The Research Council of Norway

DEMO 2000 – Bridging the gap between R&D and field use

Programme

Project-related technology development in the petroleum sector – DEMO 2000

About the Programme

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The DEMO 2000 programme is an initiative supported by the Ministry of Petroleum and Energy (MPE) to ensure long-term competitiveness in the oil and gas industry and the continued profitable development on the petroleum resources on the Norwegian Continental Shelf. The programme also aims to develop innovative Norwegian industrial products, systems and processes for the global offshore market. The steering group for the programme consists of representatives of oil companies, the service industry and research institutes.

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Better than all the rest
MPM's multiphase metre is so precise that it satisfies oil companies' requirements for fiscal accuracy. It will make calculations of production volumes and taxes far easier.

More oil and gas, less pollution

The quest for oil and gas drives operators towards ever more demanding challenges – ultra-deep offshore development projects, zero footprints on the environment, extremely long tiebacks and getting more value out of the ground. New technology is the key and DEMO 2000 is helping us get there.

The Norwegian petroleum industry has become a technology leader in several areas, driven by a demanding domestic market and an export-oriented industry located in one of the major offshore oil and gas provinces of the world. The know-how built up by the Norwegian petroleum industry over a period of almost 40 years now competes on a global market.

Today, however, the upstream oil and gas industry faces new challenges, e.g. deeper water, the demand for higher oil and gas recovery and, last but not least, environmental concerns.

Technological research and development are key to solving these challenges. The companies have invited equipment suppliers and the service industry to develop the necessary solutions and to have them field tested and ready for market on time. Pilot tests require substantial resources and close cooperation between suppliers and oil companies. DEMO 2000 is an important contributor to this, paving the way for testing and allocating funding which, in turn, triggers funding from industry.

Morten Wiencke

Easy on the environment

New technologies developed under the DEMO 2000 programme are intended to enhance the recovery rate of oil and gas, but that is not their only advantage.

"Perhaps the most important aspect of the new technologies we have helped develop is that they make petroleum production more environment-friendly", states Morten Wiencke, programme director for DEMO 2000.

"All the projects we have supported involve technologies that are vast improvements over conventional technology when it comes to the environment. This refers to better resource utilisation, reduced air and water pollution, and less energy spent on operations".

Delayed without DEMO 2000

In a joint effort, the Norwegian Government and the oil industry set up the DEMO 2000 programme to promote Norway's long-term competitiveness in the oil and gas industry and continued profitable development of the petroleum resources on the Norwegian Continental Shelf. Since the start in 1999, operators, the service industry and research organisations have given their wholehearted support to DEMO 2000.

"Introducing prototype technologies to the market is a challenging task", remarks Svein Bredahl, chairman of the DEMO 2000 programme board and senior vice president, Aker Kværner Field Development.

"The DEMO 2000 programme has clearly been instrumental in the final testing and implementation of key technologies in our business. These include high-resolution seismic imaging, smart wells, subsea separation, seabed boosting and compression, deepwater risers and installation systems, to name just a few. Without DEMO 2000, these developments would have been delayed by several years", Bredahl points out.

Svein Bredahl

At home and abroad

DEMO 2000 aims to develop and accelerate the uptake of new technologies in all parts of the value chain in the upstream oil and gas industry by bridging the gap between R&D projects and their implementation. The programme has pinpointed three main objectives. These are to:

- Initiate specific projects for development, technology demonstration, field trials and piloting;
- Develop new technology to increase the value of exploration and development of the Norwegian Continental Shelf;
- Develop new Norwegian industrial products, systems and processes for the global offshore market.

"Exports are definitely a target for the DEMO 2000 projects", reports the programme director. To qualify for support, a product must have export potential and be in demand on the international arena.

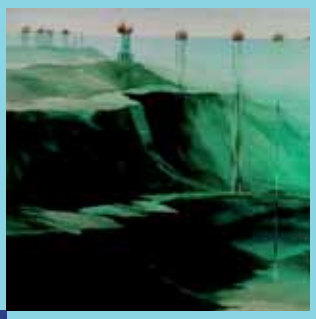
Innovation always important

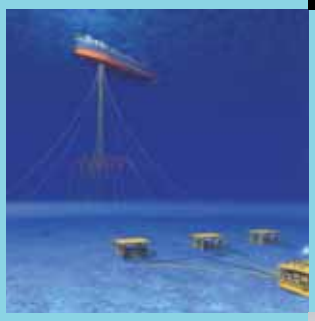
"DEMO 2000 depends on close cooperation with the major operators, both in Norway and abroad", observes Wiencke.

DEMO 2000 has also been following developments closely since the merger of two of Norway's largest petroleum companies (Statoil and Hydro). "Naturally, DEMO 2000 will cooperate closely with StatoilHydro", he adds.

