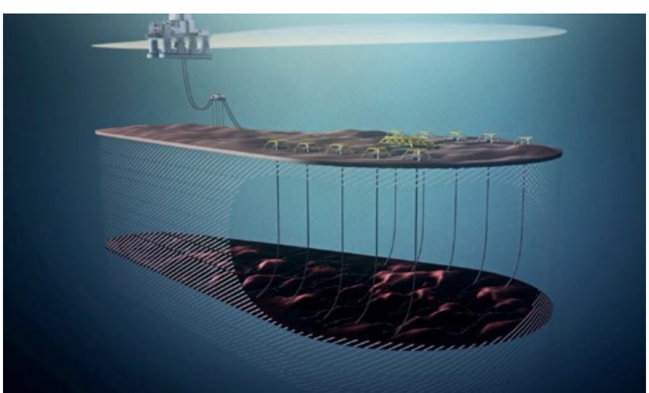
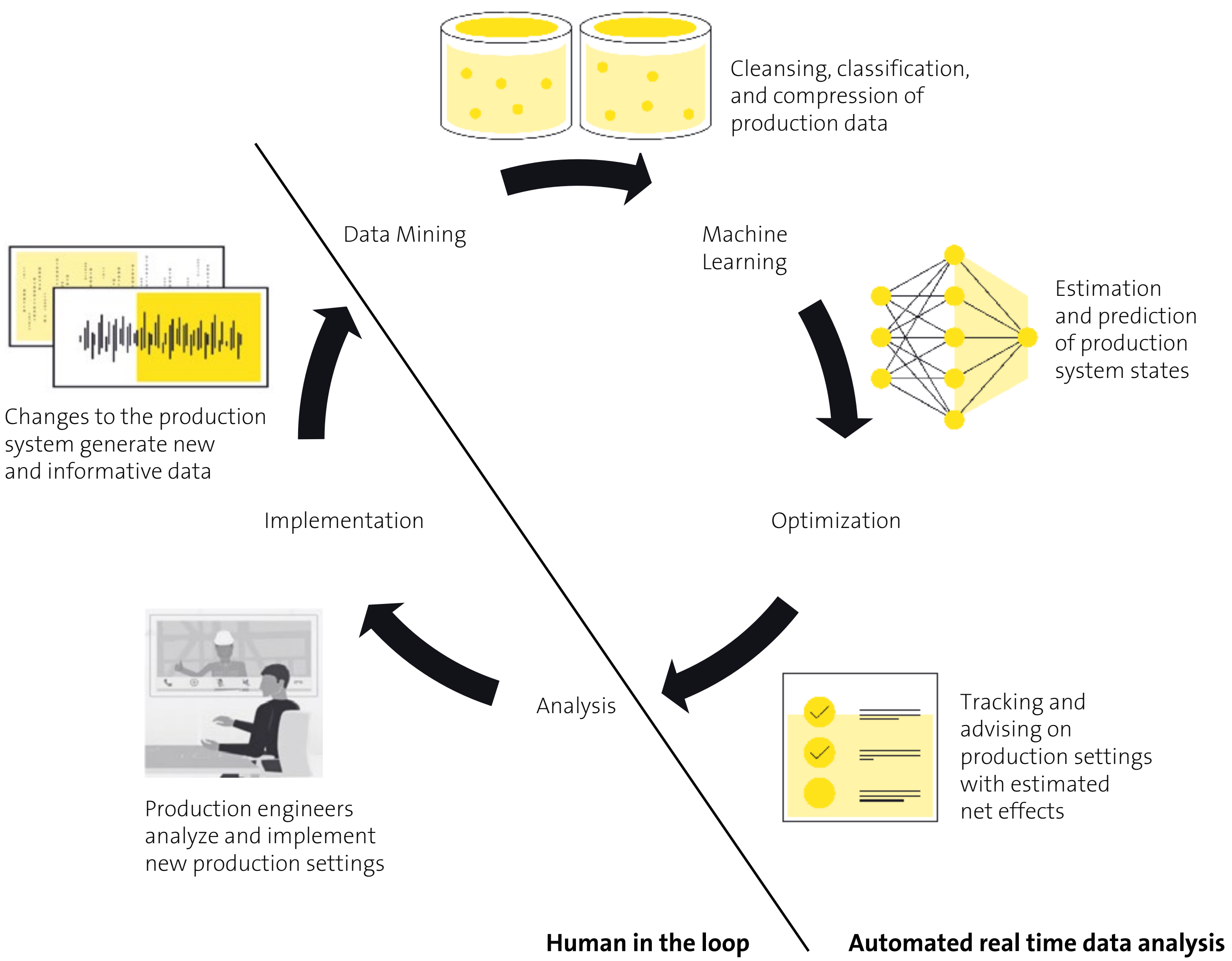


Photo: NTNU

Photo: Solution Seeker



ProductionCompass AI – Real Time Data Mining, Machine Learning and Optimization.

A better image of the subsurface with less use of energy

PGS is conducting research into new types of seismic sources for imaging reservoirs and surrounding rock formations. This can produce better images, which will enable more precise exploration, development and operation of the reservoirs. Furthermore, energy consumption associated with the generation of acoustic waves can be significantly reduced, and the technology can thus help to reduce emissions of CO_2.

Photo: PGS

Ramform Atlas

The oil and gas reservoirs are located far below the seabed. Acoustic waves are used to create images of the reservoirs and surrounding rocks. Acoustic waves, generated by seismic sources just below the sea-surface, propagate through the water column, are reflected at geological interfaces in the subsurface and are measured on their way back to the surface. PGS is researching new types of seismic sources. One of these is the marine vibrator, in which electrical energy is used directly to create vibrations that generate sound waves.

Marine vibrators generate controlled acoustic signals for given frequencies at given times from oscillating surface plates enclosing the vibrator cavity. The surface plates may be made to oscillate synchronously- by changing the enclosed volume for monopole-type of sources, and asynchronously- by moving a fixed enclosed volume for dipole-type of sources. The vibrators can be configured in separate modules covering the whole frequency range for seismic surveys. Given the complementary nature of the dipole- and monopole-type of sources with respect to the sea surface ghost reflections, the two types of sources will be combined to generate seismic waves that propagate only downwards, free of sea surface ghost reflections. This is particularly relevant for preserving the low frequencies of the generated source signal.

A combination of monopole and dipole type of source can be configured to focus the energy on desired subsurface locations where imaging of the geological formations is of the greatest interest. This will secure high-resolution imaging of the subsurface formations, particularly in areas which are

Photo: PGS

difficult to image due to weak penetration/illumination of the signals, for example in the Barents Sea.

In addition to producing better images, the new marine vibrators will use less energy than the air guns currently used for seismic shooting. Such air guns are charged with compressed air generated by compressors. This is a less efficient way of creating acoustic energy. When air is compressed, a lot of heat is generated that needs to be removed, while electric marine vibrators effectively transform electric energy to acoustic energy.

Use of marine vibrators instead of air guns for seismic surveys is expected to offer energy savings of approximately 250 kW per vessel compared with today's consumption. Assuming a 60 per cent work cycle for the year as a whole, total annual energy savings will potentially amount to approximately 1,300 MWh.

Since approximately 0.2 kg oil is needed to produce 1 kWh, the total consumption of oil will be reduced by 260 tonnes per year. Assuming that the combustion of 1 tonne oil generates 3 tonnes carbon dioxide, carbon dioxide emissions can potentially be cut by 780 tonnes. There are uncertainties in the estimated energy consumption of both the current and the new system. The above estimated emission cuts are just for one single production vessel. The marine seismic fleet currently totals 25–30 vessels.

