The Research
Council of Norway

Raising energy efficiency and reducing greenhouse gas emissions

An analysis of publicly funded petroleum research
2018–2021
PETROMAKS 2 / DEMO 2000

Empowering ideas for a better world

PETROMAKS 2 / DEMO 2000

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

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 forward-looking industrial development in the sector.

The primary objective of the programme is to generate new knowledge and technology to facilitate optimum 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.

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.

https://www.forskningsradet.no/en/about-the-research-council/Portfolios/petroleum/

Table of contents

Examples from the project portfolio

Overview of the projects

NOV is working on a highly efficient hybrid energy storage system that enables large fuel savings

Eelume's remotely operated drone can revolutionise underwater operations

Empig's pioneering cold-flow technology can save the oil industry significant amounts of energy, materials and CO_2 emissions

Photo: NOV Process & Flow Technologies AS

Preface

The petroleum activities on the Norwegian continental shelf make a major contribution to Norway's economy and they will continue to do so for decades to come, via central government revenue, industrial activity, employment and technological developments. Overall responsibility for the optimum management of Norway's petroleum resources in an environmentally sustainable manner is therefore very important.

The Climate Action Plan points out that petroleum research can contribute to reduced greenhouse gas emissions through more energy-efficient development and operation of oil and gas installations. Research-based knowledge about the significance of these activities is therefore important, both now and in the future, including the many possibilities for minimising their carbon footprint. The sector is one of the biggest sources of greenhouse gas emissions from Norwegian territory, and research and technology developments that help reduce emissions to air are an important precondition for resource management on the Norwegian continental shelf and for reaching the Government's climate goals.

One of the most important goals of publicly funded petroleum research is to generate new knowledge and technology to ensure good management of oil and gas resources. This also means continuously improving energy efficiency and minimising emissions to air and sea. To achieve these goals, it is also essential to reduce, as far as possible, the time it takes from the research is carried out until it is taken into use, in the best interests of both the sector and the environment in Norway and globally. The analysis for this brochure shows that the Research Council's two programmes PETROMAKS 2 and DEMO 2000 have provided funding to 137 new projects between 2018 and 2021, both to the research communities and to trade and industry, which will have positive effects for the environment when they are taken into use. Many of the research results will contribute to reduced emissions of greenhouse gases, both directly - by reducing the number of tonnes of CO_2 produced from an emissions source, or indirectly – through more energy-efficient processes.

The projects cover the whole value chain from basic research, via industrial research, to experimental development and piloting. They cover technology that can be quickly implemented, as well as longterm research that targets the 2050 goals. We present some of the projects in this brochure. A complete overview of the projects that have confirmed that they will be able to contribute to energy efficiency and reduced greenhouse gas emissions are listed at the back of the brochure. This is the fourth edition of this report. Similar analyses were conducted in 2012, 2015 and 2018.

Happy reading!

Siri Helle Friedemann
Director, Department for Petroleum Research

Petroleum research with potential for energy efficiency and reduced emissions to air

At least NOK 35 million of the Ministry of Petroleum and Energy's annual allocation to the Research Council shall be set aside for research aimed at energy efficiency and reduction of greenhouse gas emissions from oil and gas production on the Norwegian continental shelf.

The Research Council has conducted an analysis of research and development projects targeting the oil and gas sector to obtain an overview of projects that can lead to greater energy efficiency and/or reduced emissions to air. The results show that the funding granted for this purpose far exceeds the required amount.

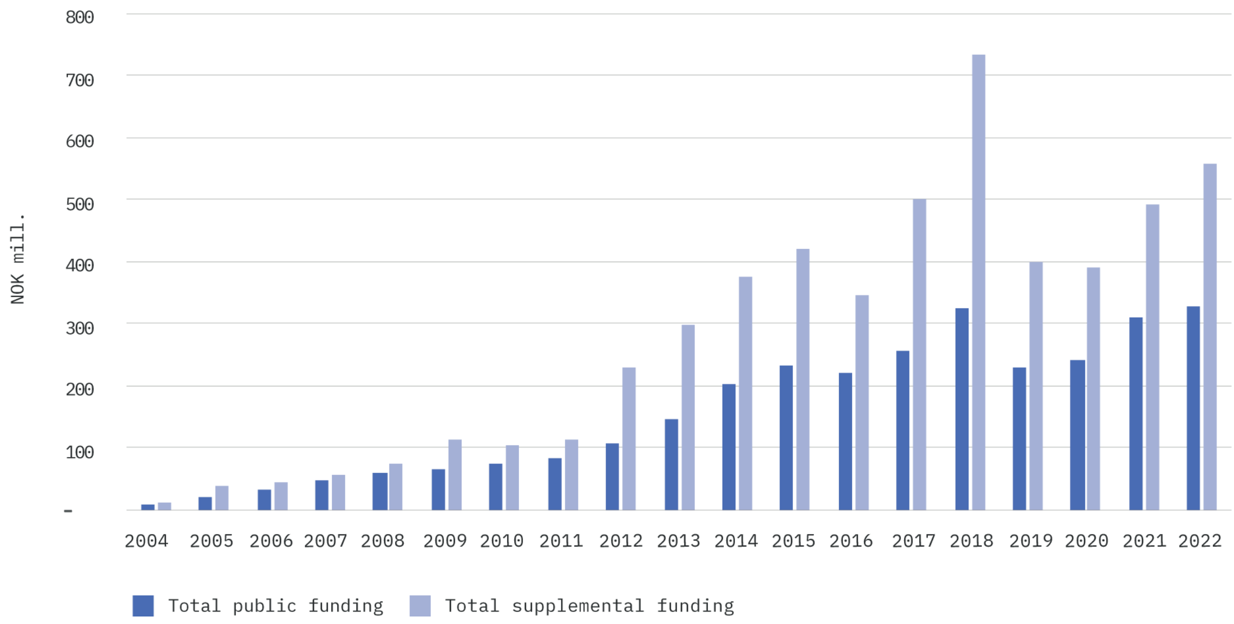
The Research Council has granted a total of NOK 1.741 billion to 201 new petroleum projects in the PETROMAKS 2 and DEMO 2000 programmes initiated between 2018 and 2021. The projects have also triggered NOK 2.305 billion in cash financing and in-kind contributions from other sources and efforts invested by the projects and their partners. Of these, 137 of the projects have reported a potential for energy efficiency and/or lower emissions to air when their technology is implemented. These projects have received NOK 1.183 billion in public funding and NOK 1.952 billion from other sources. The total budget for research with a potential for energy efficiency and/or reduced greenhouse gas emissions has been NOK 3.135 billion over the past four years.

Four sets of analyses (2012, 2015, 2018 and 2022) show that since 2004, around 390 projects with a potential for energy efficiency and/or reduced greenhouse gas emissions have been awarded funds under the PETROMAKS 2 and DEMO 2000 programmes. The graph shows public and supplemental funding of projects that contribute to environmental benefits that started up during the period 2004–2021. During this period, NOK 3.2 billion has been awarded under the programmes to projects with a potential for energy efficiency and/or reduced emissions to air from the oil and gas sector. This funding has in turn triggered NOK 5.5 billion in cash contributions and own efforts on the part of the projects and their partners, so that a total of more than NOK 8.7 billion has been spent on research relevant to the climate settlement (klimaforliket).

Continuously investing in R&D for energy efficiency and reduced greenhouse gas emissions pays off. In particular, investments in the industry-related part of the portfolio produce results that can be quickly introduced on the market and contribute to the sector's ambitious goals in this field.

NOK 35 mill.

In the Research Council's annual allocation from the Ministry of Petroleum and Energy, at least NOK 35 million is earmarked for research aimed at improving energy efficiency and reducing climate gas emissions related to oil and gas production on the Norwegian continental shelf.



Overview of public and supplemental sourced funds for petroleum research relevant to the climate settlement, initiated between 2004 and 2021.

Mechanical shallow water TRL4 test of Empig's underwater cooler

Projects offering new opportunities

Government-funded petroleum research contributes to Norway realising its part of the global climate goals. An analysis shows that 68 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, as well as energy efficiency measures on existing and new installations on the Norwegian continental shelf.

The analysis is based on projects in the Research Council's PETROMAKS 2 and DEMO 2000 programmes that were initiated between 2018 and 2021. All projects were contacted, 201 projects in total, and 187 projects responded, corresponding to a response rate of over 90 per cent. The analysis is based on figures provided by the respondents.

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 processes.

The analysis also looks into whether the projects are directly targeted at, or are of relevance to, reduced emissions to air. The targeted projects have energy efficiency and lower CO_2 emissions as their main goal. The analysis shows that 14 per cent of the projects are directly aimed at lower greenhouse gas emissions, while 54 per cent of the projects are of relevance when the technology is put to use. Energy efficiency is not the primary goal of 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.


Photo: HYDROPHILIC AS

Workshop Hydrophilic logging tool - a new measurement method that makes it possible to determine the size of a discovery directly from the discovery well

68 %

137 of the projects (68%) confirm that their projects have potential for energy efficiency or reduced emissions to air.

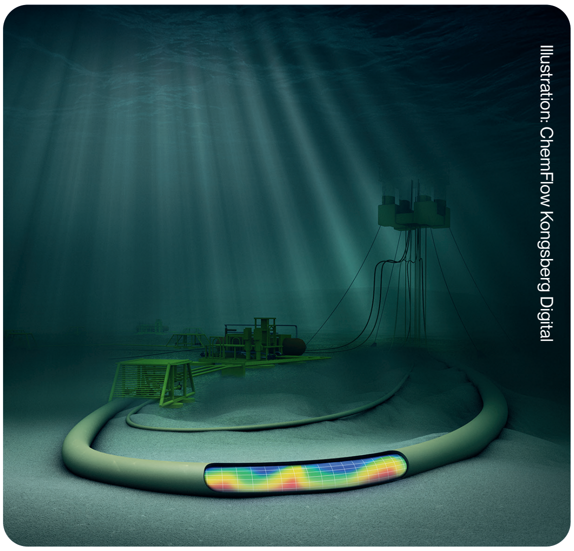


Illustration of LedaFlow Slug Capturing

The projects' own classification of environmental potential
137 of the projects (68%) confirm that their projects have potential for energy efficiency or reduced emissions to air. 118 of the projects (59%) state that they have a potential for energy efficiency and 64 projects (32%) potential for lower emissions to air – across project types and discipline areas. In addition, 14 per cent reported relevance to electrification and 31 per cent that they also have other environmental potential, such as reduced discharges to sea, carbon capture and storage, less use of chemicals and more use of renewable energy. See the table of the projects' self-reporting below. 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. Examples of research and technology developments that will contribute to reduced emissions from oil and gas production are shown after each thematic sub-chapter, as well as eight project examples from page 22. The projects that have confirmed their relevance to energy efficiency and/or reduced emissions to air are listed at the back of this brochure.

The projects' own classification of environmental potential	Number of projects	Percentage of whole portfolio
Energy efficiency	118	59
Lower emissions to air	64	32
Electrification	28	14
Other (such as emissions to sea/renewable energy)	62	31
Projects with a potential for energy efficiency and/or reduced emissions to air, total	137	68

Overview of the projects' own responses.

Research targeting environmental exploitation of petroleum resources

In 2020, emissions from oil and gas activities represented approximately a quarter of Norway's total greenhouse gas emissions. Just over 80 per cent of the CO_2 emissions were from gas turbines used for local power production offshore. Large amounts of power are needed for offshore operations, and we must therefore develop more competence and new technology for new or improved ways of generating power. 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 less or no greenhouse gases. Greater energy efficiency in power generation is one of the most important and environmentally friendly means of saving energy and reducing emissions.

14 per cent of the projects in the petroleum portfolio that were initiated between 2018 and 2021 directly target the development of new technologies for energy efficiency and reduced greenhouse gas emissions on the Norwegian continental shelf. A similar analysis conducted in 2018 showed that 7 per cent of the PETROMAKS 2 and DEMO 2000 portfolios were targeted, so this is a positive increase from previous years.

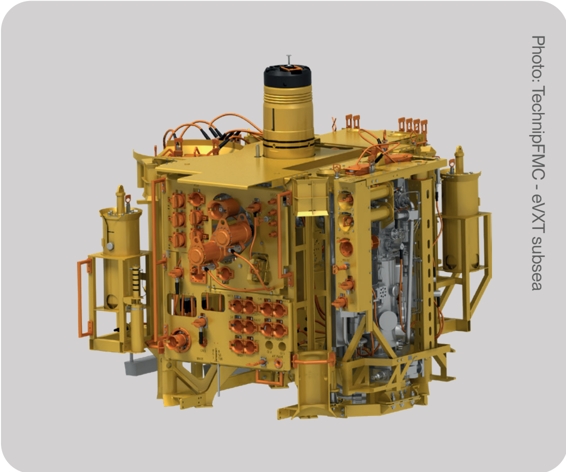
There are many different technologies and methods that can help to lower emissions, both by reducing power needs and that energy production can first become hybrid" (using both fossil and renewable sources), and eventually completely renewable. The majority of these projects address power generation with less emissions to air, electrification of subsea installations (subsea all electric) and electrification using offshore wind farms. The targeted projects have a particular focus on technology that contributes to less need for added power and lower greenhouse gas emissions, hybrid power solutions and the further development of combined power plants such as subsea infrastructure for storage and distribution of hydrogen, hydrogen for blending with natural gas and ammonia as fuel. The projects cover a large part of the TRL scale where some projects produce results relatively quickly, while others will generate results in the longer term. The oil and gas industry are responsible for a large proportion of the targeted projects, which shows that the industry focuses strongly on technology that can help to reduce emissions.