Wiencke hopes that DEMO 2000 will provide inspiration for the supply industry to develop solutions continuously to meet the technological challenges of tomorrow in the oil industry. "Even when oil prices are high and the industry is busy, it is important to stay focused on innovation and new technology", Wiencke concludes.

Although R&D calls for players to take a long-term perspective, results are already beginning to emerge. You can read about some typical DEMO 2000 projects on the following pages. For more information about the DEMO 2000 programme, the projects and points of contact, please see **www.forskningsradet.no/DEMO2000** or **www.demo2000.no**





Key technology areas

DEMO 2000 focuses on seven key technology areas, as defined in Norway's national strategy "Oil and Gas in the 21st Century" (OG21):

- **Subsurface.** Real-time reservoir management. Enhanced recovery. Geophysical methods of exploration and production
- **Wells:** Cost-effective drilling. New drilling and well concepts. Smart wells. Well intervention
- **Remote Processing:** Seabed and compact processing. Long-range multi-phase transportation. Seabed boosting
- **Deep Water and Subsea:** Floaters for deep water or marginal fields. Mooring and risers. Development of marginal fields. Subsea systems. Development under icy conditions
- **Gas technology:** Competitive gas production and offtake. Gas conversion. Cost effective development of marginal fields with associated gas
- **E-fields:** Integrated operations
- **Technology for the Arctic:** Safe, environment-friendly petroleum production in the Arctic

An engineer's dream come true

The Tordis IOR SSBI project is the first ever to fulfil the age-old engineering dream of separating oil, sand and water on the seabed before anything is pumped up. This ground-breaking technology has the potential to extend the lifetime of an oil field by 15 to 17 years.

Maturing fields that have been producing oil and gas for several years can pose problems. As reservoirs are depleted, wellstreams consist of less oil and more excess water and sand.

Situated at a depth of 200 metres between Gullfaks and Snorre, Statoil's Tordis field, is maturing rapidly. The field has been running since 1994, but has been producing more and more water and less and less oil in recent years. The platforms have not had the capacity to handle all the excess water pumped up from the field. This has made it particularly difficult to engage in optimal production with the technology applied up until now. However, this is about to change.

FMC Technologies has designed and built a groundbreaking full-scale separation facility for subsea use, the goal of which is to reduce pressure in the reservoir and separate the water and the sand, making it easier to extract oil. This new technology will make the Tordis field the world's first full-scale commercial subsea separation, boosting and injection system.

A new era in oil production

The new Subsea Separation Boosting Injection System (SSBI) on Tordis IOR (Increased Oil Recovery) is the industry's first full-scale application based on seabed separation of oil, water and sand. It is tailor-made to address the problems of maturing fields.

» After all, this system is not something you build from a spec, but by putting the best and brightest heads together.

"The system extracts water and sand from the wellstream on the seabed, and then re-injects the water into a separate subsea well, thereby reducing the back pressure towards the Tordis field and allowing more hydrocarbons to be produced. A multiphase pump is then used to boost the oil and gas back to the Gullfaks C offshore platform", explains Ann Christin Gjerdseth, project manager for FMC Technologies.

The system, including the boosting pumps, has been designed to handle large volumes of sand (50 to 500 kg per day) based on its sand management system.

"Sand disposal is an important function", adds Gjerdseth.

"By flushing the sand into a de-sander module and then into the disposal well where it is mixed with separated water, we also save considerable wear-and-tear on the injection pump caused by abrasion as sand passes through it".

Along with other upgrades to the field infrastructure, the recovery rate on the Tordis field is expected to increase from 49 per cent to 55 per cent, which translates into roughly 35 million extra barrels of oil. FMC's subsea processing equipment is expected

NEW ERA: FMC Technologies has designed and built a full-scale separation facility for subsea use. Project Manager Hans Kristiansen, Statoil, and Project Manager Ann Christin Gjerdseth, FMC, are pleased with the teamwork. Photo: FMC Technologies

to account for about 19 million barrels of the increased recovery.

"Tordis is opening up a new era in offshore production", predicts Gjerdseth.

Began with DEMO 2000

The Tordis IOR SSBI technology started with a programme managed by DEMO 2000 involving Statoil's Norne Pilot Project in 2003. At the time, this was the world's largest full-scale test of a subsea separator.

The subsea separator was a full-scale model built in a flow loop in the lab and tested at CDS Engineering in Arnhem, The Netherlands. Actual flow rates were tested and the project provided invaluable information, teaching researchers a great deal about sand management. Although the Norne Pilot was never

» We also save considerable wear-and-tear on the injection pump caused by abrasion.

brought to fruition, the results were used to design the subsea processing installation for Tordis. Statoil held several rounds of competition before ultimately awarding the contract to FMC Technologies in 2005.