The frequency range for the new electric source system can be controlled and adapted as necessary for imaging of geological formations, generally limited to frequencies smaller than 100 Hz. Air guns have a much wider range and the generated frequency band is more difficult to control. A reduced and well controlled frequency range is perceived as beneficial for fish and mammals.[8]

The new technology is expected to be launched on the market sometime between 2021 and 2023, depending on access to funding.

8 A. J. Duncan at. el, «A modelling comparison between received sound levels produced by a marine Vibroseis array and those from an airgun array for some typical seismic survey scenarios», Marine Pollution Bulletin, Volume 119, Issue 1, 15 June 2017, Pages 277–288.

Electrical shutdown of subsea production wells

Aker Solutions is working together with a number of partners to develop battery-operated electrical systems capable of shutting down subsea oil and gas production wells just as safe, with greater energy efficiency and at lower cost than traditional hydraulic solutions. They will also contribute to higher well availability.

▶ The industry is increasingly focused on finding electrified solutions for subsea development. Aker Solution's electrical actuators are designed to operate subsea valves using locally stored energy from batteries. The systems also include a control element which improves monitoring, reliability and availability, at the same time as the costs of oil and gas installations subsea are reduced.

Aker Solutions will use electrical actuators to reduce the complexity of systems for closing subsea valves. An electrical solution will lessen the need for topside hydraulic systems and remove the need for hydraulic lines in the umbilical, thereby reducing the need for materials.

Today, the valves on subsea wells are controlled by actuators with hydraulics supplied and controlled from the platform through umbilicals. In case of a shutdown, the hydraulic pressure drops, and the valves are forced to a closed position by spring-loaded mechanisms installed on the valves. The solutions that have emerged so far focus on controlling the valves using electric motors, while retaining the mechanical spring to achieve what is referred to as a Fail Safe Close (FSC) shutdown.

Aker Solutions is seeking a solution involving the use of batteries for FSC shutdowns that are capable of using stored energy in a battery to close subsea valves to a safe state, in compliance with all relevant regulations. The main objective is to prove that use of batteries for shutdowns is as safe as a conventional hydraulic/spring mechanism.

The subsea systems are now being placed deeper and further away from the topside based processing plants. This requires longer umbilicals, larger topside platforms and stronger spring-loaded mechanisms on the subsea valves. It also increases the quantity of hydraulic fluid that needs to be stored subsea. This means that the costs of investment escalate significantly, making these field developments not commercially attractive.

The energy needed to build and operate an electrified production well will be comparable to current electro-hydraulic systems, as the equipment and functions will be similar. Material consumption and CO_2 emissions will also be comparable for the two systems.

The technology is intended to make the all-electric system more reliable, more cost and energy efficient, and improve performance compared with the systems used today. In addition to lower energy consumption, costs savings of up to 40 per cent by using all-electric subsea systems can be expected for large operators. This can also open up possibilities for recovery from more marginal fields. Furthermore, it eliminates the risk of hydraulic leakages. The technology will also reduce the risk of a major accident on the Norwegian shelf, through continuous monitoring.

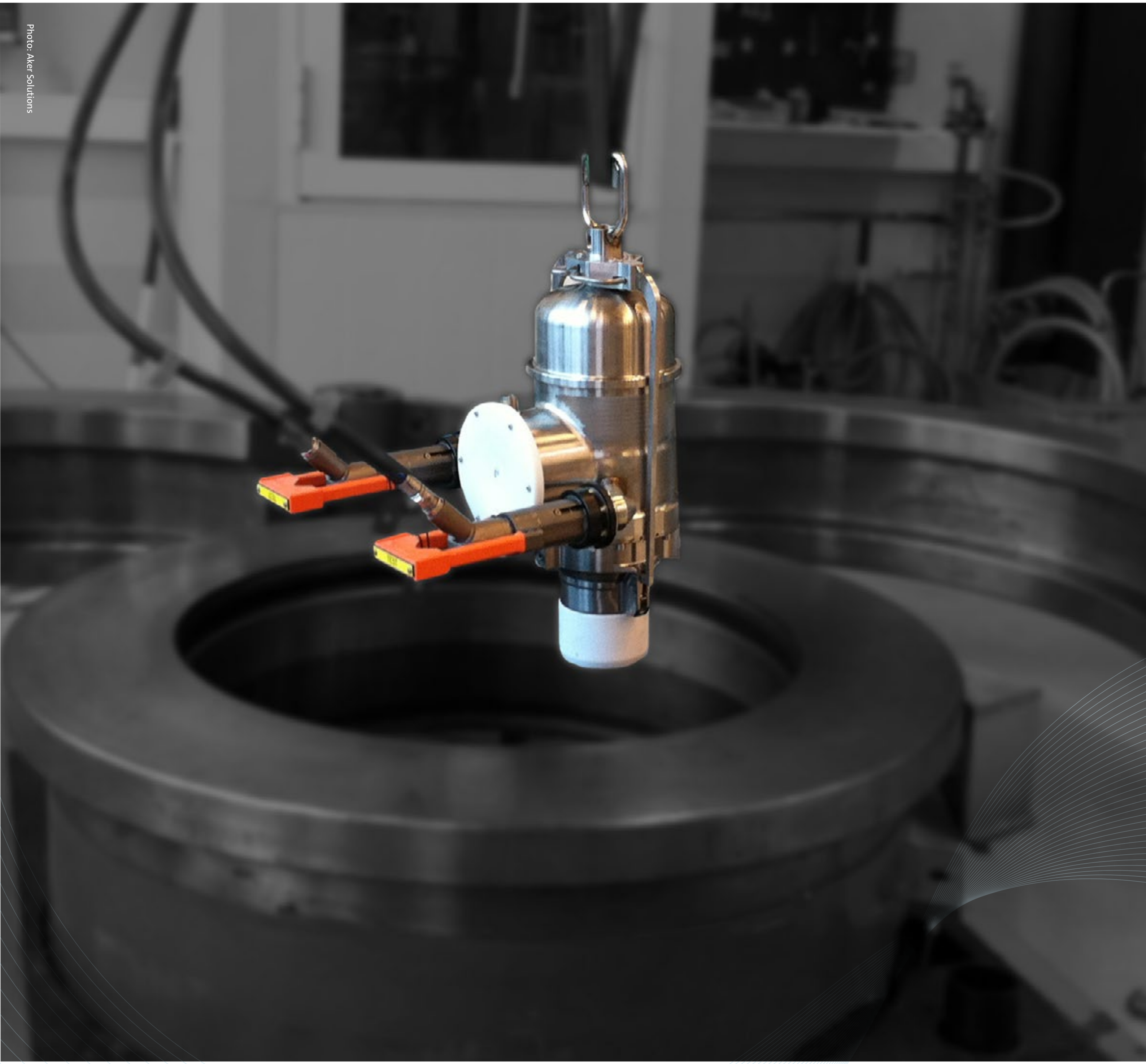


Photo: Aker Solutions

Offshore hydrogen technology – for a CO_2-free and stable energy supply

The ocean offers great opportunities for sustainable economic development in Norway, and floating wind power has a great potential for increasing the share of renewable energy globally. In Norway, the most favourable wind resources are found far from shore, where fossil energy consumption is high on offshore facilities and in the maritime sector.

▶ An alternative energy supply to offshore facilities based on offshore wind power has a potential for significant reductions in emissions from the Norwegian continental shelf. However, the variation and unpredictability associated with offshore wind poses major challenges in achieving a stable energy supply to the offshore facilities.