In addition, the "LowEmission PETROSENTER" is making targeted efforts to reduce greenhouse gas emissions and increase energy efficiency in the oil and gas industry. The centre develops new technologies and concepts for offshore energy systems, energy efficiency and integration of existing infrastructure for renewable power generation technology for implementation on the Norwegian continental shelf.

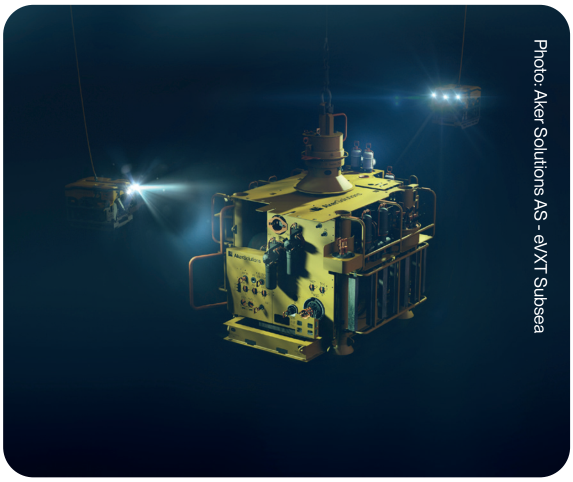
The first six project examples in the next chapter, page 22, show examples of targeted projects from the PETROMAKS 2 and DEMO 2000 portfolios.

Electrification is more than power from shore

14 per cent of the projects report relevance to electrification. Electrification of the Norwegian continental 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 integration of offshore wind. Moving the oil and gas production from the platform deck to the seabed has favourable consequences for the installation's energy efficiency, such as major savings on materials (for platforms), fewer operating personnel, more energy-efficient processing and transport of



Model of the next generation electric christmas tree



Installation of electric christmas tree on the seabed

well flow. Electrical systems are also more energy efficient than hydraulic systems and there is no risk of hydraulic oil discharge to sea.

The projects relating to the electrification of subsea installations comprise both new technology and improvements to existing electrical systems with a view to safer and more efficient operation. These projects develop subsea power systems, control systems for data and electricity transmission, easier connection of underwater facilities, charging stations for AUVs/ROVs and non-hydraulic valves.

– Aker Solutions AS is working to develop fully electrical battery-operated systems capable of shutting down subsea oil and gas production wells just as safe, and with greater energy efficiency and at lower costs than traditional hydraulic solutions. Such technology requires development and testing of several different components, and they are now set to qualify and demonstrate the system to the maturity level required for it to be taken into use.

– Benestad Solutions AS is developing Wet Mate Connectors (WM), a cost-efficient solution that will simplify subsea power distribution. The development of efficient and flexible solutions for subsea power connectors that can be connected and disconnected under water is important for realising the development of large gas reservoirs with subsea compression, as well as to electrification on the Norwegian continental shelf in general. Benestad's connectors will reduce complexity, weight and the number of interfaces on the seabed. This multi-functional connector enables remotely controlled operations and monitoring, so that the need for offshore operations is reduced and maintenance is optimised. This technology will increase flexibility compared to what is available on the market today. The system will reduce the complex offshore operations and will be relevant for the coming growth in renewable offshore energy production such as wave, tidal and wind power.

– A project at NTNU is working towards two goals: 1) Increase the sustainability of the power generation, by focusing on offshore wind energy and reduce the use of polluting gas turbines. Such a solution requires thorough analyses to ensure that the wind irregularity does not compromise the stability of the electric grid and jeopardise the security of supply to critical loads; 2) Reduce and rationalise power consumption by reducing losses and boosting system efficiency. This means identifying, analysing and mitigating local power quality problems that have a direct impact on energy conservation, employees' safety and continuous operation on the platform.

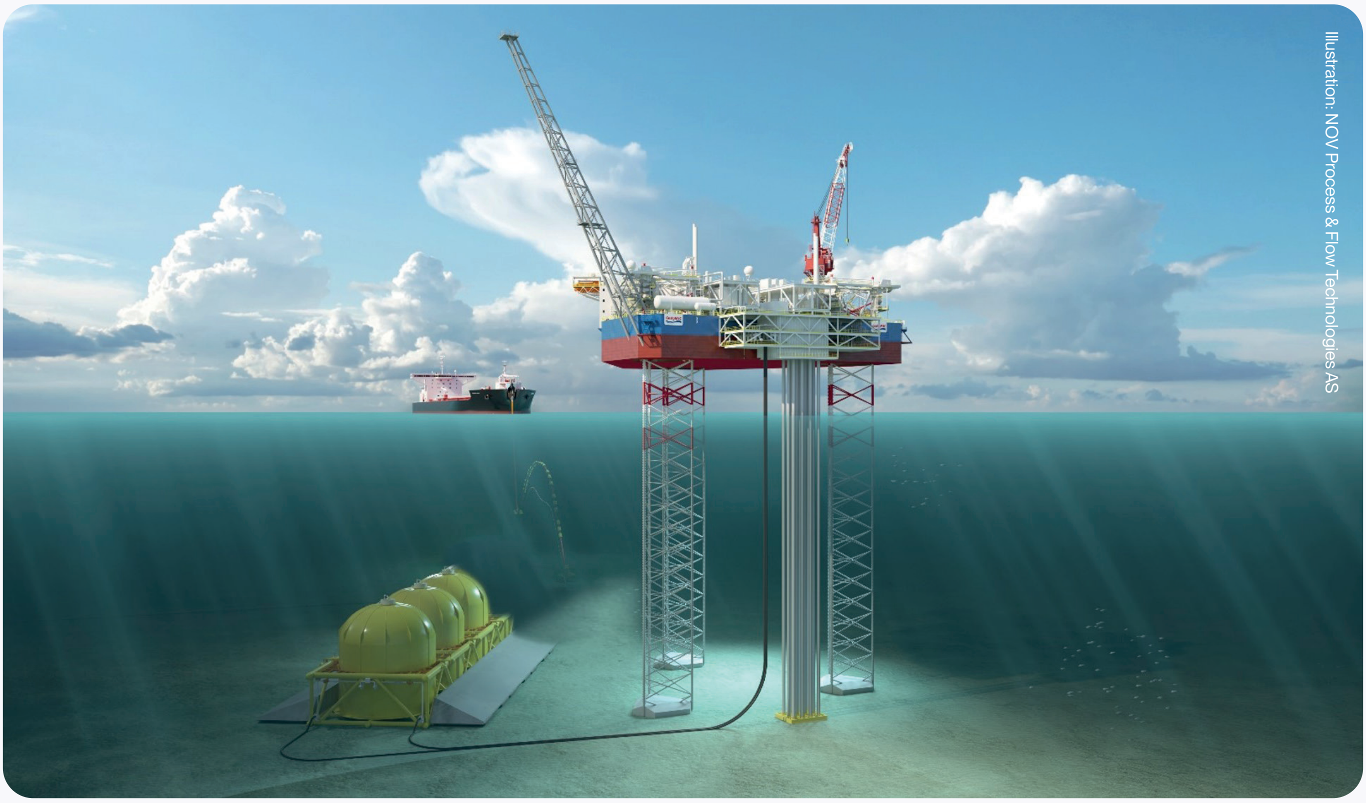
This can be achieved through targeted measures, such as load scheduling and coordination of compensating equipment. The crucial and still underexplored factor in ensuring the viability and optimisation of the two strategies above is to deploy energy storage systems on the platforms. The project investigates how battery energy storage systems and their cooperative control can increase energy efficiency, reduce produced greenhouse gases and ease wind integration in present and future oil and gas platforms.

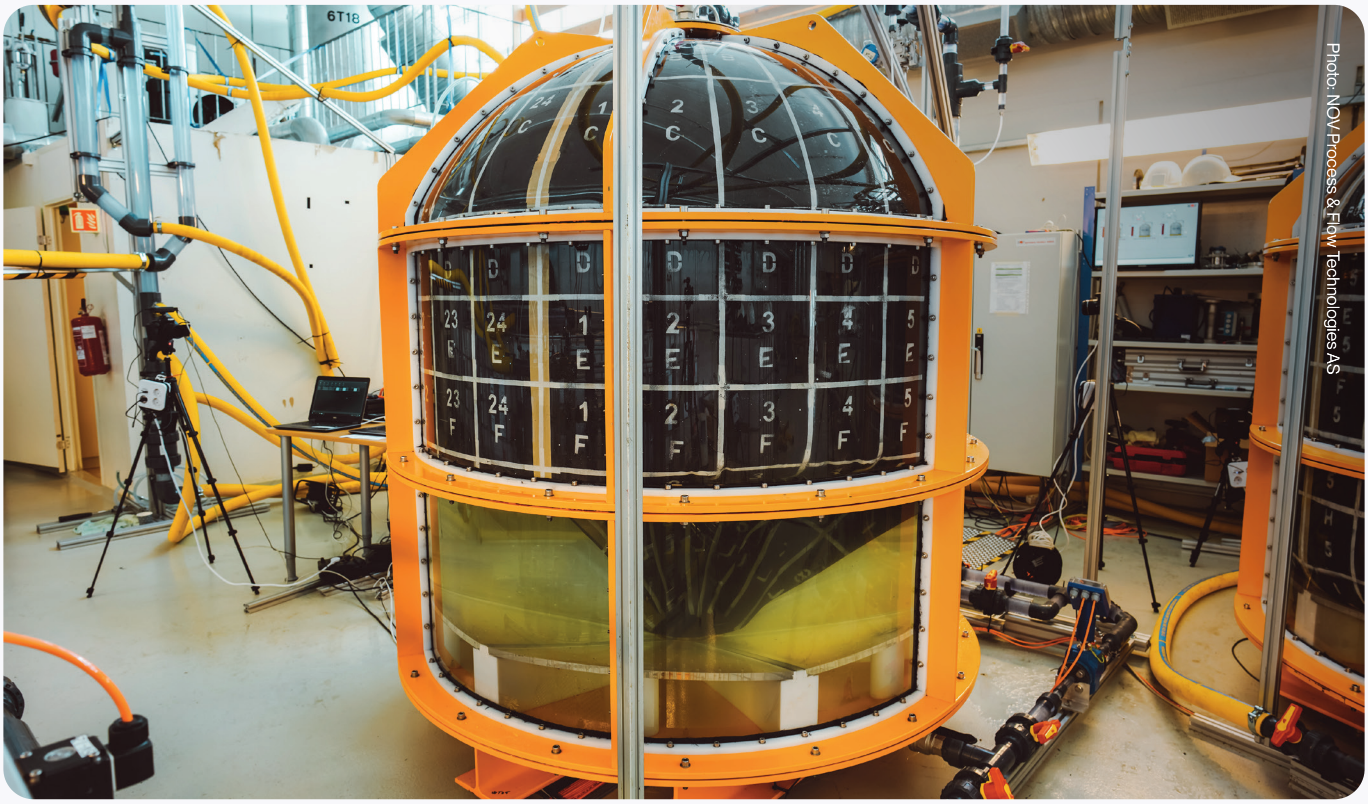
Energy management and hybrid energy systems

It is important to reduce the need for added energy to platforms and subsea installations. Many of the projects develop knowledge and technology that will contribute to more efficient use of energy, thus reducing the need for supplied energy. The projects have a wide thematic scope, such as more efficient gas turbines (both new and existing), further development of combined power plants (heat recovery units and steam turbines), hybrid solutions for power supply to offshore infrastructure (offshore wind, battery solutions, fuel cells, wave power, etc.), hydrogen and blending hydrogen with natural gas. The majority of projects target energy management and energy systems, including hybrid energy systems, subsea infrastructure for storage and distribution of energy (e.g. hydrogen), hydrogen and green ammonia for energy (fuel) and new value chains.