Sand removal

System assembly was completed in early April 2007. There was then a period of extensive testing before the system was delivered and installed in mid-August. The PLIM (Pipeline Infield Module) was installed in summer 2006, followed by a water injection tree in early 2007 and the subsea separation, boosting and injection system in summer 2007. The full system was handed over to the Statoil operations team in October.

"The first major phase of testing took place prior to assembly of the station. It involved a three-month test of functionality. We assembled the whole system and ran through all the auto sequences", continues Gjerdseth. "The aim was to ensure that the controls, instrumentation and pumps all worked together as an integrated system. To make the testing more realistic, a dynamic field simulator was used to provide feedback on the effects of control operations".

Two cultures

Gjerdseth points out that one of the biggest challenges on this project has been to bring two very different cultures together.

"The subsea culture, as we know it today, aims to achieve high reliability by keeping things simple. But the next generation subsea system, like the separation station for Tordis will be a complex processing system that must be capable of flexible, real-time control and fine-tuning, just like a topside system".

Gjerdseth is very pleased with the cooperation between the parties involved. "The teamwork has been excellent. After all, this system is not something you build from a spec, but by putting the best and brightest heads together", Gjerdseth remarks.

Tordis IOR SSBI*

Subsea processing system, which comprising subsea water separation, multiphase boosting, and the re-injection of water.

- **Company:** FMC Technologies *(fmctechnologies.com)*
- **Partners:** Process internals – CDS Engineering, Pumps – Framo Engineering, SSBI fabrication – Grenland Group
- **Pilot:** CDS Engineering in Arnhem, The Netherlands

Photo: FMC Technologies

An effective catalyst

Who should shoulder the risk associated with testing new technology for the first time? "This is invariably a difficult question", states Morten Loktu of StatoilHydro. "It is therefore splendid that DEMO 2000 exists and acts as an effective catalyst".

Morten Loktu was recently appointed Chair of the Programme Board of OG21 and is senior vice president of research and development at StatoilHydro, a merger of two oil companies which, combined along with contracting partners and other oil companies, have taken advantage of the DEMO 2000 scheme repeatedly since 1999.

What has the scheme meant for StatoilHydro?

"The DEMO 2000 scheme is very welcome catalyst, both for us and for the oil industry in general. The scheme improves our testing and allows us to qualify technology more quickly. This is good".

Photo: Øyvind Hagen, StatoilHydro

Morten Lotku, Statoil Hydro

What is the most important aspect of the scheme, the money or the quality assurance?

"Both aspects are important for StatoilHydro. Testing is expensive, so financial contributions are an incentive", observes Loktu.

"However, it is equally important that the scheme paves the way for pilot programmes and qualifications of new technology. There is a high risk associated with first-time implementation, which is why no one wants to be first. It is better to be the second or third to use the technology, once most of the teething problems are resolved. For that reason, new technology has a tendency to be left hanging. This is where DEMO 2000 comes in, and that is important".

Technology gave Shtokman-admittance

StatoilHydro has been involved in most of the technological innovations presented in this publication, and in many more of the 160 projects supported by DEMO 2000.

"DEMO 2000 has played an important part in the development of Norwegian petroleum technology. As far as StatoilHydro is concerned, I would refer to subsea activities in particular, where a great deal of progress has been made in recent years. Tordis IOR (Increased Oil Recovery) is a prime example, as is MultiBooster technology", Loktu points out.

"I am fairly certain that our subsea technology has also been decisive for gaining admittance to the Shtokman field".

Are there special technological challenges associated with oil production in the Arctic?

"Most definitely. The Shtokman field is located 500 kilometres from land. That in itself raises a series of technical and logistical challenges. Extremely low temperatures present a major challenge. Arctic operations are completely dependent on the development of new technologies".

More research in future

Many have been worried that overall research efforts at StatoilHydro will diminish now after the merger, but Morten Loktu rejects that out of hand.

"We have no plans to cut back, quite to the contrary", he underlines.

"As we now move into new waters, go deeper and start to produce heavy oil, we will have to focus intently on research and the development of new technologies. Environmental and climate-related challenges require that of us as well".

What does StatoilHydro expect of DEMO 2000 in the years ahead?

"We hope the programme will continue and be further expanded. With the right technology, there is still considerable recovery enhancement potential on the Norwegian Continental Shelf. Norway must also be proactive with a view to new oil and gas fields all over the world. DEMO 2000 helps us maintain a brisk pace of R&D", concludes Loktu.

New drilling system puts the pressure on

A totally new drilling concept will enhance recovery rates, cut drilling costs and make drilling safer. The secret lies in a dual channel drill string with a piston that generates pressure.