TechnipFMC is developing solutions for stable offshore energy production based on hydrogen technology in combination with floating wind turbines. These solutions offer a stable local energy supply in the form of electricity or hydrogen, or a combination of the two. This can supply CO_2-free and stable energy to offshore facilities and the maritime sector. Hydrogen is produced offshore by electrolysis of purified and desalinated seawater and stored on the seabed in large enough quantities to supply energy for an extended period – during times and seasons of little wind or in the event of planned or unforeseen stops of a gas turbine or a diesel generator. The hydrogen can be re-electrified in fuel cells when needed or it can be blended with natural gas to fuel existing gas turbines.

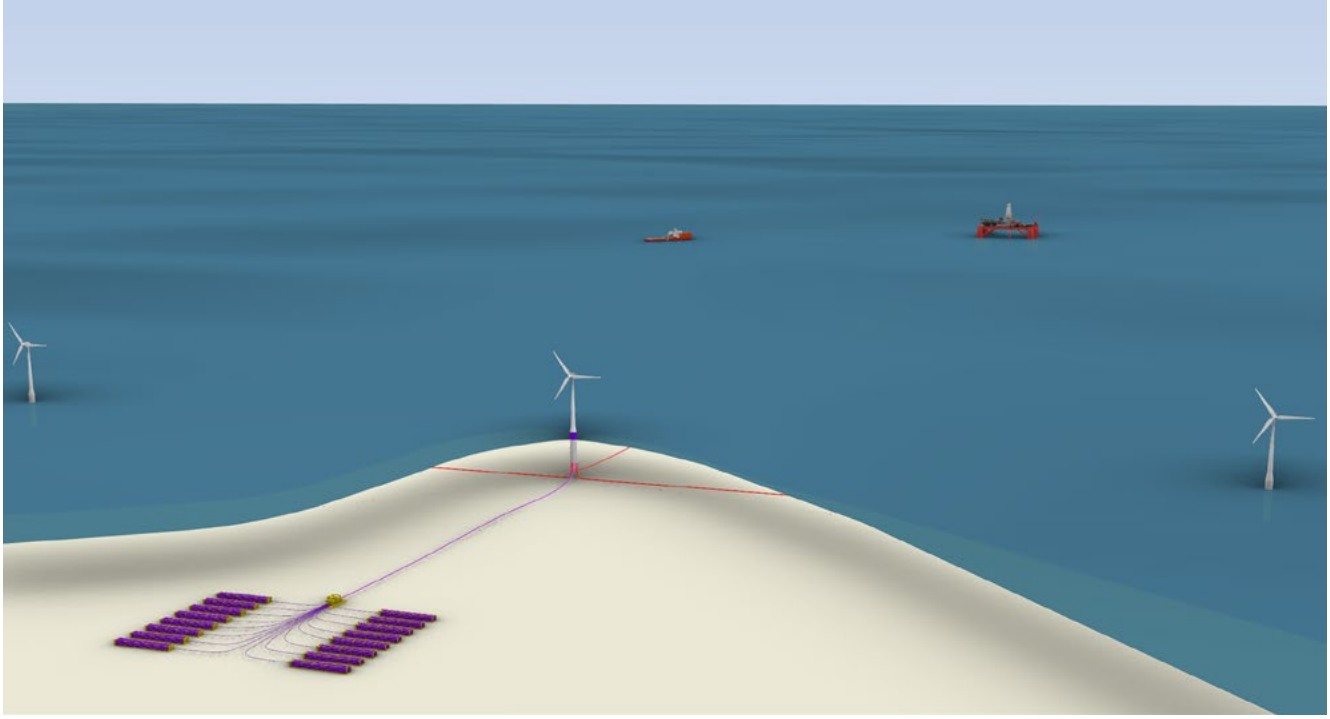
The same technology can be used for offshore production of hydrogen for storage and transport by pipeline to shore, and for providing a stable, emission-free fuel supply to hydrogen-powered express boats, ferries and other consumers. The solution includes infrastructure for supplying hydrogen to ports and areas near the coast. The wind farm can be established far out at sea, where there is ample space and optimum wind resources, where they cannot be seen from shore and have no impact on bird life along the coast. The hydrogen is stored on the seabed without occupying valuable port areas, at a safe distance from populated areas.

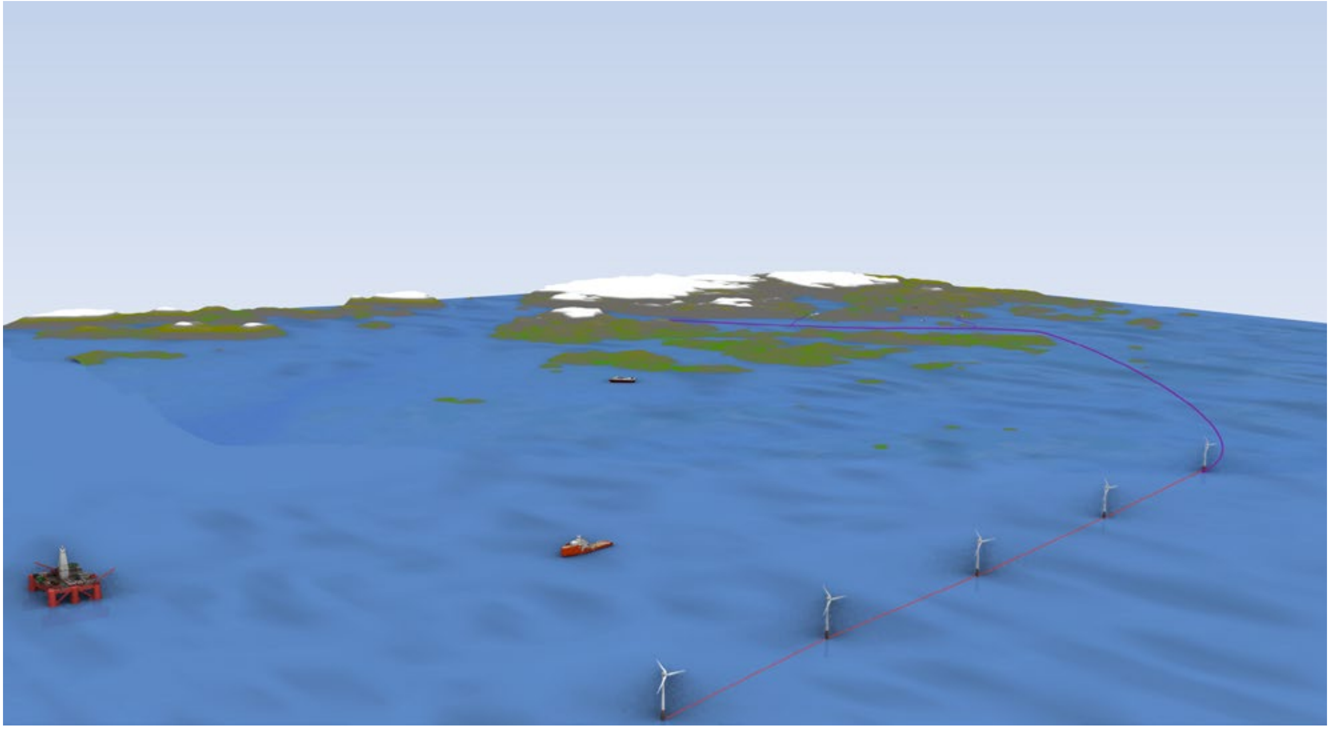
A combination of offshore wind and large hydrogen storage facilities to handle seasonal wind variations will enable significant cuts in CO_2 emissions beyond what can be achieved by an offshore wind farm alone. Such a stable power supply offers high regularity, optimum operation of remaining gas turbines and reduced need for installed effect of the wind farm. Furthermore, local and stable energy production does not depend on distance to shore or the energy market's electricity tariffs. The combination of floating wind turbines, offshore hydrogen production and subsea storage reduces the need for infrastructure, thereby reducing capital costs and increasing profitability.