– A variable energy resource such as wind power cannot be adjusted up or down according to the demand for energy. In isolated systems that cannot exchange power via the power grid, a form of buffer is therefore required to ensure a balance between energy consumption and production at all times. SINTEF Energy Research looks at how flexibility in energy consumption can be exploited to ensure better harmony between variable wind power generation and energy consumption, which will reduce the need for energy storage. Utilising flexibility is mainly about smarter management and has a low cost compared to the cost of energy storage. The project will help to reduce the costs of electrification using offshore wind. The technology utilises flexible loads in combination with energy storage and is one of the factors that can enable wind power to replace natural gas as an energy source for oil and gas platforms without umbilicals to shore. The project expects this to reduce emissions by 40 percent by 2030 – based on the assumption that, up to this level, gas turbines will still be needed to harmonise the system – and 100 per cent by 2050 – based on the assumption that all energy will come from renewable sources (wind, solar power, etc.).

– Storing fluids on the seabed will reduce gas emissions and infrastructure and production costs, as well as provide renewable energy on site. NOV AS has developed a new and unique system for subsea storage of fluids. The fundamental new component is a membrane, in which the fluid is stored. The membrane is compatible with oil, seawater, ammonia and chemicals required in oil and gas production. The system, which is placed on the seabed, can be adjusted in capacity, and it will significantly reduce CO_2, NO_x and VOC emissions compared with current solutions. The technology can be moved and reused anywhere. Storing hydrogen, in the form of ammonia, is an important step in the transition to renewable energy. Ammonia can be safely stored under water in large quantities at a low cost and replace gas turbines and diesel generators. The use of ammonia can reduce gas emissions by up to 100,000 tonnes of CO_2 per platform per year. Oil storage will also be an integrated part of the development of unmanned offshore platforms. This also means a significantly reduced environmental impact compared with standard solutions such as FPSO and FSU (vessels for transporting or processing oil). It is calculated that, over a ten-year period, gas emissions can be reduced from 160,000 tonnes to 50,000 tonnes of CO_2 for an FSU.





Mobile offshore production unit (top) and NOV Subsea Storage System (bottom)

Great potential for environmental benefits in several technological areas

The majority of the projects that reported a potential for energy efficiency or reduced emissions to air, do not have reduction of greenhouse gas emissions as their primary objective. The potential is released when knowledge and technology developed for innovations initially created for completely different purposes are taken into use. An indirect way of achieving lower emissions to air is by making the processes more efficient, enabling the task to be performed faster. When an operation takes less time, it also generates less emissions to air. Reduced completion time for energy-intensive processes and improved work processes related to production and operation, are examples of this.

Improved utilisation of production data, increased knowledge for better decision support, optimal operations and automation of processes will result in more efficient oil and gas production. An important consideration in these projects is to reduce the risk of undesirable incidents. This will in turn lead to greater operational reliability, less flaring, lower risk of leakages and a safer working environment. Many offshore operations depend on support vessels or rigs. Reducing the time spent on such operations, or reducing the size of support vessels, will significantly reduce emissions of greenhouse gases from fuel. Furthermore, carrying out some of the oil/ water separation on the seabed and reinjecting the water back into the oil well, will lead to a more energy-efficient production. The majority of the projects are in the areas of drilling and well technology, multiphase transport, subsea solutions, optimised production strategies, life extension of infrastructure and increased knowledge of the subsurface and reservoirs.

Drilling and well technology

The costs for drilling and wells comprise a large part of the total costs of the development of oil and gas fields. The operators want research and technology that can make operations more cost-effective and the processes more energy efficient. Energy efficiency can be achieved through faster and smarter performance of drilling and well operations, moving some of the operations from big drilling rigs to lighter vessels or by 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 increases the insight into the complexity of the operations and provides better decision support, contributing to more efficient and safer operations. The majority of the projects are within new drilling technology and permanent plug and abandonment of wells (P&A), automation and optimisation of operations, and new and more efficient methods for well design and well intervention.

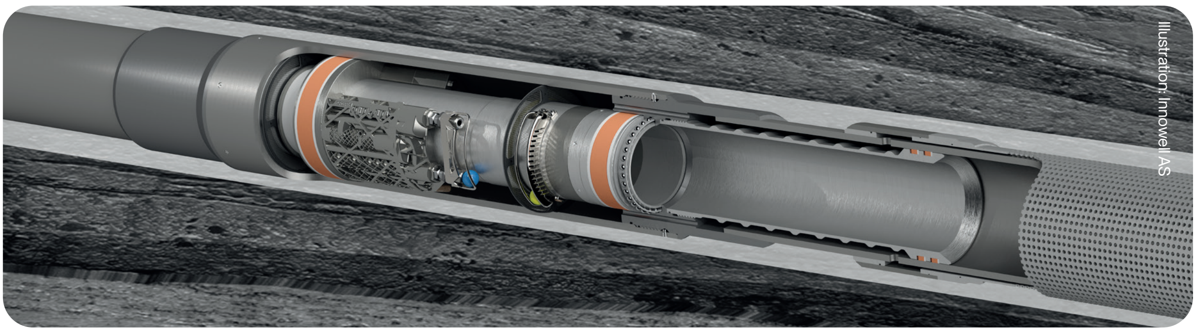


Illustration of Innowell DAR technology – technology for increased recovery and less water production

– Over the next 40 years, the Norwegian oil and gas industry must shut down more than 2,000 wells. A normal plugging procedure requires a barrier/plug to be installed through the full cross section of the well. The purpose is to ensure that the reservoir is isolated to prevent contaminated water or hydrocarbons from leaking out. Annual emissions of 260,000 tonnes of CO_2 are estimated in connection with plugging of Norwegian oil and gas wells. A large part of these emissions is caused by drilling rigs. Innovation Energy AS has developed an electrochemical process that can accelerate the dissolution of the steel in the casing enabling the process to be performed without the use of a rig. A traditional shutdown takes an average of 35 days. Necessary electric energy using this technology is estimated to result in the emission of 1.5 tonnes of CO_2. This is equivalent to using a drilling rig for less than 10 minutes.

– Today, well planning processes consist of calculations carried out internally in the oil companies and blowout simulations outsourced to consultancy firms, since there is no available commercial software that allows oil companies to do this themselves. The work process is ineffective and results in the well design being over-dimensioned to ensure compliance with official requirements. Oliasoft AS is developing a software that integrates blowout and kill simulations with the other mandatory calculations. This integrated solution means that the engineer controls all calculations throughout the design process and prevents over-dimensioning of the well. The solution can reduce the amount of steel used, and the drilling operation itself will take less time, resulting in reduced use of chemicals and greenhouse gas emissions. In operational terms, integrated planning software can save five days per well. Smaller casing dimensions and

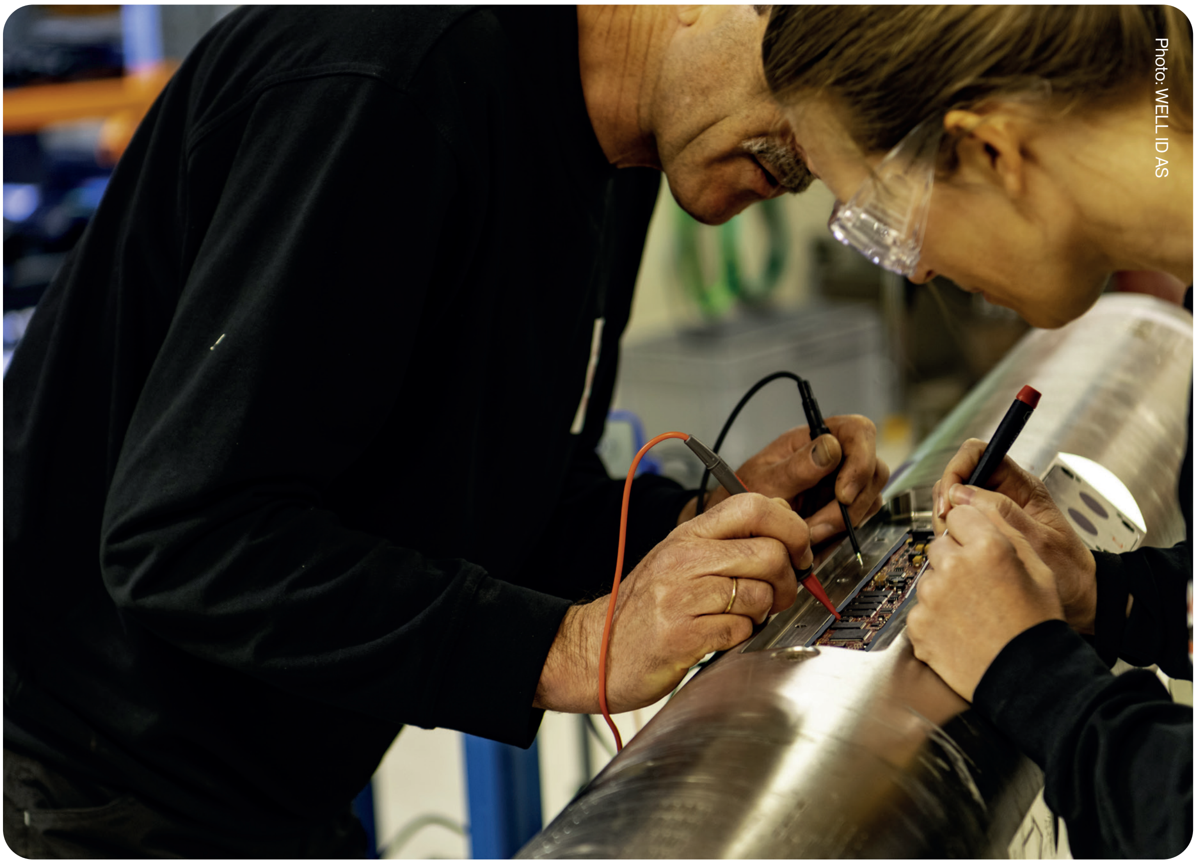


Photo: WELL ID AS

Workshop Well ID Impulse Radar LWD tool – technology for imaging boreholes and increased information about formations during drilling fewer casing sections also contribute to reduced steel production, which in turn leads to reduced CO_2 emissions. CO_2 emissions per tonnes of steel produced vary between 1.3 and 4.0 tonnes depending on production country (Global CCS Institute, 2013). The potential for reduced emissions to air is therefore considerable.

– Altus Intervention Group AS is developing a platform (DWI - Digital Well Intervention) to reduce the costs and energy consumption of well intervention operations. This technology will provide improved quality and streamline intervention operations, and ensure optimal production of reservoirs using existing infrastructure and fewer manual steps. Digital well interventions will make it easier to identify intervention candidates and define and design the intervention tool string without cumbersome manual interaction with multiple vendors. Digitalised tools and improved work processes on the platforms will allow real-time collaboration between disciplines onshore and on the rig. The DWI software will improve and connect the currently fragmented work processes, from planning an operation to execution and reporting. Among other things, this will enable end-to-end interventions that minimise the risk of human error and time spent on operations, remote operations (reducing the need for personnel on board the rig), operational automated diagnostics and proactive interventions. It will also optimise the operation time.

Multiphase technology

Multiphase technology is about transporting oil, gas and water in the same pipe from the drilling site to an oil platform or to a facility on land. The transport stage can be many tens of kilometres long over hilly seabeds, cracks and rocks. The uphills and downhills in particular, where the mixture of water, oil and gas – the untreated well stream – slows down or accelerates, present a number of challenges. Increased knowledge of the chemistry of multiphase flow and flow regimes is important to ensure more energy-efficient transport over long distances. These challenges are addressed using simulation tools to be able to choose the best possible technical solutions. More accurate predictions can result in significant savings. It is therefore important that the simulation tools are as accurate as possible for field design and operational decisions.

The majority of the projects look at how multiphase transport can be optimised based on increased knowledge of the properties of multiphase blends, better models for multiphase transport over long distances, materials for safe multiphase transport, less use of chemicals and multiphase flow at ambient temperature (cold flow – flow that does not require insulated pipes or heating cables).

– The Western University of Applied Sciences is studying the process behind an everyday phenomenon that most of us have experienced in the kitchen or the bathroom: blocked pipes. A similar kind of blockage can also occur in oil pipelines. Although the phenomenon is very common, this process is still not entirely understood. To understand more, the process will be reproduced in a laboratory. By knowing how the clogs are formed, the amount of chemicals used to protect the pipelines from clogging can be reduced. This will significantly reduce CO_2 emissions. The results of the project are also relevant to medical studies of flows in living organisms, such as blocked blood vessels – one of the most common causes of strokes.

– Gas hydrates can plug pipelines and process equipment and is one of the biggest challenges in oil and gas production. A study at SINTEF shows that CO_2 emissions from oil production can be reduced by 20 to 30 per cent if production can take place without using traditional hydrate management methods. Some oils contain naturally occurring hydrate active components that prevent hydrate problems, but these components have not yet been identified, partly because they occur in extremely low concentrations. The project uses "big data" by combining very high-resolution mass spectroscopy of many different crude oils and advanced data analysis and machine learning. The goal is to identify the components responsible for non-plugged crude oil systems and develop methods that can considerably reduce the environmental impact of oil production by avoiding the use of heat and chemicals.