It was Dr Ola Michael Vestavik who conceived the idea of installing a piston on the drill string. It allows him to put the liquid under pressure and thus to move forward with hydraulic power using the drilling fluid as a 'hydraulic lubricant'.

In conventional drilling, the drill string is moved forward by gravitational force, while Vestavik's piston system picks up the pace significantly. The piston works like a ram. A simple principle, according to Vestavik, but it works.

"I patented the invention some years ago when I worked for RF-Rogaland Research (now IRIS), but the time was not ripe at that point", comments Vestavik, who founded a company of his own, ReelWell, in the Rogaland Knowledge Park in 2004.

His project was supported by PETROMAKS during the R&D stage and is now ready for technology demonstration with the help of DEMO 2000 fundings.

Drills long distances and in all directions

To date, there have been serious limitations on how steeply it has been possible to drill horizontally. The idea behind the ReelWell solution is that it is possible to drill in any direction and to increase the horizontal range considerably. That translates into a significant increase in the recovery rate.

The pending demonstrations will test the dual jointed pipe version of the drilling system.

First, the device will be put to the test at IRIS' laboratory at Ullrigg in Stavanger in a 1300-metre deep vertical well. Then the drilling system will be tested in a pilot well on an oil field some place in the world.

If the tests are successful, ReelWell's new concept for managed pressure drilling will be ready for industrial use in the North Sea as well as worldwide.

Tens of billions of NOK

"The new drilling technology is good for several reasons", maintains Ola Vestavik.

"First of all, it will offer better control of the pressure in the well. That will make drilling safer and reduce the chance of a blow-out – the most feared phenomenon in the petroleum industry. Our system offers an extra safeguard in the drill string that facilitates this", he reports.

"Secondly, we will be able to drill further from the platforms. And last but not least", continues Vestavik, "costs will be reduced. Drilling will be less expensive because the device will solve some of the problems on site. Drilling will proceed more quickly, and require cheaper, lighter equipment".

» ReelWell will make drilling safer and reduce the chance of a blow-out.

"All in all, the ReelWell drilling concept will enable us to recover a lot more oil from the ground. Calculations indicate that we can create added value worth tens of billions of NOK as a result of this technology each year in Norway alone", concludes Vestavik.

MORE: The ReelWell drilling concept will enable us to recover a lot more oil from the ground. Photo: ReelWell

ReelWell

A new drilling concept using pressure on a downhole piston to move the drill string forward.

- **Company:** Reel Well AS *(www.reelwell.com)*
- **Partners:** StatoilHydro and Shell
- **Model test:** IRIS' laboratory at Ullrigg in Stavanger

Fibre rope revolution

The installation of oil production components is heavy going. This is especially true since cranes, winches and wires of steel are extremely heavy in themselves. With activities moving into continuously deeper water, the sheer weight of the system makes operations almost impossible. ODIM's CTCU technology appears to be the solution.

From its Subsea Equipment Support Vessel (SESV) which has recently been contracted by the Brazilian oil company Petrobras, Aker Oilfield Services will be providing a broad range of services related to subsea equipment intervention, handling, testing, retrieving and installing subsea X-mas trees at depths of 2000 metres and beyond. However, when running its advanced deepwater equipment, the company will not be using cranes or conventional steel wires.

Aker's new enterprise is going to do what many oil companies and marine contractors the world over are now contemplating, i.e. switching from steel wires to fibre rope. Fibre rope weighs only one-tenth as much as steel wire. This can signal a revolution for installation at extreme water depths! Technology from the Norwegian company ODIM can make this possible.

ON BOARD: CTCU Technology in use on Aker oilfield services vessel. Photo: AOS

Gentle treatment of rope

It all began with an idea at ODIM for a device to handle long lengths of coil, such as cables and fibre rope, in a gentle manner. The idea was patented in 1998 and has subsequently been further developed, produced as a prototype and tested in collaboration with several oil companies and DEMO 2000. The resultant technology is known as a Cable Traction Control Unit (CTCU).

"We are currently in discussions with most of the players operating in the new deepwater fields off the coasts of Brazil, Mexico and West Africa", states Per Ingeberg, managing director of ODIM Alitec, a technology development company under ODIM ASA. "Aker Oilfield Services has already ordered a 125-metric tonne CTCU hoisting system that is scheduled for completion in 2009. The industry appears to be accepting the use of fibre rope".

One-tenth the weight

No wonder, really. Using fibre rope instead of steel wires to install equipment and secure platforms offers tremendous advantages. This is particularly true when working at great depths that require long wires from the cranes.

Fibre rope is just as strong as steel wire in the same dimension, but weighs only one-tenth as much in air. In water, fibre rope is virtually weightless. This enables the rope to handle far more weight than steel wires in deep water, since it need not carry much net weight of its own.