The Deep Purple project is part of the Research Council's ocean technology initiative and is conducted in collaboration with SINTEF, Subsea Valley and Maritime Association Sogn & Fjordane. The project aims to bring the concepts to validated solutions through testing and other research activities related to the main challenges. The project's primary focus is on hydrogen safety and autonomous, cost-effective, scalable system solutions adapted for industrial manufacture. The tests will emphasise environmental impacts, onshore-to-offshore technology transfer and testing of offshore technology with hydrogen.

The development of an offshore hydrogen value chain in Norway, based on combining existing technology and competence in the field of oil and gas with Norwegian hydrogen expertise, will create great opportunities for domestic value creation and job creation. Development of the technology will also create opportunities for supplying global markets, so that stable, renewable wind-based and solar energy is made available to populated coastal areas worldwide.

Illustration: TechnipFMC





Projects included in the analysis
PETROMAKS/PETROMAKS 2

Key

- Energy efficiency
- Lower emissions to air
- Electrification
- Other

PETROMAKS/PETROMAKS 2 projects with a potential for energy efficiency / lower emissions to air

Project	Project owner	Project title	Energy efficiency	Lower emissions to air	Electrification	Other
282311	TechnipFMC AS	Deep Purple – CO_2-fri hydrogenbasert offshore energiproduksjon til installasjoner og maritim sektor		x	x	x
281986	Prototech AS	Innovative hybrid energy system for stable power and heat supply in offshore oil and gas installation	x	x		x
281980	EARTH SCIENCE ANALYTICS AS	Machine learning in geoscience		x		
281927	Westad Industri AS	Additive manufacturing for repair and refurbishment of offshore components to extend structural lifetime	x	x		
281917	AKER SOLUTIONS AS	Certified battery shut down system		x	x	
281881	LEDAFLOW TECHNOLOGIES DA	Accurate multiphase flow predictions for long tiebacks and subsea developments	x			
281855	OLIASOFT AS	Muliggjøre autonom brønnplanlegging ved å integrere alle myndighetspålagte beregninger for brønndesign i en integrert plattform.	x	x		
281848	STIMLINE AS	Real-Time Remote and Autonomous Well Intervention On Normally Unmanned Installations	x			
281810	PGS GEOPHYSICAL AS	Improved Subsurface Resolution by Controlled Marine Seismic Stimulation	x	x	x	
280942	SINTEF AS	Advanced laboratory methods for cuttings analyses	x			
280934	STIFTELSEN SINTEF	Autonomous subsea intervention (SEAVENTION)	x	x		x
280713	SINTEF ENERGI AS	Compact Offshore Steam Bottoming Cycles Phase 2: COMPACTS2		x		
280705	STIFTELSEN SINTEF	Improved lifetime estimation of mooring chains	x			x
280650	SINTEF AS	Shale Barrier Toolbox: Designing future wells for efficient completion and simpler P&A	x	x		x
280610	SINTEF AS	Enabling non-disruptive production conditions – slug flow with surfactants	x	x		
279249	SINTEF AS	PIRE: Multi-scale, Multi-phase Phenomena in Complex Fluids for the Energy Industries	x	x		
269415	SUBSEA 7 NORWAY AS	Arctic Subsea Processing System	x	x		
269349	MARINE ALUMINIUM AS	Lightweight Offshore Condenser Skid		x		

Project	Project owner	Project title				
269246	EMPIG AS	ACS: Always-clean Cooling System	📊	☁		✓
269212	SHAWCOR NORWAY AS	High temperature thermal insulation for deepwater pipelines	📊			
269193	DNV GL AS	Wind-powered Water Injection (WIN WIN)	📊	☁	💡	✓
269178	WESTERNGECO AS	Production optimization by exploiting new technologies for look-ahead geosteering and completion design while-drilling	📊			
268216	UNIVERSITETET I BERGEN	Nanoparticles to Stabilize CO_2-foam for Efficient CCUS in Challenging Reservoirs	📊	☁		
267669	NORGES TEKNISK-NATURVITEN-SKAPELIGE UNIVERSITET NTNU	A Multidisciplinary Approach to Characterize Coalescence in Petroemulsions	📊			
267620	INSTITUTT FOR ENERGITEKNIKK	SUM – Scaling and Uncertainty Modelling in multiphase production	📊			
267651	SINTEF AS	Voltage on casing for improved well cement quality	📊	☁		✓
267615	NORGES TEKNISK-NATURVITEN-SKAPELIGE UNIVERSITET NTNU	Carbon Membranes for CO_2 Removal from High Pressure Natural Gas in Subsea Process	📊	☁		
262516	WISUB AS	Universal AUV Pinless Charging and Data Transfer Interface	📊	☁	💡	
262510	4SUBSEA AS	Flexible Pipe Pressure Liner Life Extension Tool	📊			✓
262483	IRIS-SOFTWARE AS	Improved modelling of near well multiphase flow for optimised planning of ICD/AICD valves in production wells	📊			✓
256573	HALFWAVE AS	ART – Crack Detection		☁		✓
256533	INFLOWCONTROL AS	Smarte gassbrønner med autonom innstrømningskontroll	📊			
256522	TRELLEBORG OFFSHORE NORWAY AS	Next generation polymer based thermal insulation material	📊			
256507	NEXANS NORWAY AS	Next Generation Electrical Heating for Flow Assurance	📊		💡	
256479	TYPHONIX AS	Development of a Low Shear Polymer Flow Control Technology		☁		✓
256425	STATOIL PETROLEUM AS	Offshore Wind integration with the stand-alone electric grid at Oil and Gas Offshore Installations		☁	💡	✓
256406	HEAVELOCK AS	HEAVELOCK: MULIGGJØR MPD FRA FLYTENDE RIGGER	📊	☁		
256341	AARBAKKE INNOVATION AS	Micro-Tube Removal tool (MTR)	📊	☁		
255507	NORGES TEKNISK-NATURVITEN-SKAPELIGE UNIVERSITET NTNU	Durable Arctic Icephobic Materials (AIM)	📊			
255418	SINTEF AS	Reduced uncertainty in overpressures and drilling window prediction ahead of the bit	📊			
255348	HØGSKOLEN I SØRØST-NORGE	Sensors and models for improved kick/loss detection in drilling (Semi-kidd)	📊			✓
255174	NORGES TEKNISK-NATURVITEN-SKAPELIGE UNIVERSITET NTNU	New Strategy for Separation of Complex Water-in-Crude Oil Emulsions: From Bench to Large Scale Separation	📊			✓
255170	INTERNATIONAL RESEARCH INSTITUTE OF STAVANGER AS	Leakage risk assessment for plugged and abandoned oil & gas wells		☁		
245606	DNV GL AS	Affordable Composites in the oil and gas industry	📊	☁		