– Transport of oil, gas and production water in the same pipeline from wells on the seabed to platforms or onshore processing plants makes production considerably cheaper and more energy efficient. However, complex chemistry can cause severe problems such as flow instability, separator flooding, poor separation and foam formation. This leads to production losses and increased CO_2 emissions. For example, if the gas contains too much fluid after the separation stage, it must typically be flared. Schlumberger Information Solutions AS has significantly improved predictions in steeply inclined or vertical risers and wells for the multiphase simulator OLGA. This will reduce the uncertainty margins for the design and operation of offshore fields, reduce energy consumption, lower the costs, improve safety and reduce the environmental impact, e.g., by enabling the use of existing infrastructure rather than having to build new. It allows for developments that would otherwise not be profitable. LedaFlow Technologies AS has developed new models in the multiphase simulator LedaFlow that take into account the characteristics of production flows with different chemicals. This can contribute to reduce energy consumption and minimise flaring, as well as enable transport of oil and gas over longer distances.

Experiments are carried out in SINTEF's multiphase laboratories to further develop the multiphase simulator LedaFlow

Subsea technology

Moving oil and gas production from the topside platform to the seabed will lead to major savings in materials (platform development), fewer operating personnel, and more energy-efficient processing and transport of multiphase flow. On the other hand, equipment placed on the seabed needs to be robust and operationally reliable. These projects study process equipment and materials adapted for subsea operation, such as pumps, valves and separation units, unmanned operations and autonomous systems such as subsea vessels (underwater drones/ROV/UUV), and subsea power supply and distribution.

– Fluidsep AS has developed a system for downhole water separation, which allows the water to be separated down in the well and be reinjected into suitable zones in the reservoir without lifting the water to the surface. 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. This leads to a considerable reduction in CO_2 emissions and less use of chemicals. In addition, the injected water can be used for pressure support and improved recovery rate from the reservoir.

– OneSubsea AS has developed a new cost-effective, reliable and energy-optimised pump design. The new pump can operate at a longer distance from the power source, in several cases without a platform, or, alternatively, from decommissioned platforms such as unmanned electric power stations. The pump solution is more adapted to free-standing installations and only requires electrical power. This will make the systems better adapted to future low or even zero emission power solutions. The pump targets subsea water treatment and injection systems, but other applications and process media will follow.

Life extension, integrity monitoring, new materials and smart sensors

Due to cost and environmental considerations, companies prefer to use existing rather than develop

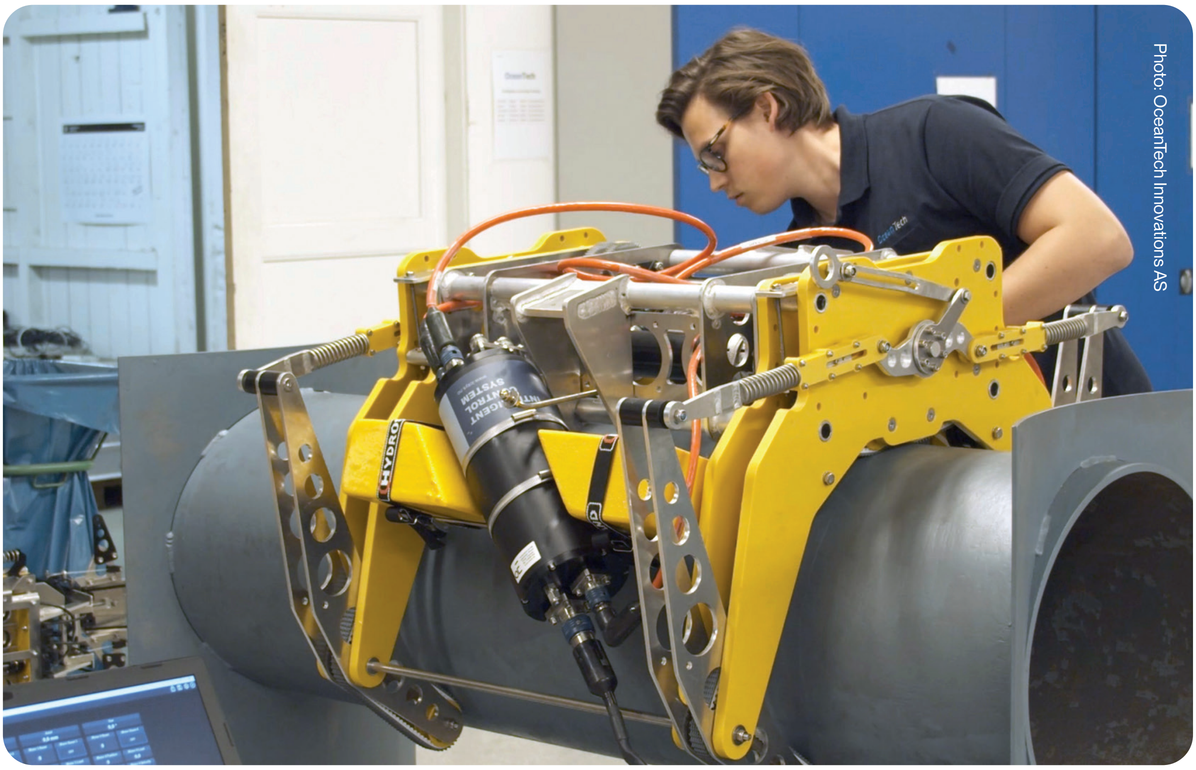


Photo: OceanTech Innovations AS

Workshop assembly of the OceanTech inspection robot

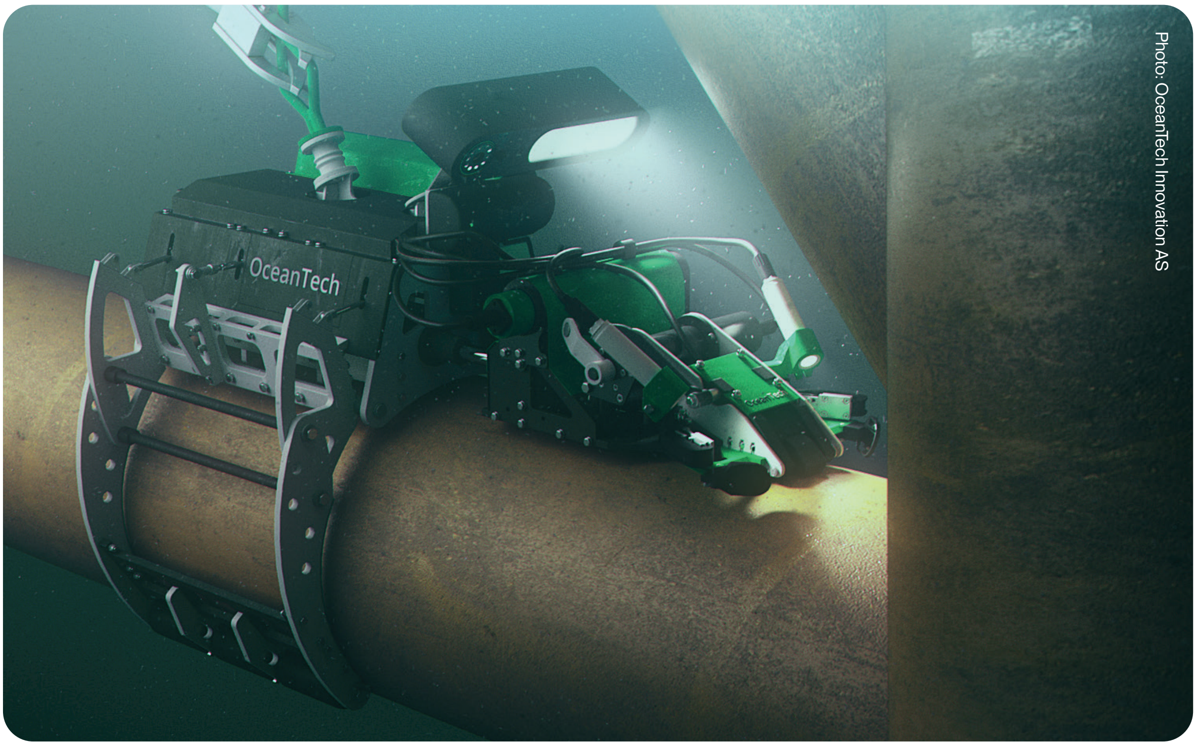


Photo: OceanTech Innovation AS

OceanTech underwater probe test

new infrastructure. Many new field developments will therefore be realised as so-called “tie-backs”. These are pipes that transport oil and gas along the seabed to permanent installations. However, these pipes must be insulated and often require heat to prevent the pipes from clogging. The projects will contribute to ensuring that infrastructure can be safely used beyond the projected service life, and that tie-backs can be implemented at lower costs, with reduced need for added energy and less use of materials.

– The splash zone is the area right below the water surface down to approximately 15 metres, where it is very difficult for divers and remotely operated underwater vehicles (ROVs) to operate. At the same time, inspection of the exposed splash zone is important to verify the platform’s structural integrity. OceanTech Innovation AS is developing a robot that will inspect offshore steel platforms more efficiently, more environmentally friendly and with considerably more reliability compared to current methods, without the use of large offshore support vessels. A new camera and laser system makes autonomous inspection possible. The robot is deployed at the inspection point without using support vessels and follows the welded joints, which are quickly and efficiently inspected. Furthermore, a new type of inspection probe will make it much easier, with significantly greater reliability, to discover faults in materials. This technology enables inspection of previously inaccessible areas. This provides more reliable data, which in turn can extend the service life of offshore platforms. There are also savings in terms of emissions from support vessels, considering that a simple inspection assignment on a platform can take 6–8 weeks. The technology can also be used for offshore wind.

– A new method, based on robot technology developed by Kongsberg Ferrotech AS and subsea welding technology for great ocean depths developed by Equinor and SINTEF, will enable repair of underwater equipment. The technology contributes to extended service life of existing infrastructure, reduced need for production and transport of new parts, as well as reduced emissions without involving major installation projects. In most cases, it should be possible to use the method without affecting oil and gas production. The development process is based on extensive simulations followed by verification in a laboratory. The verified simulation models will become part of a "digital twin" that will be a core component for planning, execution and quality assurance of repairs. The digital twin will be updated after each repair and will thereby constitute "as built" documentation that provides traceability and verifiability for the repair in question. The technology can also be used for subsea cables and offshore wind turbines.

– Shawcor Norway AS has developed new pipeline insulation with integrated sensors and heating cables. The insulating properties are much higher than in previous solutions. The combination of passive insulation and energy-efficient heating makes it possible to lay pipelines connecting existing infrastructure to wells as far as 100 kilometres away. The heating cables only emit heat where the pipeline is too cold, and they have a 90 per cent efficiency rate. The solution makes it possible to transport oil and gas over long distances without the use of harmful chemicals, and reduces energy consumption in the processing unit. Sensors can be installed in the insulation to optimise the operation of the pipeline. Sensors can also be used to evaluate the pipeline's lifetime and maintenance requirements. This technology is also relevant to offshore wind, for cable installations in pipes over long distances.

Subsurface understanding

Based on current production plans, more than half the proven oil resources are left in the ground. The goal is to increase the recovery factor of existing fields. Injection of water, gas or other fluids, such as CO_2 foam, is used as a means to recover the remaining oil, but the current methods are very energy intensive. The projects study how to improve efficiency and safety in connection with oil recovery and CO_2-storage, how to better monitor hydrocarbon reservoirs and improve seismic methods. A better understanding of the subsurface will increase the likelihood of boreholes hitting targets (fewer exploration wells and fewer "dry" wells) and generate more knowledge and understanding relating to the development of exploration models relevant for the Norwegian continental shelf.