Cranes and winches and the vessels or rigs on which they are installed can also be smaller, calling for less power to perform operations. That is also a good thing for the environment.

"This expands considerably the fleet of vessels that can install equipment, and it also promotes competition and

PROTECTION: ODIM's CTCU uses individually controlled sheaves which move at different speeds, protecting the fibre rope. Photo: ODIM

lowers costs. More and smaller vessels mean that the work can be performed more quickly", states Ingeberg.

Technological challenges

Fibre rope is nothing new, and there are several technological challenges associated with it. For instance, fibre rope stretches by one to three per cent under stress. Moreover, with the traditional traction winch, slippage between the rope and drums generates heat and abrasion, causing wear on the rope and leading to premature failure.

ODIM's patented Cable Traction Control Unit (ODIM CTCU™) has proved its ability to overcome these problems using individually controlled sheaves which move at different speeds, distributing the load evenly to prevent spinning and slippage.

"A pilot project was performed on Norway's Ormen Lange field in 2005. Anchors were attached to a template at a depth of 860 metres. The success of the pilot project has been very important for convincing the industry that this technology is worthwhile", comments Ingeberg. Since then, ODIM has demonstrated this technology in the Gulf of Mexico, and is currently working in Nigeria. These efforts have also been successful.

"The DEMO 2000 grant triggered funding from the oil companies so that we could perform the first pilot project. That was absolutely decisive for making us what we are today", adds Ingeberg.

>> The DEMO 2000 grant was absolutely decisive for making us what we are today.

International attention

As the deepwater market grows, CTCU technology will attract more and more international attention.

"We are the only technology of our kind that has managed to penetrate the market", continues Ingeberg. "This is incredibly exciting, and the deepwater market is still in its infancy".

ODIM is currently looking for new applications for its technology, and is involved in two new DEMO 2000 projects.

ODIM CTCU™

A cable traction control unit that makes it possible to use fibre rope instead of steel wires in the petroleum industri.

- **Company:** ODIM Alitec *(www.odim.com)*
- **Partners:** 2002-2005: Odim, Petrobras, Hydro, Technip, Statoil, Subsea 7, Shell and Innovation Norway. New project: Subsea 7, Statoil, Shell, Aker Oilfield Services
- **Pilot:** Ormen Lange field, Norway

Steeled against the elements

The development of offshore technology that can stand up to severe environmental conditions is extending into deeper water. The need to further develop riser systems is paramount. Aker Kværner Engineering & Technology has accepted the challenge and is preparing its steel risers for stormy weather.

In ultra-deep water, riser systems present a technical challenge. High pressures and great water depths cause flexible solutions to encounter both weight and cost problems.

"Under harsh environmental conditions like those we see off the coast of Norway, semi-submersible platforms with flexible risers have proved their value for the development-projects on oil and gas fields in medium to deep water over the past few decades. However, as development moves to even greater depths, the industry has a growing need for Steel Catenary Risers (SCR)", points out Gunnar Arnesen of Aker Kværner Engineering & Technology.

To meet the industry's needs, Aker Kværner Engineering & Technology has cooperated on a DEMO 2000 Joint Industry Project (JIP) with Statoil, Hydro, Shell, BP and MARINTEK to develop a robust gas field development solution. The solution involves a semi-submersible platform featuring a draft of 40 m, which is equipped with a 24-inch steel catenary gas export system for harsh environmental conditions. All parts of the system have been declared suitable for deepwater conditions on the Norwegian Continental Shelf.

Existing technology in a new package

Over the past decade, the industry has invested extensive efforts in producing SCR technology as an alternative to flexible risers.

>> As the development moves to even greater depths, the industry has a growing need for Steel Catenary Risers.

"In harsher deepwater environments such as those off the coast of Norway, the use of flexible risers become more and more difficult. More reliable Steel Catenary Risers are needed. That requires the semi to be especially designed for this type of risers", explains Arnesen.

Deepwater testing

The project has demonstrated the feasibility of the concept through extensive coupled analysis. It has also performed a model test by truncating mooring and riser lines and simulating full depth.

The semi-submersible platform features a topside that weighs about 25 000 tonnes and steel catenary risers for gas export through pipes with a diameter of up to 24-inches. The solution has been tested in MARINTEK's basin, one of the deepest in the world.

"We evaluated and analysed various measures for addressing the problem of riser fatigue. Ultimately, we concluded that using a deep draft semi combined with weight coating on a limited length of the risers is an effective measure for achieving the integrity we need on the hull, moorings and risers", concludes Arnesen.

The semi hull delivered by Aker Kværner's Verdal fabrication yard last year is the commercial breakthrouh for this novel design.