Key: Energy efficiency · Lower emissions to air · Electrification · Other

Project	Project owner	Project title				
245589	4SUBSEA AS	Flexibles Pipe Corrosion Monitoring	●			●
245587	WESTERNGECO AS	Integrated dynamic drilling hazard identification	●			
245574	INNOWELL SOLUTIONS AS	Ny selvreguerende innstrømningsventil for olje og gassbrønner	●	●		●
245554	PGS GEOPHYSICAL AS	Broadbanded Environmentally friendly Seismic Source	●	●	●	
245532	GOE-IP AS	Microbial Water Diversion Technology for Enhanced Oil Recovery in Sandstone and Carbonate Reservoirs	●			
245489	Prototech AS	Clean, Highly Efficient Offshore Power	●			
245408	TYPHONIX AS	Chokeseparator – Single Well Production	●			
245359	INTERNATIONAL RESEARCH INSTITUTE OF STAVANGER AS	Micro Sonde Well Logging System	●			
245228	LEDAFLOW TECHNOLOGIES DA	Next generation flow assurance models for wells and risers in LedaFlow	●			
244615	RISE PFI AS	Green high performance systems for Enhanced Oil Recovery	●			●
244570	STIFTELSEN NORSAR	Real-time Reservoir Monitoring Integrated with Stress Field Modelling to Allow for Early Detection of Deformations and Leakages		●		●
244205	UNIVERSITETET I AGDER	Off-shore-On-shore Collective Analytics & Intelligence for condition-based monitoring in drilling & operations using heterogeneous networks	●		●	●
244068	NORGES TEKNISK-NATURVITENSKAPELIGE UNIVERSITET NTNU	Field life extension through controlling the combined material degradation of fatigue and hydrogen (HyF-Lex)	●	●		●
235440	ECOTONE AS	New technology and methods for mapping and monitoring of seabed habitats	●	●		
235366	C6 TECHNOLOGIES AS	Advanced Composite Well Intervention Rod for Extended Operating Environments	●		●	
235317	SOLUTION SEEKER AS	Decision support for production optimization	●	●		
235254	VISURAY AS	3D Cement Evaluation in new and old wells using novel X-ray tomography		●		
235245	BADGER EXPLORER ASA	Research and Development of Downhole High Power (Ultra)Sonic Technologies and Applications	●	●		●
235238	RESMAN AS	A unit for automatic detection and reduction of produced water	●	●		●
235233	INTERWELL TECHNOLOGY AS	Nytt konsept for plugging av brønner	●	●		●
234162	STIFTELSEN TEL-TEK	Improving Efficiency of Offshore Drill-cuttings Handling Process	●			●
234161	SINTEF PETROLEUM AS	Hole Cleaning Performance of Oil and Water based Drilling Fluids in Circular and Non-Circular Boreholes	●	●		●
234131	INTERNATIONAL RESEARCH INSTITUTE OF STAVANGER AS	Three-Phase Capillary Pressure, Hysteresis and Trapping in Mixed-Wet Rock	●	●		●
234130	NTNU FAKULTET FOR INGENIØRVITENSKAP OG TEKNIKK	Hydrogen-induced degradation of offshore steels in ageing infrastructure – models for prevention and prediction (HIPP)		●		●
234122	INSTITUTT FOR ENERGITEKNIKK	Condition monitoring tool for separators based on combined use of tracer technology and multiphase flow modeling	●			●

Project	Project owner	Project title				
234115	STIFTELSEN SINTEF	Thermo Responsive Elastomer Composites for cold climate application		☁		✓
234112	NTNU FAKULTET FOR NATURVITEN-SKAP OG TEKNOLOGI	Improved Mechanisms of Asphaltene Deposition, Precipitation and Fouling	📊			✓
234111	UNI RESEARCH AS	VOM2MPS: from virtual outcrop models to multipoint statistics training images for improved reservoir modelling	📊	☁		✓
234110	STIFTELSEN SINTEF	Knowledge basis for repair contingency of pipelines		☁		✓
234108	NTNU FAKULTET FOR INGENIØR-VITENSKAP OG TEKNIKK	Next Generation Subsea Inspection, Maintenance and Repair		☁		✓
234074	SINTEF PETROLEUM AS	Shale rock physics: Improved seismic monitoring for increased recovery	📊	☁		✓
233947	SINTEF ENERGI AS	Compact Offshore Steam Bottoming Cycles	📊	☁		
228599	NORGES TEKNISK-NATURVITEN-SKAPELIGE UNIVERSITET NTNU	Nano-enabled Sustainable Cement Sheath Behind Casings		☁		✓
228513	STIFTELSEN SINTEF	Fundamental studies of materials behaviour for future cold climate applications	📊	☁		✓
228400	NORGES TEKNISK-NATURVITEN-SKAPELIGE UNIVERSITET NTNU	Geophysical methods for subsurface imaging and monitoring		☁		
228391	INTERNATIONAL RESEARCH INSTITUTE OF STAVANGER AS	«English: Advanced Wellbore Transport Modelling Norsk: Avansert modellering av trasport i oljebrønnen»	📊	☁		✓
228357	UNIVERSITETET I BERGEN	Modelling and inversion of seismic waveform and electromagnetic data using integral equation methods		☁		✓
228344	SINTEF ENERGI AS	High Voltage Subsea Connections	📊	☁	💡	✓
228222	INSTITUTT FOR ENERGITEKNIKK	Increased Knowledge of Localized Internal Corrosion in Pipelines		☁		✓
228105	NORGES GEOLOGISKE UNDERSØKELSE	NEONOR2 Neotectonics in Nordland – Implications for petroleum exploration		☁		
226160	HAUGALAND KUNNSKAPSPARK AS	Improved safety and efficiency in O&G operations by developing superhydrophobic nanotechnology for passive anti-icing protection.	📊			✓
226009	HAMMERTECH AS	AquaWell Permanent Downhole Water Fraction and Salinity Measurement	📊			✓
225965	BERGEN TECHNOLOGY CENTER AS	Ultrasonic spatial imaging and flow measurement through casing for assessment of cement condition and well integrity		☁		✓
225958	TYPHONIX AS	Enhanced oil recovery by reduced mechanical degradation of polymers	📊	☁		
225926	WISUB AS	MicroWave communication for high performance wet-mate subsea connectors		☁	💡	✓
225922	IMPACT TECHNOLOGY SYSTEMS AS	«Enhanced oil recovery by pressure stimulation employment – Method proposed by Impact Technology Systems AS»	📊	☁		
224878	UNIVERSITETET I BERGEN	Reservoir Scale Simulation of Hydrate Dynamics		☁		
217234	NORTEK AS	Sanntids Undervanns Trådløst Sensornettverk for å Overvåke Isdrift i Nordområdene	📊			

Key: Energy efficiency | Lower emissions to air | Electrification | Other

Project	Project owner	Project title				
217233	PRO ANALYSIS AS	Robust anti-fouling and cleaning technology for optical windows enabling maintenance-free subsea operation of optical instrumentation	●			●
217223	ELECTROMAGNETIC GEOSERVICES ASA	Next generation CSEM inversion and modelling		●		●
217211	STATOIL PETROLEUM AS	Development of an Osmotic Membrane Pressure Actuator for Enhanced Oil & Gas Recovery	●			●
215665	SINTEF IKT AVD OSLO	Flow diagnostics on stratigraphic and unstructured grids	●			
215584	SINTEF Energi AS	Pressure Tolerant Power Electronics for Subsea Oil and Gas Exploitation	●		●	●
215577	INTERNATIONAL RESEARCH INSTITUTE OF STAVANGER AS	Reservoir data assimilation for realistic geology	●	●		●
215563	Institutt for kjemisk prosessteknologi	A Combined Surface-Colloid Chemical and Rock-Fluid Interaction Approach towards more Efficient Enhanced Oil Recovery Strategies	●			
210432	NTNU	Intelligent Drilling–Automated Underbalanced Drilling Operations	●			
208677	Typhonix AS	Low shear centrifugal pump for produced water applications	●	●		●
208526	Iris-Software AS	Energy Efficiency of Field Development: IOR, System Analysis and Risk Evaluation	●			
207661	IRIS	Water weakening of chalk at realistic reservoir conditions	●			●
207538	NTNU	Increased energy savings in water/oil separation through advanced fundamental emulsion paradigms	●	●		
207537	IFE	Improved Glycol Loop Operation	●	●		●
206989	SINTEF Materialer og kjemi	High Pressure Gas Liquid Separation – II	●	●		
206976	SINTEF Energi AS	Fundamental understanding of electrocoalescence in heavy crude oils	●	●		●
203404	Teknova AS	Optimization of electrical energy production in offshore installations	●	●	●	
203310	SINTEF Energi AS	Energy efficiency in offshore oil and gas production	●	●		
203284	Iris-Software AS	Automated drilling fluid processing	●			●
200714	Wireless Instrumentation Systems AS	Wireless communication and power generation for Downhole Wireless Retrofit Instrumentation	●	●		
200665	Hole in One Producer AS	Hole in One Producer Prototype	●	●		
200624	IFE	Shut-in and Restart of Waxy Crude Pipelines: Software Module Development	●			
200600	IRIS	Optimizing Water Chemistry for Enhanced Oil Recovery	●			●
200593	SINTEF Petroleumsforskning AS	Non-circular wellbores – a new dimension in well construction	●	●		
200553	Schlumberger Norge AS	Miljøteknologi for fremtiden – Automatisert EPCON CFU system	●			
200548	Smartmotor AS	Innovative efficient and survivable electric drive systems for subsea and downhole applications	●		●	●
200500	Badger Explorer ASA	Drilling in a Closed Cavity near Pore Pressure	●	●		●