Euripides Papamichos in the formation physics lab

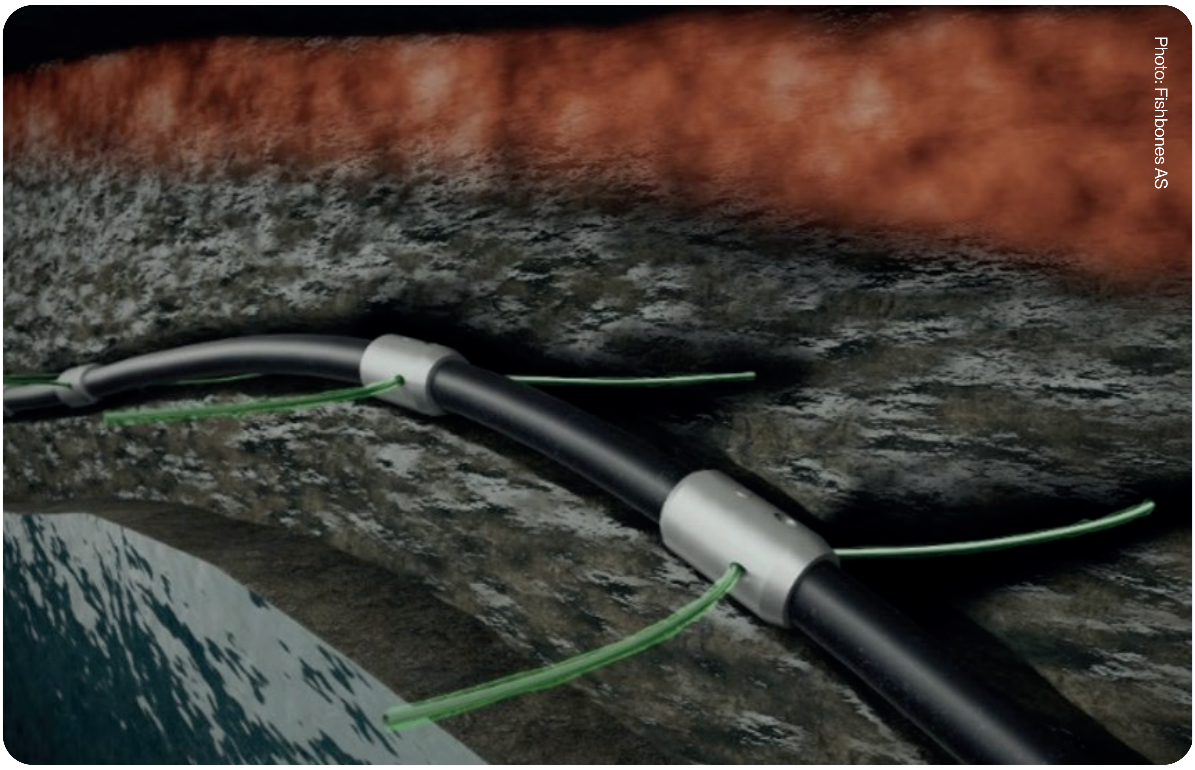


Illustration of Fishbone's multilateral technology for stimulating oil and gas wells

– A project at Earth Science Analytics will increase the discovery rate of exploration wells, increase production from producing fields and reduce the amount of time geologists spend analysing seismic and well data by 70 per cent. Data collected over 50 years will be used to train artificial intelligence technology (AI) to carry out tasks in hours that would previously take weeks or months. The technology will also produce more accurate information about the rocks and the fluids captured within them. Improved information will reduce uncertainty and errors, and lead to more commercial discoveries, fewer dry wells and increased production. The technology will generate more knowledge about the reservoir's properties by combining large amounts of seismic data and data from well logs. This will increase reserves through better placed wells and reduce CO_2 emissions through less need to drill wells.

– Fishbones AS's technology for stimulation of oil, gas and geothermic wells is a relatively new method. With great accuracy and efficiency, it accelerates the production of hydrocarbons from oil and gas wells and can help improve the recovery rate. The method is used to generate many small canals in the reservoir which can then be drained more efficiently. This method can be explained through the analogy of tree roots, which have many smaller roots to maximise the draining of water from the soil. Many reservoirs are very thin or have over and underlaying zones where penetration is unfavourable. It is therefore desirable to have a system ensuring controlled orientation of the laterals to avoid contact with these unwanted adjacent zones in the reservoir. A study shows that, compared with conventional Propped Fracturing, Fishbones Drilling can reduce CO_2 emissions by up to 95 per cent.

Other environmental effects

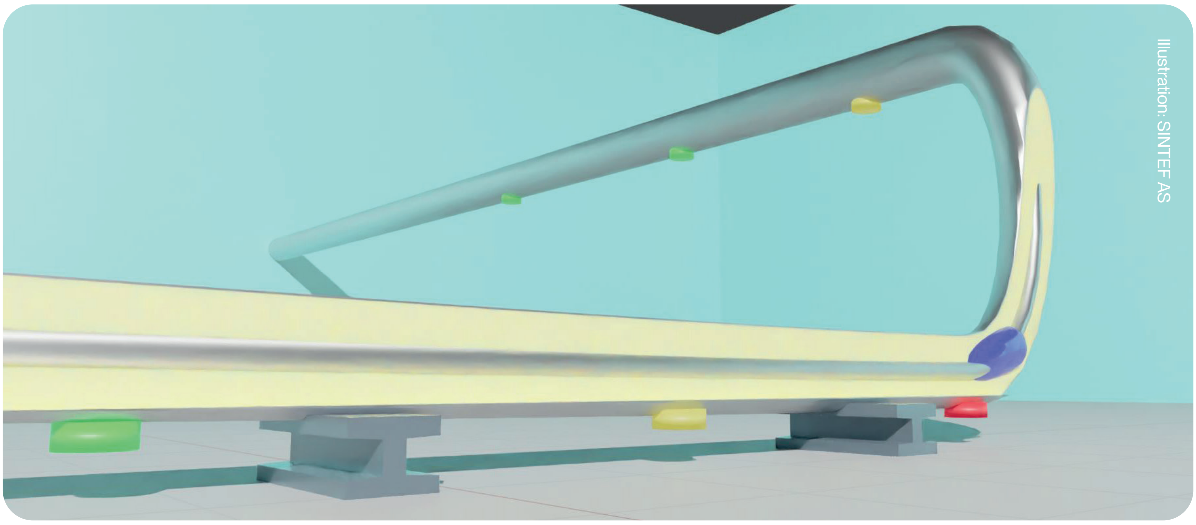
In addition to energy efficiency or lower emissions to air, 31 per cent of the projects also have other environmental benefits, such as reduced emissions to sea, more efficient and environmentally friendly production chemicals and lower consumption of chemicals. Furthermore, several projects are relevant to carbon capture and storage (CCS) and renewable energy.

Relevance to other industries, such as renewable energy

Technologies from the oil and gas industry can be utilised for much more than their original purpose. Much of the research carried out in the petroleum programmes can be transferred to other parts of society. Many of the PETROMAKS 2 and DEMO 2000 projects are relevant to other industries, especially within renewable energy, such as carbon capture and storage, offshore wind, geothermal energy, floating solar power, green hydrogen, renewable onshore power generation and wave power. Other purposes include onshore energy-intensive industry, fuel such as ammonia and e-methanol for the transport industry, maritime industry, chemical process industry, battery techno-logy, seabed minerals, water purification, removal of greenhouse gases from the cement industry and constructures for aquaculture.

In the oil and gas, chemical and process industry, there are thousands of kilometres of insulated pipe-lines, as well as a great number of insulated process equipment such as columns, valves and tanks. The equipment is insulated to save energy, protect against fire or reduce noise. Although the insulation is encapsulated, it is common for water to pene-trate the system, which can under certain circum-stances lead to corrosion under the insulation. This can cause major accidents and emissions unless maintenance is carried out in time. The insulation and encapsulation must be manually inspected at regular intervals. The standard practice is to remove the mantling and insultation material, perform careful

Ole Meyer looks at results from long-term testing of the sensors used in field instrumentation



The figure shows how it is envisioned that sensors can help detect the water hidden inside the system, without peeling away the sheathing and insulation

visual inspection of the stripped pipe run and re-apply insulation and mantling. The annual costs of such maintenance and inspection in Norway amount to several billion NOK.

– Kaefer Energi AS is developing a new sensor-based monitoring system to detect corrosion under insulation. The system will detect areas that are especially susceptible to moisture, thereby increasing the accuracy of manual inspections, which will in turn increase the facility's integrity and reduce maintenance costs. Optimised maintenance will also reduce excess consumption of insulation material and reduce waste production. The sensors will be installed by an autonomous robot in accordance with recommendations based on numerical calculations. The amount of insulation material saved will lead to significant reductions in CO_2 emissions. The technology will also improve the facility's integrity because it can identify "invisible" moisture in the insulation and reduce the risk of potential incidents with major consequences for personnel, facilities and the environment and lead to financial losses.

– SINTEF is researching moisture transport in porous insulation materials in order to develop new technology that can make maintenance more accurate. The new technology has a considerable potential to improve the facility's integrity and reduce the risk of major accidents. The solution will also reduce waste production and CO_2 emissions from the production of insulation that is replaced unnecessarily often. The monitoring solution combines moisture sensors in the insulation with advanced predictive simulation tools to identify the pipe stretches that require inspection. A medium-sized European processing plant with a maintenance period of 10 years can avoid replacing up to 500,000 cubic metres of usable insulation material. These materials are difficult to recycle and often end up at mass disposal sites. For example, a life-cycle analysis of mineral wool shows that CO_2 emissions from the production of 500,000 cubic metres of new insulation corresponds to the annual emission of around 730 petrol-driven cars. The mantling is often made from stainless steel that can be recycled, but far from all the material is actually re- used. With a recycling rate of 50 per cent, producing the necessary amount of new mantling material corresponds to the annual emissions of 1,500 cars. In total, accurate maintenance of such processing plants can save 10,000 tonnes of CO_2 equivalents per year.

Underground hydrogen storage to help the offshore industry cut emissions

Oil production can become more sustainable by introducing renewable energy to power offshore operations. This can be achieved by means of wind power, solar cells and power cables from shore.

Investing in renewable offshore infrastructure is also very favourable when oil and gas production is to be phased out completely; the infrastructure will then be exclusively used for environmentally friendly power production. The project *Clean offshore energy by hydrogen storage in petroleum reservoirs* will investigate whether hydrogen production can help the oil industry cut offshore emissions.

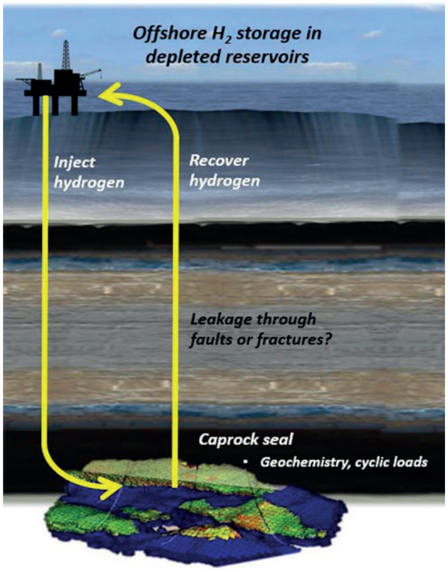
To ensure a reliable power supply, it must be possible to store part of the hydrogen surplus (for example on windy days) for later use (on calm days). SINTEF Industry, together with SINTEF Energy Research, SINTEF Digital, NORCE and Queen Mary University in London, are looking at how hydrogen can be stored in depleted oil and gas reservoirs underground. The hydrogen can then be pumped up for use in gas turbines or fuel cells as required. When there is a surplus of renewable energy, hydrogen will be pumped back into storage.

Mechanical testing in a load cell, to see if different rocks in the underground are weakened after exposure to hydrogen.

There are several challenges to be solved:

- Cyclic injection and production can lead to cracking in the rocks where the hydrogen is injected.
- The amount of hydrogen lost during each cycle due to mixing with the liquids remaining in the pores where it is stored.
- Leakage through the caprock that normally seals the reservoir and confines the natural gas that was already there.

These challenges will be investigated in laboratory experiments where hydrogen is injected into rock samples which are then tested to see whether they have become weakened as a result of contact with hydrogen. The goal is to increase the amount of pure hydrogen that can be stored instead of having to mix it with other gases.



Hydrogen is injected into the underground when there is a surplus of energy production on the platform, to be pumped up again when energy is needed.

Electrification of oil and gas installations by offshore wind

Offshore wind turbines are one of the most promising methods for electrification of offshore oil and gas plants. The ELOGOW project (Electrification of Oil and Gas Installation by Offshore Wind) will develop methods and tools to supply the power required for continuous operations by converting the wind energy potential in the offshore environment to electricity.

ELOGOW combines recent advancements in offshore wind turbines, batteries and energy storage/conversion systems to minimise the dependence on gas turbines. Using wind turbines to supply power requires gas turbines to be run simultaneously in case the field's power needs suddenly increase, or if the wind conditions suddenly change so that the wind turbines produce less power. One of the main goals of ELOGOW is to develop a system where gas turbines can either be completely shut down or start up when required, thus eliminating the emissions caused by the gas turbines idling. This is achieved by combining wind turbines with battery and hydrogen systems.

The project is carrying out detailed feasibility studies on each energy source in the offshore environment, developing a system simulation model of typical offshore installations electrified with wind and energy storage/conversion, and developing an autonomous control and energy management system. The feasibility of the technologies developed in the project is also being studied.

ELOGOW's goal is to design a robust, stable, and predictable energy system that can be used by oil and gas facilities to considerably reduce greenhouse gas emissions. The goal is to offer systems that can achieve 50, 60 and up to 90 per cent reductions in CO_2 emissions.