Integrated SEMI/Steel Catenary Risers (SCR)

Combines the Semi-submersible Production Platform and Steel Catenary Riser design, developing a new, simple and robust integrated solution.

- **Company:** Aker Kværner *(www.akerkvaerner.com)*
- **Partners:** Statoil, Hydro, Shell, BP, MARINTEK and DNV.
- **Model test:** MARINTEK

Moving on to greater depths

Norway's AGR Ability Group AS has dramatically altered the drilling landscape with its patented Subsea Riserless Mud Recovery (RMR). The technology has already proven operational at depths of up to 400 metres. Now it's going deeper and becoming more environment-friendly.

Seabed geology featuring shallow geohazards presents conditions such as soft soils, swelling clay, shallow gas and shallow water flows. These factors often make it difficult to drill and increase the likelihood of damaging wells by soil movement.

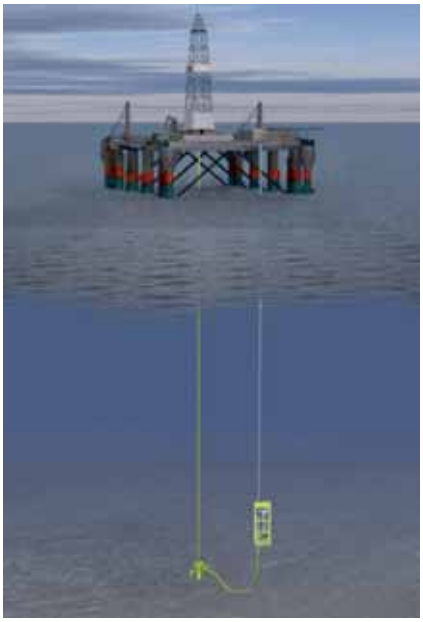
>> RMR makes drilling more efficient and more environment-friendly.

Traditionally, approaches to top hole drilling have involved either full mud circulation to the surface through a Marine Drilling Riser or relied on 'pump and dump' methods, based on spilling mud and cuttings onto the seabed. In deep water, the 'pump and dump' method is by far the most common, and the fluid is weighted up to control any shallow hazard. Up to three vessels may shuttle to and from shore to keep up with the fluid volumes, possibly supplying as much as 50 000 to 60 000 barrels of fluid that is dumped on the seabed. If unexpected fluid losses occur or bad weather hampers the supply chain, there is a risk of loosing the well.

Already in 2003, AGR Subsea Inc. came up with a solution to overcome these drilling challenges. Now, they are working hard to make their Riserless Mud Recovery system operational at greater water depths.

Field trial in Malaysia

RMR differs from conventional drilling approaches. Instead of using a conventional riser through the water column to extend the annulus around the drill pipe to the surface, the return flow is collected and diverted at the seabed, and then pumped to the surface as though drilling had been moved to seabed level.



GOING DEEP: AGR has developed a method that make it possible to drill in deep water without pipe liners for reinforcement. Photo: AGR

Since its launch, the system has been used to drill the top hole sections of more than 50 wells at depths up to 400 m (1 300 ft) in the North Sea, Barents Sea, the Caspian, Egypt, off Sakhalin Island, and off the coast of Australia.

The RMR Deepwater JIP steering committee recently decided to field test an updated version of the technology at Shell Miri in Malaysia in mid-2008.

"This is the next step in exploring the depth capacity of our cutting edge technology", says Roger Stave, president of AGR Subsea Inc.

Environment friendly

AGR's riserless drilling is more than merely an efficient way to make a top hole. Just as unique is the fact that the system allows the operator to collect spent drilling fluid and cuttings from the seabed and then pump them back to the rig, thus ensuring that the zero discharge goal can be achieved for this part of the drilling process. The cuttings are separated on the rig before the drilling fluid is reused.

"In shallow water, returns to the surface via a Marine Drilling Riser are common. However, this is prohibited in Norway owing to the danger of gas on the rig. Consequently, when drilling in Norway or in deep water, it is common to return elements with obvious environmental consequences to the seabed. We need to use reasonably priced fluids consisting of seawater (brine), bentonite and starch", explains Stave.

"RMR makes it possible to use higher quality fluid since it is recycled and re-used, making the drilling operation more efficient and more environment-friendly", he concludes.

DEMO 2000 RMR Deepwater JIP
Subsea Riserless Mud Recovery.

- **Company:** AGR Subsea Inc *(www.agr.no)*
- **Partners:** BP and Shell
- **Pilot:** Shell Miri in Malaysia

THE COMPRESSOR: This CAD model shows how the wet gas compressor is envisaged integrated into a subsea module. (Ill.: Framo Engeneering)

Compressing gas on the seabed

With the Framo Wet Gas Compressor 2000 (WGC2000), Framo Engineering AS is presenting one of the world's largest, most powerful subsea gas compressors to date.