Project	Project owner	Project title				
200492	ResMan AS	Design konsept for miljøvennlige sporstoffer og matrikssystemer for permanent monitorering av innstrømming i brønner	📊	☁		✓
200455	SINTEF Materialer og kjemi	Acid Gas Removal with no damaging Effect on the Environment in offshore applications	📊	☁		
193134	NTNU	Improved imaging, mapping and monitoring of hydrocarbon reservoirs		☁		
193108	SINTEF IKT	High Temperature Power Electronic Packaging	📊			
193062	SINTEF Energi AS	Enabling low-emission LNG systems – Fundamentals for multilevel modeling	📊	☁		
192974	Typhonix AS	Development of a subsea Typhoon Valve	📊			✓
192967	SINTEF Materialer og kjemi	Deep water repair welding and hot tapping	📊	☁		✓
192950	eDrilling Systems AS	Complex Operations Control	📊	☁		
188981	eDrilling Systems AS	eDrilling Qualification and Demonstration	📊	☁		
187391	IRIS	Water Weakening of Chalk – Physical and Chemical Processes	📊			✓
187389	SINTEF Materialer og kjemi	Arctic Materials – Materials technology for safe and cost-effective exploration and operation under arctic conditions	📊	☁		✓
187320	Seabed Rig AS	Development of Seabed Drilling Rig, Co-operation with Universities	📊	☁	💡	
180038	SINTEF Materialer og kjemi	SMOOTHPIPE: Applied Surface Technology for Multiphase Pipelines	📊	☁		
179790	Seabed Rig AS	Development of Seabed Drilling Rig, Phase 1	📊	☁	💡	
176611	SICOM AS	SmartPipe – Self diagnostic pipelines and risers for future integrated process management				✓
176137	IFE	Liquefaction of Unprocessed Well-Stream	📊			
176134	SINTEF Energi AS	Electrical Insulation Materials and Insulation Systems for Subsea High Voltage Power Equipment	📊	☁	💡	✓
176025	SINTEF Energi AS	Feasible power electronics for demanding subsea applications	📊	☁	💡	✓
176024	SINTEF Energi AS	Electric power systems for subsea processing and transportation of oil and gas	📊	☁	💡	✓
176018	IRIS	E-centre laboratories for automated drilling processes	📊			✓
175997	Typhonix AS	Development and testing of a new low shear valve concept	📊	☁		✓
175968	Universitetet i Bergen	CO_2 Injection For Stimulated Production Of Natural Gas		☁		
175918	SINTEF Materialer og Kjemi	Reducing the Environmental Impact of Acid Gas Cleaning Technology	📊			✓
174036	Eureka Pumps AS	Underwater ElectroMagnetic Sensorsystem	📊	☁	💡	✓
169477	NTNU – Institutt for kjemisk prosessteknologi	High Pressure Gas Liquid Separation	📊	☁		
169466	SINTEF Energi AS	Electrocoalescence – Criteria for an efficient process in real crude oil systems	📊	☁		✓
169439	Axon Norway AS	Drilling optimization in Real Time	📊	☁		✓

Key: Energy efficiency · Lower emissions to air · Electrification · Other

Project	Project owner	Project title	Energy efficiency	Lower emissions to air	Electrification	Other
169429	Institutt for energiteknikk	Optimisation of Glycol Loop Design and Operation	✓	✓		✓
169381	Seabed Rig AS	Feasibility Study regarding a Subsea Drilling Module	✓	✓	✓	
169293	Seabox AS	SWIT – Subsea water injection and treatment	✓			
168284	Remora AS	Model Test – HiLoad LNG Regas Terminal		✓		
168274	Statoil	Compressed Energy Technology		✓		
168159	SINTEF Petroleumsforskning	Prediction of deposition and transport of sand in sand-liquid flows (STRONG)	✓			✓
163253	Badger Explorer ASA	Badger Explorer Prototype	✓	✓		✓
156662	Statoil ASA – Trondheim	Compact LNG Heat Exchangers	✓	✓		
146710	SINTEF Energi AS	Eletrocoalescence – Droplet-droplet interaction and coalescence in eletric fields and turbulent flow – eksperiments and modelling	✓	✓		✓
143992	Norges teknisk-naturvitenskapelige universitet – NTNU	High Pressure Gas SEparation (HiPGaS)	✓	✓		
Total	**156**	**Numbers**	**127**	**100**	**22**	**77**

Key

- Energy efficiency
- Lower emissions to air
- Electrification
- Other

Projects included in the analysis **DEMO 2000**

DEMO 2000 projects with a potential for greater energy efficiency / lower emissions to air

Project	Project owner	Project title				
282158	TOOLSERV AS	Completion time saving tool	Energy efficiency			
282122	SUBSEA CHOKES INTERNATIONAL AS	Pilottest av undervanns elektrisk aktuator	Energy efficiency		Electrification	
282115	NOV PROCESS & FLOW TECHNOLOGIES AS	Kinetic Hydrate Inhibitor Removal, Recovery and Reuse from Produced Water and Rich MEG Streams	Energy efficiency			Other
282085	FORCE TECHNOLOGY NORWAY AS	Development of a Field Gradient Sensor (FiGS®) for autonomous subsea vehicles	Energy efficiency	Lower emissions to air		
282036	KONGSBERG DIGITAL AS	Digitized Fluid Transport	Energy efficiency			
282027	BENESTAD SOLUTIONS AS	HV Wet Mate Connection System (WMCS)	Energy efficiency	Lower emissions to air	Electrification	
282016	NATIONAL OILWELL VARCO NORWAY AS	PowerBlade Hybrid	Energy efficiency	Lower emissions to air		
281998	PETRELL A/S	Advanced Lower Completion Tool	Energy efficiency			
281939	SCHLUMBERGER INFORMATION SOLUTIONS AS	HD-technology for Steeply Inclined and Vertical Flow: Production Optimization for Wells, Risers and Pipelines	Energy efficiency			Other
272135	IKM TECHNOLOGY AS	Variabel oppdrift	Energy efficiency			
272129	GEOMEC HOLDING AS	Geomechanical software for multi-well injection optimisation of complex fields	Energy efficiency			Other
272126	REELWELL AS	RDM-C Reelwell Liner- and Casing Drilling	Energy efficiency	Lower emissions to air		Other
272124	XSENS AS	Advanced non-invasive subsea and topside flow meter	Energy efficiency	Lower emissions to air		
272095	ABB AS	Subsea Power System Integration and Shallow Water Testing – Joint Industry Project	Energy efficiency	Lower emissions to air	Electrification	
272003	NORSE OILTOOLS AS	Downhole Swarf Collection Tool	Energy efficiency			
269440	SOLUTION SEEKER AS	Demonstration of data-driven software for daily production optimization	Energy efficiency			
269339	COREALL AS	Prototype Development and Testing of Internal Drilling Device for ICS	Energy efficiency			
269324	FUGLESANGS SUBSEA AS	Omnirise Singlephase Boosting Pump, without Barrier Fluid and with internal Variable Speed Drive	Energy efficiency			Other