The project is carried out by the Institute for Energy Technology (IFE) in cooperation with the University of Oslo, NORCE, Aibel, ConocoPhilllips, Equinor and Energy Valley.

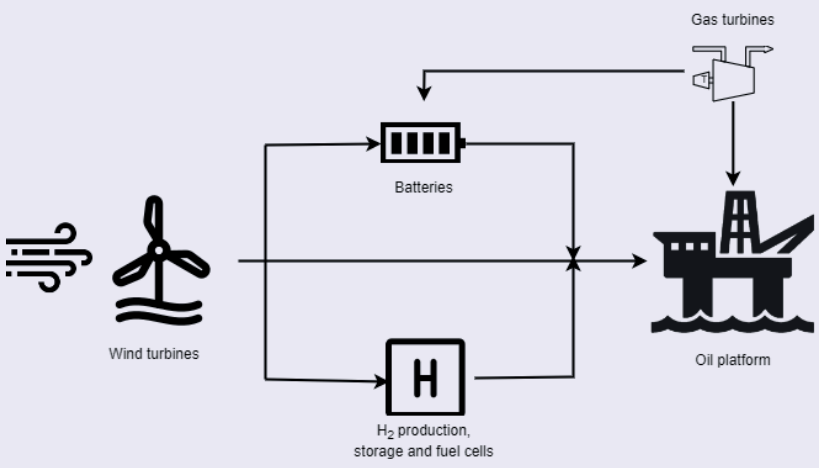


Illustration: Institutt for energiteknikk (IFE)

Reducing greenhouse gas emissions with an offshore hybrid energy system

Today, gas turbines are widely used to cover the power and heating needs of offshore installations. A research project at Clara Venture Labs, with NTNU and Lundin Energy Norway as partners, can reduce CO_2 emissions by up to 40 per cent through a hybrid energy system where hydrogen serves as back-up for renewable wind power.

Norway has a great unexploited potential in offshore wind power. The project *Innovative hybrid energy system for stable power and heat supply in offshore oil and gas installations* (HES-OFF) combines the two systems with an energy storage concept.

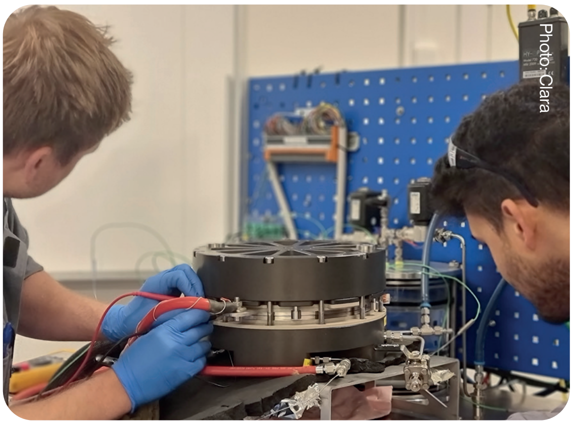
On days with high wind speed, the system can store excess energy by producing hydrogen. In periods with high power demand, the system can then use hydrogen to produce electricity.

The fuel cell system will function as a backup power supply system, and the renewable energy source is fully utilised. The hydrogen can also be used directly as fuel to the gas turbines and thereby reduce the consumption of natural gas. This gives cleaner fuel with lower greenhouse gas emissions. The HES-OFF concept can reduce CO_2 emissions by up to 40 per cent compared with a standard installation.

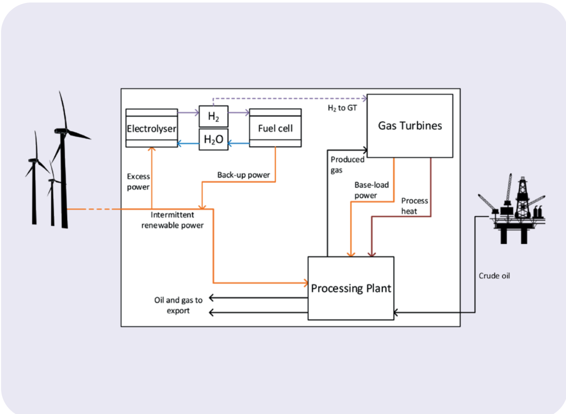
HES-OFF is developing a new concept for a stable power and heat supply to offshore oil and gas installations by combining expertise in fuel cells, offshore operations, modelling and experimental testing of hybrid systems. A tool for analysing such hybrid systems has been developed as part of the project results.

If waste heat is used more efficiently and heating needs are covered by a source other than gas turbines, emissions can be reduced by up to 80 per cent.

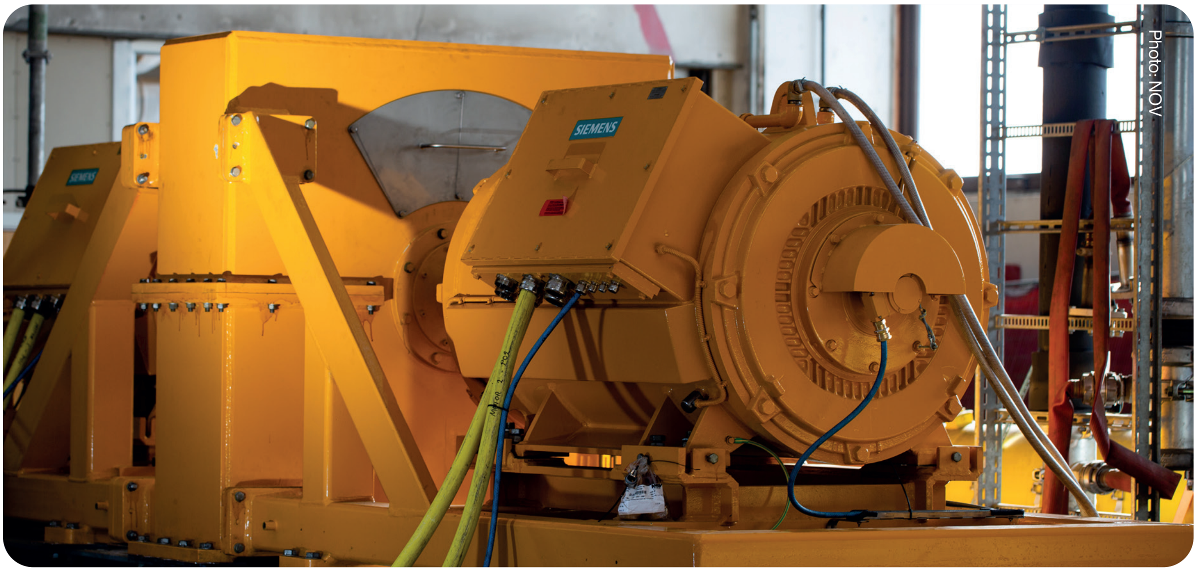
The following illustration shows the concept of how the various elements are connected in the hybrid system:



Fuel cell prototype at Clara Venture Labs.



PowerBlade™ Hybrid: Reducing harmful greenhouse gas emissions and increasing fuel savings on offshore installations



PowerBlade flywheel fully assembled at NOV's test area at Hunsfos, Vennesla

If offshore installations and vessels reduce their fuel consumption, it can lead to major cuts in emissions and operating costs. The PowerBlade project will develop a reliable and highly efficient energy storage system with limited space requirements. The system will ensure considerable fuel savings on floating drilling vessels.

The PowerBlade™ Hybrid system comprises a flywheel and a battery package that will reduce both fuel consumption, maintenance of diesel generators and harmful greenhouse gas emissions, and increase efficiency. It is an energy recovery system that stores surplus energy (produced by major consumers such as rigs hoisting systems) and returns it to the power grid when needed. The system regenerates energy that would otherwise be lost and can then replace energy that would normally be supplied by diesel generators. This will not be able to replace all diesel generators, but can assist them in a manner that makes operations more efficient.

PowerBlade™ Hybrid has a so-called “peak-shaving” property that means that it can handle the energy peaks, while the generators can supply the rig at a steady revolution per minute (RPM). Running a generator at a steady and optimal RPM will save both fuel and maintenance, since any major fluctuations are prevented. At best, the number of diesel generators can also be reduced. Calculations show that the PowerBlade system can save around 8,000 litres of diesel (which is approximately 20 per cent of what a vessel/rig uses), 17 tonnes of CO_2 and 300 kg of NOx every day. The project is carried out by National Oilwell Varco Norway AS in cooperation with Odfjell Drilling.

Carbon-free ammonia can provide emission-free shipping

Combustion engines and ammonia fuel – the key to de-carbonising shipping? Wärtsilä is currently developing combustion engines that can use ammonia as a fuel for ships and rigs, which can contribute to a possible zero-emissions solution for shipping.

A radical reduction in greenhouse gas emissions from shipping requires that the power production on board the vessels use carbon-free fuel. If ammonia can be produced without emissions of CO_2, it will be an important step towards making shipping emission-free. Ammonia in the form of gas or liquid is a well-known substance from the chemical industry and artificial fertiliser production, and well-known technology exists for handling ammonia in liquid form on large, sea-going vessels.

A great deal of the natural gas expertise Norway acquired from the 1960s and towards the 2000s is now possessed by Wärtsilä in Norway. Together with Nordic industry partners, the company has now proposed to use ammonia as a carbon-free fuel in shipping in the future. The main goal of the project is to develop systems and knowledge for better utilisation of green ammonia as a fuel in combustion engines, which can give the Norwegian industry and shipping a technological advantage regarding ammonia engines for ships and rigs. One important part of the project has been to develop safety systems related to ammonia combustion, which has been essential to obtain the necessary permits from safety authorities both in Finland and Norway. The first full-scale tests of ammonia combustion were performed in Wärtsilä's test laboratory in Vaasa. The technology is now set to be verified and improved through long-term testing of the engines at the Sustainable Energy Catapult Centre in Stord.

Following successful engine tests, the plan is for the technology to be installed and put into operation on board tankers or platforms in two–three years. The estimated reduction in CO_2 emissions corresponds to 1.3 tonnes for each tonne of ammonia used by the combustion engine.

The project is being carried out by Wärtsilä, in cooperation with Knutsen Oas Shipping AS, Repsol Norge AS, Maritime Cleantech AS and Sustainable Energy AS.

Photo: Wärtsilä AS

Egil Hystad, Willy Vågen, Kjell Storelid

Plugging oil wells using artificial magma

In the years ahead, several million oil and gas wells will be plugged after completing their service. In the past 10 years, Interwell has worked to develop a new method for permanently shutting down oil and gas wells (Plug & Abandonment – P&A).

The method and technology entails going down in the well with a simple tool containing artificial magma in the form of a thermite composition consisting of a metal-chemical powder that burns at approximately 3000°C. Thermite is a well-proven and safe substance, which is used, among other things, to weld together railway rails. When electrical energy is supplied, the chemical mixture ignites and melts all elements in the intersection of the well path and allows the melted mass to harden into a permanent gas-tight barrier in the well with bonding to the surrounding rock formation. The barrier prevents any future leakages in all annulus, where it could otherwise leak to the sea or air.

With this technique, the wells can be plugged using light intervention equipment from a vessel instead of a platform or rig, which is normally used. It installs in hours instead of days, which is considerably less resource intensive. In addition, only the chemical termite material brought with you is used, so that the need for cement is eliminated.

Interwell is cooperating with DNV and SINTEF on the technology qualification in addition to authorities and operators in selected geographical areas. The technology is currently in the commercialization phase in North America, where several successful field tests have so far been carried out onshore in Canada. This allows the technology to be tested in real wells and provides valuable feedback and confidence before further development and implementation in the more advanced multi-string wells offshore on the Norwegian continental shelf in the coming years.