Natural gas streams smoothly enough through kilometres of pipelines on the seabed and is controlled by flow and pressure metres. Wet gas, on the other hand, causes problems.

Wet gas must be thoroughly dried prior to transport, but even today's advanced scrubbers are not perfect. Small amounts of fluid accompany the gas to the compressors and represent a risk of operational disruptions and reduced life due to erosion or mechanical break-down in compressors that are not designed to operate on a mixture of gas and liquid. This situation is unacceptable for reasons of safety as well as because of the high costs incurred.

Photo: Framo Engeneering

WET GAS COMPRESSOR: This compressor enable gas export either onshore, offshore or subsea.

The Framo Wet Gas Compressor 2000 offers the solution. It is one of the world's largest, most powerful subsea gas compressors to date.

Smart solution

"Present technology in gas fields that require increased export pressure separates the gas and liquid and then increases the gas pressure by means of dry gas compressors and the liquid pressure by means of pumps. The alternatives are either to put the platform subsea, which inevitably results in very large subsea stations, or to use wet gas compressors that can increase the pressure directly without separators, resulting in compact, simple subsea compressor stations.

>> The compressor is ideal for boosting production from small gas fields.

Present-day dry gas compressors can only tolerate very small amounts of liquid in the gas. The Framo Wet Gas Compressor, on the other hand, is designed to operate continuously on zero to 10 liquid (by volum) in the gas and can be operated on any mixture up to pure liquid", says Jørgen Eide at Framo Engineering AS.

The vertical compressor has two times 10 stages that are driven by two counter-rotating electric motors, one on top and one underneath the compressor section. This results in a very short and compact compressor section. The mechanical design and the non-surging characteristics of the impellers offer a compact machine that eliminates the need for a fast-acting protection control system.

The electric motors are the same as those used in subsea multi phase pumps and are protected from the seawater and process fluid by a light oil that is kept above the gas pressure and cooled by the surrounding seawater. The motors are driven by a common frequency converter that enables a soft-start and stepless speed control from 1 500 to 4 500 rpm.

K-Lab testing

The installation and testing of the compressor were conducted at K-Lab at Kårstø, a large-scale laboratory owned by Statoil.

"The compressor that has been tested has a net shaft power of 3 600 KW and is ideal for increasing the production from small gas fields. A larger compressor suitable for full field development is being manufactured under an ongoing in-house project and will be tested in spring 2008", concludes Eide.

Framo Wet Gas Compressor 2000

A Subsea Wet Gas Compressor that can be operated on any mixture up to pure liquid.

- **Company:** Framo Engineering AS *(www.framoeng.no)*
- **Partners:** Statoil, Shell and Hydro
- **Model test:** K-Lab at Kårstø

Going north

The prospects of making formidable petroleum discoveries in the Barents Sea have made the oil companies look to the High North. The area offers entirely new technological challenges with a view to recovery as well as the environment.

Photo: Tom Schandy / NN / Samfoto

Norwegian Minister of Foreign Affairs Jonas Gahr Støre has named the High North Norway's most important strategic target area, and a large number of strategies for the High North have been presented over the past two years. The Research Council of Norway has been very active in this area.

The source of this new interest lies in the knowledge that approximately one billion cubic metres of oil equivalents are located in the cold remote Barents Sea (Norwegian Petroleum Directorate estimate). With today's oil and gas prices, this could translate into assets worth about USD 350 billion. No wonder the stakeholders in the area have begun to jockey for position.

The outside world has followed along with Russia and Gazprom's every move relative to the Shtokman field with great interest. StatoilHydro recently gained admittance to Shtokman, probably as a result of its technology.

Photo: Sebastian Gerland, Norsk Polarinstitutt

Must protect the environment

The environment is at the heart of the efforts in the High North. Oil and gas production in the Arctic could have major consequences for ecosystems on land and at sea, as well as for the people in the area. The oil industry and the public sector must and will take this into account.

>> DEMO 2000 contributes to the development of technology that makes recovery easy on the environment.

"For DEMO 2000, this implies contributing to the development of technology that makes recovery easy on the environment", says Programme Director Morten Wiencke, adding that the development of technology that can cope with the cold, ice and remote location of the fields also presents formidable challenges, and that they should be the focus of attention.

"OG21 indicated that R&D aimed at recovery in Arctic waters should focus on certain elements, e.g. fluid control for pipeline transport to land across very vast distances, power supply for heating and boosting subsea pipelines and production systems, robustness, an adequate design basis in cold, harsh and icy waters, and system availability of subsea systems during ice", adds Wiencke.