Key: Energy efficiency · Lower emissions to air · Electrification · Other

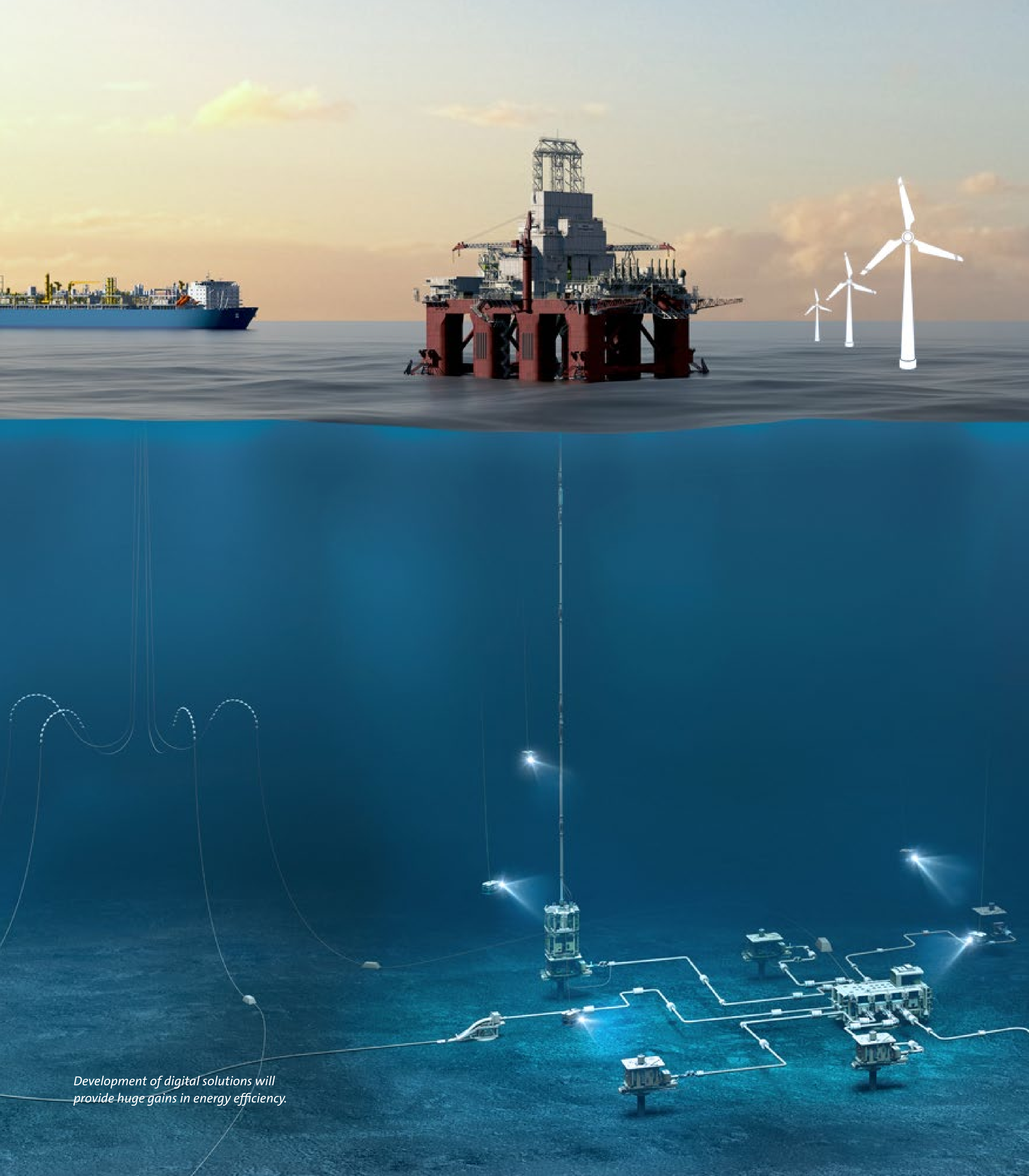
Project	Project owner	Project title	Energy efficiency	Lower emissions to air	Electrification	Other
269317	WELL ID AS	Superior Well Caliper	✓	✓		✓
269314	NATIONAL OILWELL VARCO NORWAY AS	AutoViscosity	✓	✓		
269300	INTERNATIONAL RESEARCH INSTITUTE OF STAVANGER AS	CHEmical Control Knowledge demonstration project: Monitoring And Treatment Enhancement	✓			✓
269242	HI FLO AS	Qualification testing of dual plate check valve with rising stem override	✓			
269225	AKER SOLUTIONS AS	Subsea CFU Pilot	✓	✓		✓
269119	ELDOR TECHNOLOGY AS	AlarmTracker – Demo2000	✓	✓		
269102	SUBSEA CHOKES INTERNATIONAL AS	Offshore pilot test of Choke valve	✓			
269066	MHWIRTH AS	DEAL med Smartmoduler – Automatiserte og samhandlende kontrollsystemløsninger for økt bore-effektivitet	✓	✓		
259250	FUTURE TECHNOLOGY AS	Kostnadseffektiv, miljøvennlig og kontrollerbar subseakjøler – FSCC	✓			✓
259245	INTERWELL P&A AS	Utvikle en brønnbarriere for bruk i forbindelse med permanent nedstengning av brønner (P&A) som kan realiseres uten en boreinnretning	✓			
259235	INNOVA AS	Subsea Hydraulic Power Unit			✓	✓
259195	SCANWELL TECHNOLOGY AS	Produksjonsoptimalisering og integritetsovervåkning av gassløft-brønner	✓	✓		
259155	KONGSBERG DIGITAL AS	Cost effective management of hydrates and wax with LedaFlow	✓			
259145	PGS GEOPHYSICAL AS	Continuous Shooting, Recording and Imaging of seismic data	✓			
258997	ABB AS	Technical Qualification of the next generation subsea control and auxiliary system – Joint Industry Project	✓	✓	✓	
258943	WEST DRILLING PRODUCTS AS	Demonstrate CMR superior drilling performance and value case (cost reduction by 30–50%)	✓	✓	✓	✓
258925	ABB AS	Demonstration of technology for cost efficient and reliable operation of electrically driven gas compressors	✓	✓	✓	
256588	SEABOX AS	Building and testing of a fully qualified subsea system prototype for production of Sulphate free or low salinity water	✓			✓
256553	FMC KONGSBERG SUBSEA AS	eSpring – electrically powered actuator for fail-safe-close applications	✓		✓	✓
256548	MINOX TECHNOLOGY AS	Compact unit for gas dehydration	✓			
256460	HUISMAN NORGE AS	Drilling Mud Process Control	✓			
256335	ABB AS	Technical Qualification of a pressure compensated subsea switchgear – Joint Industry Project – for Statoil	✓	✓	✓	
248886	SEKAL AS	Wired Pipe adaption for DrillTronics to take full advantage of wired pipe data to provide precise estimations even for highly complex wells	✓	✓		✓
248881	NOV SUBSEA PRODUCTS AS	Subsea Automated Pig Launcher Qualification	✓	✓		
248854	CANRIG ROBOTIC TECHNOLOGIES AS	Offshore Pilot of Drill Floor Robot at North Sea Semi-Submersible	✓	✓	✓	