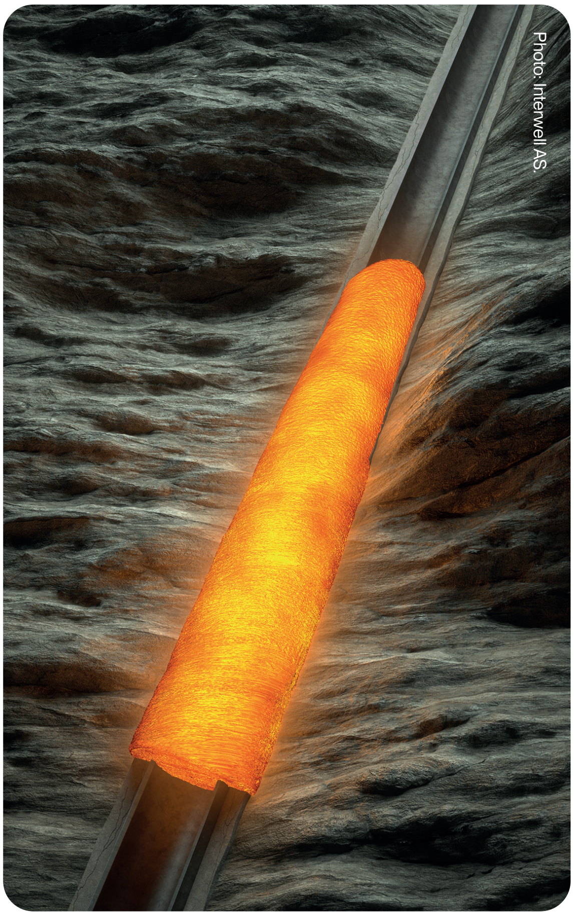


Illustration of how the thermite mixture melts all the elements in the well, establishing a gas-tight permanent barrier through the entire cross-section

Remotely operated drone can revolutionise underwater operations

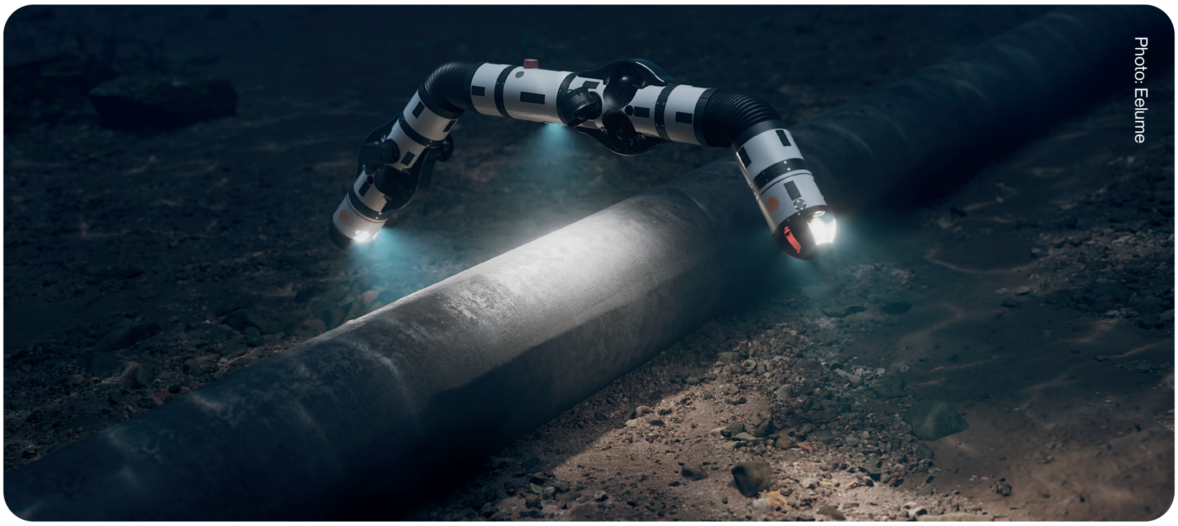
The Trondheim-based company Eelume is attracting international attention: A subsea drone controlled from land can totally transform how subsea operations are conducted.

Inspection, maintenance and repair of subsea installations in the offshore oil and gas industry, fish farming and offshore wind power are normally carried out by a diver or an underwater robot. The robot is remotely controlled, e.g. from a surface vessel. These solutions are time-consuming and, due to the need for a surface vessel, costly. Daily rental rates of NOK 1 million for a vessel that controls one robot are not uncommon. Reducing the need for surface vessels and ROVs (Remotely Operated Vehicle) also means less greenhouse gas emissions.

The use of autonomous underwater drones can completely transform subsea operations. An underwater drone can be installed and "live" permanently on the seabed near the offshore oil and gas installation without support from a surface vessel. The drone can start up in a matter of seconds and it operates on its own, so the need for control is minimal. Typical assignments are inspection of oil and gas pipeline, valve operations and inspection of fish farms.

Eelume is a three- to four-meter-long snake robot with sensors, lights, camera and tools. The robot is slender to ensure easier access to difficult areas. It can operate down to a depth of 500 metres and charge at a docking station without having to go up to the surface. The goal is for the robot to be able to "live" on the seabed for six months or more, and make offshore operations safer and cheaper, with reduced environmental impact.

The technology will be tested on the Åsgård field in a demonstration project funded by the Research Council. The drone will operate autonomously and carry out wireless inspections of oil and gas pipes and production facilities on the seabed. The project partners are Eelume, Equinor, Gassco, Kongsberg Maritime, MMT, Norbit, EIVA and DNV GL.



Eelume executes pipeline inspection on the seabed

Longer distances and reduced CO_2 emissions with new subsea technology

Deposits in oil and gas pipelines on the seabed are one of the biggest challenges in the oil and gas industry. Problems typically arise when the oil cools in the cold seabed environment, and it is therefore common to use a combination of heating cables, pipeline insulation and powerful chemicals. This leads to extensive costs and emissions.

The picture shows the cooler in dry dock in Trondheim where the mechanical system was recently qualified in a shallow water test.

Managing director Lars Strømmegjerde closest, and CTO/founder Fredrik Lund inside the flow loop facility.

Today, very expensive measures are taken to prevent wax and hydrate deposits (ice plugs). The Trondheim-based company Empig AS has, in cooperation with SINTEF, developed a cold-flow technology enabling energy-efficient and profitable field development without the use of environmentally harmful chemicals, thermal insulation or heating systems. The key is a subsea cooler that cools down the warm well stream on the seabed in a controlled manner, while simultaneously handling wax and hydrate deposits.

The oil is cooled as soon as it leaves the wellhead so that deposits are formed on the inside of the pipes in a dedicated cooling zone. Using induction heating, a robot then removes the deposits, which follow the pipe flow in solid, stable particles all the way to the platform/shore. Since there is no need to keep the oil warm, enormous amounts of energy, materials and money are saved.

By removing the current range limitations, the oil can be transported all the way to shore, and available capacity in existing offshore infrastructure (platforms) can be utilised. This leads to considerable cost savings and a significantly reduced carbon footprint. A concrete oil field in the Barents Sea has a potential for reducing its CO_2 emissions by 20–40 per cent compared with pipes that are heated.

Empig has partnered with four operators: Lundin, Repsol, Neptune Energy and TotalEnergies. The plan is for the whole system to be qualified and ready to enter the pilot phase after summer 2023.

Projects in the analysis PETROMAKS 2

Key

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

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

Project	Project owner	Project title				
280473	NORCE Teknologi	Decision-driven big data and analytics for the digital subsurface	Energy efficiency			
280610	SINTEF AS	Enabling non-disruptive production conditions - slug flow with surfactants	Energy efficiency			
280650	SINTEF INDUSTRI AS	Shale Barrier Toolbox: Designing future wells for efficient completion and simpler P&A	Energy efficiency	Lower emissions to air		Other
280705	SINTEF INDUSTRI AS	Improved lifetime estimation of mooring chains	Energy efficiency	Lower emissions to air		Other
280713	SINTEF ENERGI AS	Compact Offshore Steam Bottoming Cycles Phase 2: COMPACTS2	Energy efficiency	Lower emissions to air		
280919	NORCE Miljø/ Klima VESTLAND	High-throughput metabarcoding of eukaryotic diversity for environmental monitoring of marine sediments (Metamon)				Other
280934	SINTEF Digital	Autonomous subsea intervention (SEAVENTION)	Energy efficiency	Lower emissions to air		Other
280950	SINTEF Digital	Digital Subsurface: Flow Diagnostics and Data-Driven Modeling in Optimized Reservoir Management	Energy efficiency			
281810	PGS GEOPHYSICAL AS	Improved Subsurface Resolution by Controlled Marine Seismic Stimulation	Energy efficiency			
281848	STIMLINE AS	Real-Time Remote and Autonomous Well Intervention On Normally Unmanned Installations	Energy efficiency			Other
281855	OLIASOFT AS	Muliggjøre autonom brønnplanlegging ved å integrere alle myndighetspålagte beregninger for brønndesign i en integrert plattform.	Energy efficiency	Lower emissions to air		Other
281877	DNV AS	Safety 4.0: Demonstrating safety of novel subsea technologies			Electrification	
281881	LEDAFLOW TECHNOLOGIES DA	Accurate multiphase flow predictions for long tiebacks and subsea developments	Energy efficiency			
281917	AKER SOLUTIONS AS	Certified battery shut down system	Energy efficiency	Lower emissions to air	Electrification	Other
281927	KLINGER WESTAD AS	Additive manufacturing for repair and refurbishment of offshore components to extend structural lifetime	Energy efficiency			Other
281980	EARTH SCIENCE ANALYTICS AS	Machine learning in geoscience	Energy efficiency			
281986	CLARA VENTURE LABS AS	Innovative hybrid energy system for stable power and heat supply in offshore oil and gas installation	Energy efficiency	Lower emissions to air	Electrification	
282063	INTERWELL P&A AS	Permanent nedstengning gamle oljebrønner med et eller flere væskefylte ringrom ved bruk av høyenergi energi kilde, termitt.		Lower emissions to air		
282311	FMC KONGSBERG SUBSEA AS	Deep Purple - CO_2-fri hydrogenbasert offshore energi-produksjon til installasjoner og maritim sektor			Electrification	

Project	Project owner	Project title				
28400	SINTEF AS	Development of SMART nanostructured layers for sensing corrosion in AQUAtic structures				✓
285568	SINTEF AS	Well fossilization for P&A	chart			
294369	SINTEF AS	Improved prediction of stress and pore-pressure changes in the overburden for infill drilling	chart			
294404	NTNU	Geophysics and Applied Mathematics for Exploration and Safe Production		cloud		
294600	UNIVERSITETET I OSLO	PeTWIN: Whole-field digital twins for production optimization and management	chart	cloud	bulb	✓
294636	SINTEF AS	New Hydrate Management: New understanding of hydrate phenomena in oil systems to enable safe operation within the hydrate zone	chart			
294688	SINTEF AS	Optimized hydraulic behaviour in well construction	chart	cloud		✓
294689	NTNU	Multiscale Hydrogen Embrittlement Assessment for Subsea Conditions	chart			
294886	NORCE Tekno-logi/Energi ROGALAND	Foam dynamics in the presence of oil during multiphase flow in porous rock	chart	cloud		
295002	NORCE Tekno-logi/Energi VESTLAND	Assimilating 4D Seismic Data: Big Data Into Big Models	chart			
295035	SINTEF AS	NEXFLOW - Next generation oil-water flow models in production technologies	chart			
295132	SINTEF AS	Tophole monitoring of permanently plugged wells				✓
295173	NORCE Tekno-logi/Energi ROGALAND	Project of quantitative risk analysis for designs of permanent abandonment of wells	chart			✓
295708	INNOVATION ENERGY AS	Probing the use of electrochemical cells in downhole conditions to reduce the environmental footprint of Oil & Gas well Plug & Abandonment	chart	cloud		
296039	TURBULENT FLUX AS	Automatic prediction of reservoir inflow using data-driven physical modelling	chart			
296093	PETRICORE NORWAY AS	SmartRocks - Artificial Intelligence improving Digital Rock Technology	chart			✓
296193	OPTRONICS TECHNOLOGY AS	OPG11 optics		cloud		
296263	WELL ID AS	Development of Impulse Radar LWD tool	chart			
296586	KELDA DYNAMICS AS	Hydraulics Influx Tracking (HIT) – Real-time monitoring gas expansion while circulating out an influx	chart			
300286	HØGSKULEN PÅ VESTLANDET	Fundamental studies of plugging in multiphase flows with adhesive particles	chart			
300754	UNIVERSITETET I STAVANGER	Magnetic Recycling of Oilfield Production Chemicals - A New Green Approach Giving Zero Chemical Discharge		cloud		
301201	UNIVERSITETET I BERGEN	Optimizing CO_2 Foam EOR Mobility Control for Field Pilots	chart	cloud		

Energy efficiency | Lower emissions to air | Electrification | Other

Project	Project owner	Project title	Energy efficiency	Lower emissions to air	Electrification	Other
301412	NTNU	Pore Scale Simulations for Wettability Description	x			
301910	SINTEF INDUSTRI AS	Calibrated rock physics model for quantitative seismic analysis of two-phase fluid saturations	x	x		
306106	SINTEF AS	Chalk influx and solids production mitigation in the North Sea	x			
308735	NTNU	Efficiency increase and emissions reduction in offshore O&G platforms by wind integration, storage deployment and cooperative control	x	x	x	
308767	NORCE Tekno-logi/Energi ROGALAND	Fluid Migration Modelling and Treatment				x
308770	SINTEF ENERGI AS	PredictCUI: Prediction of water liquid and vapour migration for mitigating corrosion under insulation	x			x
308805	UNIVERSITETET I BERGEN	Rift and rifted margin deep-water depositional systems: Application to Late Jurassic – Early Cretaceous rifting on the NCS				x
308817	UNIVERSITETET I SØRØST-NORGE	Digital wells for optimal production and drainage	x			x
308823	SINTEF AS	KPN Hole Cleaning Monitoring in drilling with distributed sensors and hybrid methods	x			
308826	NORCE Tekno-logi/Energi VESTLAND	6n Degrees of Freedom Transient Torque & Drag	x	x		
308832	SINTEF OCEAN AS	PRAI: Predicting Riser-response by Artificial Intelligence	x			
308838	INSTITUTT FOR ENERGITEKNIKK	Electrification of Oil and Gas Installation by Offshore Wind		x	x	x
309238	DNV AS	C.PIMS - Composite Pipeline Integrity Management System	x			x
309268	WELLSTARTER AS	Heatwave Inflow Performance Source Characterization (HIPsource)				x
309280	VIPO AS	Development of Vikotherm R5	x			
309350	STIMLINE AS	Automated Well Intervention Planning and Method Selection	x			x
309397	FMC KONGSBERG SUBSEA AS	Deep Purple - H2Subsea - Undervanns infrastruktur for lagring og distribusjon av Hydrogen	x	x	x	
309552	OCEANTECH INNOVATION AS	ANDWIS - Automated Non Destructive Weld Inspection in Splash/Subsea zone		x		x
309576	XSENS AS	Clamp-on Mud Flow Rate and Quality Measurement	x	x		x
309626	SHAWCOR NORWAY AS	iHWI - Intelligent Heated Wet Insulation for pipelines	x		x	x
309921	INTERWELL P&A AS	Qualification of novel barrier materials for P&A	x	x		x

Project	Project owner	Project title
310027	RAGNAROCK GEO AS	Enhancing Reservoir Characterization by Applying Machine Learning
310055	IKM SUBSEA AS	Resident autonomous ROV with a minimal environmental footprint
310152	RANOLD AS	Etablering av beste praksis for innstrømningskontroll
310157	IDROP AS	iDROP Oceanid Navigator (iDRONA)
311505	SINTEF AS	Fleksibel Additive tilvirkning for krevende komponenter innenfor Maritim sektor
311714	SINTEF AS	Towards Artificial Intelligent Maintenance System (AIMS) via Predictive Failure Modelling and Numerical simulation
313854	NATIONAL OILWELL VARCO NORWAY AS	Fluid adjustments
313897	KAEFER ENERGY AS	Smart Sensor System to Detect Corrosion Under Insulation
313962	ALTUS INTERVENTION GROUP AS	Digital Well Internvention
314028	INFLOWCONTROL AS	Autonomous Inflow Control Valve (AICV) for økt oljeutvinning og redusert gassproduksjon
314165	LEDAFLOW TECHNOLOGIES DA	ChemFlow - Enabling subsea tiebacks with complex fluid chemistry
315804	SINTEF AS	Clean offshore energy by hydrogen storage in petroleum reservoirs
317673	ENODO AS	Structural integrity of PVDF pressure liners
317768	APPLIED PETROLEUM TECHNOLOGY AS	AI Augmented Analysis in digital biostratigraphy - paly-nology
317814	SCHLUMBERGER INFORMATION SOLUTIONS AS	Slug Field Model: The Next Generation Field Scale Slug Flow Simulator
317838	KONGSBERG FERROTECH AS	Subsea Additive Manufacturing for Lifetime Extension
318899	SINTEF ENERGI AS	Digital Twin for Optimal Design and Operation of Compact Combined Cycles in Offshore Oil and Gas Installations
319014	UNIVERSITETET I STAVANGER	New Cementitious Material for Oil Well Cementing Applica-tions - SafeRock
319158	SINTEF ENERGI AS	Offshore energy system optimisation considering load and storage flexibility
320100	UNIVERSITETET I TROMSØ - NORGES ARKTISKE UNIVERSITET	Environmental impact of Methane seepage and sub-seabed characterization at LoVe - Node 7
320257	INSTITUTT FOR ENERGITEKNIKK	Monitoring of glycol quality to Reduce operational risks

Energy efficiency | Lower emissions to air | Electrification | Other

Project	Project owner	Project title	Energy efficiency	Lower emissions to air	Electrification	Other
323858	NORCE Teknologi/ Energi VESTLAND	MarTERA - UNDINA, Underwater robotics with multi-modal communication and network-aided positioning system	✓	✓		✓
324227	SINTEF OCEAN AS	ENTrainment of oil In bREaking waves				✓
324306	UNIVERSITETET I STAVANGER	New Porous Liquids for Gas Separation and Carbon Capture		✓		
326580	NORCE NORWEGIAN RESEARCH CENTRE AS	Automated Well Monitoring and Control	✓			
326676	SINTEF DIGITAL	MAS – Meaningful Human Control in autonomy/ digitalization of safety critical systems	✓			
326711	SINTEF AS	MultiFlow SUITE: Smart Utilization of Data for CondItion Monitoring, Operational OpTimization, and Tie-in DEsign	✓	✓		✓
326725	SINTEF ENERGI AS	Clean Offshore Heat and Power Hub	✓	✓		✓
326876	RISE PFI AS	LignoWax – Green Wax Inhibitors and Production Chemicals based on Lignin	✓			✓
326965	UNIVERSITETET I BERGEN	ZechTec: A Renaissance of Central North Sea Salt Tectonics				✓
327265	INTELLIGENT MUD SOLUTIONS AS	Traceable integration of automated in-line rheology measurements with automated drilling control and diagnostic	✓	✓		
327686	WELL INTERCEPT AS	Aktiv magnetisk måling av brønnposisjon (AMM)		✓		
327806	JAGTECH AS	Optimized Shear Gun for Drilling Fluids	✓	✓		✓
327844	TYPHONIX AS	Coalescing Valve for next generation petroleum processing	✓	✓		✓
327865	HYDROTELL AS	Kontinuerlig overvåkning av hydrokarbon-reservoar	✓			
327880	SOLUTION SEEKER AS	Transfer learning for oil and gas wells: unlocking the collective potential of production data from multiple oil fields	✓			
328616	FISHBONES AS	Fishbones Post Acid Injection (FPAI) Modelling the effect of continuing acid stimulation post Fishbones jetting	✓			
328733	SAFEROCK AS	Development of Environmentally Friendly Metakaolin-Based Geopolymers for Oil Well Cementing and Well Abandonment – MGeo	✓	✓		
328742	METAS AS	Stand Alone Subsea Instrumentation System for hydrocarbon leak detection				✓
Antall totalt	**101**	**Antall**	**76**	**38**	**12**	**43**

Projects in the analysis DEMO 2000

Key

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

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

Project	Project owner	Project title	Energy efficiency	Lower emissions to air	Electrification	Other
281894	REELWELL AS	PowerPipe Pilot		✓	✓	
281939	SCHLUMBERGER INFOR-MATION SOLUTIONS AS	HD-technology for Steeply Inclined and Vertical Flow: Production Optimization for Wells, Risers and Pipelines	✓	✓		
281998	PETRELL AS	Advanced Lower Completion Tool	✓			
282016	NATIONAL OILWELL VARCO NORWAY AS	PowerBlade Hybrid	✓	✓	✓	
282027	BENESTAD SOLUTIONS AS	HV Wet Mate Connection System (WMCS)			✓	
282085	FORCE TECHNOLOGY NORWAY AS	Development of a Field Gradient Sensor (FiGS®) for autonomous subsea vehicles	✓	✓		
282101	KONGSBERG DIGITAL AS	LedaFlow model accuracy improvements required for tighter design to help lower project development and operations costs	✓			
282115	NOV PROCESS & FLOW TECHNOLOGIES AS	Kinetic Hydrate Inhibitor Removal, Recovery and Reuse from Produced Water and Rich MEG Streams	✓			
282122	SCI AS	Pilottest av undervanns elektrisk aktuator	✓		✓	
282158	TOOLSERV AS	Completion time saving tool	✓	✓		
295774	EELUME AS	No strings, piloting a subsea resident Underwater Intervention Drone (UID) system.	✓		✓	
295820	FISHBONES AS	Navigated Well Stimulation	✓			
296037	SIEMENS ENERGY AS	Next Generation Subsea Control System - Subsea DigiGRID Demonstrator	✓		✓	
296237	OLIASOFT AS	Pilotering av et komplett digitalt verktøy for brønndesign hos ledende operatører	✓	✓		
296537	INNOWELL SOLUTIONS AS	Pilotering av DAR inflow control technology for økt utvinning, oljeproduksjon og redusert miljøbelastning	✓			
296653	AKER SOLUTIONS AS	Mechanical driveline for All-electric FSC actuator	✓	✓	✓	✓
296669	NDT GLOBAL AS	Crack detection		✓		✓
309361	BENESTAD SOLUTIONS AS	Benestad High Voltage Power Wet Mate Connection System Phase II			✓	
309444	HYDROPHILIC AS	Demonstrasjon av Hydrophilic Probe	✓	✓		✓

Energy efficiency | Lower emissions to air | Electrification | Other

Project	Project owner	Project title				
309607	ROXAR FLOW MEASUREMENT AS	Adaptive Gas Lift	✓	✓	✓	
309704	EMPIG AS	Always Clean Cooler pilot: A subsea cooler that enables long distance cost effective transport of oil and gas	✓		✓	
309732	AKER SOLUTIONS AS	Control Unit for All-electric FSC actuator	✓	✓	✓	✓
309737	OTECHOS LEGACY AS	OTECHOS CRP: Robust, compact multi-phase pump for subsea boosting and well artificial lift (phase 2)	✓		✓	
309789	FAST SUBSEA AS	FASTsubsea X - The simplest and most cost effective and modular subsea multiphase pump available. "Topside-less" and "All electric"		✓		
309890	PRORES AS	At-the-Bit Mud Loss Control - Demonstration of a New Mud Loss Control Methodology and Tool Converting the Drilling Mud to a Downhole Pill	✓			
309907	COREALL AS	Field testing of Intelligent Coring System (ICS) and IDD Module	✓	✓		
309932	FLUIDSEP AS	Pilottest av nedihulls vannseparator - system for forbedret reservoarutnyttelse og redusert CO_2 utslipp	✓			
310099	WHITSON AS	Cloud-based, Fluid and PVT Management and Equation of State Model Utilization Tool	✓			
310124	DEOX AS	Oksygenfjerning fra sjøvann	✓			
313765	AKER SOLUTIONS AS AVD TRANBY	Power and Communication Gateway Module for intelligent systems	✓	✓	✓	✓
313775	NORWEGIAN TECHNOLOGY AS	CleanCut – full-scale demonstration of a new approach to treatment of offshore drill cuttings and evaluation of its environmental aspects	✓	✓		✓
313803	AARBAKKE INNOVATION AS	Kvalifisering og demonstrasjon av MTR for muliggjøring av riggløs P&A.	✓	✓		✓
313906	SEKAL AS	Demonstrating smart drilling automation application	✓	✓		✓
313941	KEYSTONE.NO AS	Digital Rig Management	✓	✓		
313976	RESMAN AS	Longevity: Providing enhanced release and analytical method to enable continuous monitoring over 10 years in producing wells	✓			
314691	WÄRTSILÄ NORWAY AS	Green Ammonia fuelled four-stroke Engines on the Norwegian Continental Shelf	✓	✓		
315086	MHWIRTH AS	Digitalisering av manuelle logistikkprosesser innen boring - bruk av elektronisk tally	✓	✓		
317795	IDROP AS	Elucidate - effektiv og kompletterende seismisk belysning med fokus på unike anomalier i sjøbunnen ved kartlegging og produksjon offshore	✓	✓		✓

Project	Project owner	Project title				
317853	WELLGRAB AS	Utvikling og kvalifisering av brønn intervensjons-roboten WERFT (Wellgrab Electric Release Fishing Tool)	📊	☁		
317857	WELLSTRØM AS	Utvikling og demonstrasjon av verktøyet T-1000 og nytt pluggdesign	📊	☁		
317900	PREDIKTOR AS	Drilling Systems Interoperability Demonstrations	📊			
317901	EDRILLING AS	An "updated-while-drilling" Advisory system.	📊			
317910	ONESUBSEA PROCESSING AS	Subsea Compact All Electric Pump - Carbon Footprint Optimized	📊		💡	✓
327596	FMC KONGSBERG SUBSEA AS	eVXT next generation subsea	📊	☁	💡	✓
327836	GMV AS	Rotamill - Innovativt section milling konsept (fresing av fôringsrør).	📊	☁		
327849	KONGSBERG DIGITAL AS	Automated real-time pore pressure and wellbore stability updates in a digital twin, using wired-pipe and log predictions ahead of bit	📊			
327959	NOV PROCESS & FLOW TECH-NOLOGIES AS	Product Validation of the NOV Subsea Storage System	📊	☁	💡	✓
Total	**47**	**Numbers**	**42**	**26**	**16**	**12**

More information about these and other relevant projects can be found in The Project Databank on the Research Council's website: https://www.forskningsradet.no/en/

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