Project	Project owner	Project title				
248844	AKER SOLUTIONS AS	System Integration Pilot and Qualification of New Subsea Products	📊	☁		
245324	SUBSEA CHOKES INTERNATIONAL AS	Instrumented Subsea Choke Valve – Pilot	📊			
245255	TechnipFMC	Reactive Flex Joint	📊			
245251	CALORA SUBSEA AS	Qualify, Verify and Demonstrate Robust Synthetic Mooring Lines with Calorfloat Cut-Resistant Jacket (CALORMOOR)	📊	☁		✓
245244	COREALL AS	Development and Testing of Intelligent Coring System with Measurement While Coring	📊			
239129	ELECTROMAGNETIC GEOSERVICES ASA	Next Generation CSEM Equipment Field Test. A demonstration / pilot project of the next generation CSEM technology prototype		☁		✓
239118	OIL TOOLS OF NORWAY AS	Downhole Umbilical Release Assembly Pilotering Prosjekt i DEMO2000	📊	☁		
239096	DEEPOCEAN AS	Demonstrasjon av intelligent inspeksjons-ROV		☁		✓
239084	SEABOX AS	Technology for removal of Sulphate and Salts from seawater at the seabed. SWIT sul/sal	📊			
239044	TYPHONIX AS	Qualification and Demonstration of a Subsea Typhoon Valve	📊			✓
235322	FISHBONES AS	Dreamliner pilot well qualification for Smørbukk Sør application	📊	☁		✓
235300	PETROTECH AS	New technology in downhole mapping will provide enhanced recovery solutions, huge cost reductions and reduced environmental impact	📊	☁		✓
235244	E PLUG AS	Prototypefremstillelse, FAT og kvalifisering av 5 1/2" mekanisk brønnplugg med tilhørende elektrisk manipulajsonsverktøy for flere settinger	📊			✓
226170	ENHANCED DRILLING AS	RID – Riser Isloation Device	📊	☁		
226054	COMPUTAS AS	Enterprise IO Collaboration		☁		
226039	WEST DRILLING PRODUCTS AS	Build Pilot of CMR Automated Drill Floor(ADF)	📊	☁	💡	✓
225952	REELWELL AS	ERD Beyond 20 km – Phase 2 – Demo phase	📊	☁		✓
225913	TOMAX AS	The Afterburner development project	📊	☁		✓
225875	FISHBONES AS	Fishbones Consolidated Chalk Project including pilot well installation	📊	☁		✓
225828	PARTNER PLAST AS	Full scale verification of float steering and positioning system for seismic gun arrays	📊	☁		
225816	KONGSBERG OIL & GAS TECHNOLOGIES AS	The Qualification and Demonstration of the Subsea Storage Unit (SSU) Technology	📊	☁		✓
220938	ENHANCED DRILLING AS	System qualification and pilot testing of ORS' Low Riser Return System	📊	☁		
220924	RESONATOR AS	Resonator high frequency electrified hammer for cost efficient well intervention and percussion drilling	📊	☁	💡	
220923	WEST DRILLING PRODUCTS AS	Build Pilot of Continuous Drilling and Circulation Unit (CDU)	📊	☁	💡	✓
215664	FMC Kongsberg Subsea	The Development and Qualification of a Compact Subsea Oil/Water Separation System	📊	☁		
215631	West Drilling Products AS	Build Pilot of CMR Rig at Ullrigg Test Centre	📊	☁	💡	✓

Key: Energy efficiency · Lower emissions to air · Electrification · Other

Project	Project owner	Project title	Energy efficiency	Lower emissions to air	Electrification	Other
215620	PRESENS AS	New generation subsea dp sensor for subsea single and multiphase meters	✓			
215605	Seabox AS	Subsea Membrane Testing	✓			
215597	Force Technology Norway AS	SmartPipe Pilot Project				✓
215565	FRAS TECHNOLOGY AS	Condition monitoring of hydraulic- and subsea machinery		✓		
215551	Badger Explorer ASA	Badger Explorer Seismic Field Demonstrator	✓	✓		✓
215548	ReelWell AS	Reelwell Drilling Method-Applications for Subsea Wells	✓	✓		✓
215538	GASSECURE AS	Pilottesting og teknologikvalifisering av system for trådløs gassdeteksjon	✓	✓		
207280	OCTIO Geophysical AS	OCTIO GEOPHYSICAL DEMO2000 – A solution for advance warning of leakage to surface from waste injection wells		✓		✓
207278	Seabed Rig AS	Qualification of autonomous, robotic drill floor for subsequent implementation on offshore platform, phase 3	✓	✓	✓	
207247	ReelWell AS	Reelwell – Extended Reach Drilling beyond 20 km	✓	✓		✓
207203	Drilltronics Rig Systems AS	Drilltronics system onshore demonstrations				✓
207013	Nemo Engineering AS	Subsea Cooler Qualification				✓
206991	Computas AS	CODIO Pilot	✓			✓
206972	Marine Ecosystem Technologies AS	Active Acoustic leak detection of oil and gas from sub sea installation				✓
189003	Aker Subsea AS	High Pressure Deep Water (HPDW) LiquidBooster Pump	✓	✓		
188991	Seabed Rig AS	Prototype test of submerged fully automated drilling rig	✓	✓	✓	
188989	Typhonix AS	Pilot Installation and Testing of Typhoon Valve	✓			✓
188983	Deep Sea Anchors AS	Installation of Two Permanent Deep Penetrating Anchors at the Gjøa Field in the North Sea		✓		✓
188982	ResMan AS	Environmentally friendly chemical tracers for production monitoring in sensitive Arctic areas	✓	✓		✓
188981	eDrilling Systems AS	eDrilling Qualification and Demonstration	✓	✓		✓
188979	Seabox AS	Seabed Water Injection and Treatment – Pilot Plant	✓			
188970	FMC Kongsberg Subsea	Next Generation Deepwater Subsea Gas-liquid Separation System	✓	✓		
188948	Rolls-Royce Marine AS	Heavy Duty Fibre Rope Deployment System JIP Phase 1 – Rope testing programme	✓	✓		
163827	Framo Engineering A/S	Pilot installation of the Wet Gas Compressor WGC2000 on a live gas field in the North Sea		✓		
163803	Petrotech AS	SILD Phase 2 – A new concept for Environmental Friendly Well Testing and Reservoir Fluid Sampling		✓		
158025	SINTEF Materialer og kjemi	ResMan Downhole Water Monitoring System – Field Verification	✓			✓
149651	Framo Engineering A/S	Testing Wet Gas Compressor – Subsea Wet Gas Compressor		✓		

Project	Project owner	Project title				
149637	Petrotech AS	Big Sild – A new concept for Well Testing and Reservoir Fluid Sampling				
139739	Petrotech AS	SILD-A New concept for Well Testing and Reservoir Fluid Sampling				
139636	Framo Engineering A/S	Offshore Cryogenic Loading – Full scale Test				
136959	Kværner Oilfield Products AS	Kværner Subsea Processing System, Multiphase pumping				
136622	Framo Engineering A/S	Subsea Wet Gas Compressor				
Total	**101**	**Numbers**	**84**	**61**	**16**	**42**



Development of digital solutions will provide huge gains in energy efficiency.

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