For more information about the Research Council's efforts in the High North, see www.forskningsradet.no/nord

Sharing Arctic information

Years of research in the High North have produced enormous amounts of data and information. How can all this expert information be made available to and benefit the oil industry? The Arctic Web has the solution.

The petroleum industry's exploration and production activities in Arctic regions present a shared challenge to all involved. Everyone expects the activities to take place without serious environmental impacts. For years, the area has been the site of significant research programmes aimed at evaluating the potential environmental impact of petroleum activities. Since 1985, about NOK 1 billion have been spent on various data collection activities in the Norwegian sector alone.

» The data collections undoubtedly represents vital knowledge for petroleum activities in Arctic areas.

Thus, vast amounts of data are available to research institutes and operators. The problem is that the data may not be utilised owing to a lack of availability.

"The Arctic Web is a new Internet portal designed to ensure full availability. With today's technology in distributed IT solutions and by signing agreements and collaborating closely with the most important data owners in Norway, such data can be adapted and made available through a *single* portal", comments Kjell-Are Vassmyr, project manager for the Arctic Web at Acona CMG AS.

Turning up gaps

"The data collections undoubtedly represent vital knowledge for petroleum activities in Arctic areas. However, oil companies and others in the petroleum industry currently find it difficult to get effective access to design basis data for their petroleum activities. The data also has to be up to date and quality controlled", adds Vassmyr.

The plan is to collect, qualify and make vital design-basis data available through an Internet-based file sharing system.

"Data is stored, updated and maintained best by those who manage this type of data", Vassmyr points out. "Instead of duplicating a number of databases inside the various petroleum companies, we ensure that data is available directly from the data owners themselves. At the same time, data from operators are also handed over to key data owners when applicable. Cooperation will thus enable continuous updated data for all parties".

"Thus far, the project includes the following data owners: The Institute of Marine Research, Norwegian Polar Institute, Met.no, Norwegian Mapping Authority, Geological Survey of Norway, Directorate of Fisheries, Norwegian Petroleum Directorate, Coast Directorate, Norwegian Institute for Nature Research (NINA) and the Directorate for Nature Management (DN)".

30 topics

To date, about 30 different data topics have been identified. The data are sorted into the following main categories: Biology, Infrastructure, Metocean, Ice and Bathymetry (Seabed).

At present, the project is limited to the Norwegian sector of the Barents Sea. Once the portal has been developed, the companies intend to expand the Arctic Web to other geographical regions in the High North.

"The Arctic Web can help ensure that any gaps in the available data are revealed and it may influence future data collection. The data collected by the petroleum industry itself will certainly be made available and systematised in a far better way than what is the case today. Our ambition is for the Arctic Web to be the preferred gateway for all important design-basis data for the High North", concludes Vassmyr.

The Arctic Web

A tailor-made portal for data and information related to the High North.

- **Company:** Acona CMG AS *(www. acona.com)*
- **Partners:** Norut IT, Akvaplan Niva

Photo: The Norwegian Polar Institute

A chilly challenge

The petroleum industry is facing entirely new challenges in Arctic waters. In these ice infested areas, safe petroleum activities call for knowledge and technology to monitor the thickness and drift of ice. Now experts are testing equipment to improve the safety of operations in these frozen waters.

Operating in cold, iceberg-infested areas presents dangers that require real-time surveillance of ice drift patterns and ice thickness in the areas around stationary or floating platforms. It is particularly important to detect the thickest ice, so-called ice keels and ice ridges, which can be more than 10 m thick. Thick ice is actually one of the most severe risk factors for operations in Arctic waters. Accordingly, such operations depend upon the existence of systems to detect and monitor the drift of thick ice.

In 2006, the Nansen Environmental and Remote Sensing Center (NERSC) in Bergen applied for support from DEMO 2000 to test a 3D imaging sonar for measuring ice thickness. In April 2007, the first tests were performed from the research vessel *Lance* north of Svalbard and in the Hinlopen Strait using the Echoscope, a 3D imaging sonar made by CodaOctopus Omnitech AS.

>> Thick ice is actually one of the most severe risk factors for operations in Arctic waters.

"We will use lessons learned from this project to establish ice monitoring systems in areas where anchored platforms will be installed. We envisage that the Echoscope will be one of the instruments in the system that will help ensure the safety of offshore operations in Arctic waters", explains Project Manager Stein Sandsven.

DOWN UNDER: Lowering the Echoscope through a hole in the ice. The insert shows Echoscope mounted on a frame with a data unit and cable for lowering into water. Photo: NERSC

Through a hole in the ice

The equipment was tested at three different locations under varying ice conditions over a period of two weeks. Scientists from the Nansen Environmental and Remote Sensing Center, Statoil and CodaOctopus carried out the test with support from scientists and students from UNIS.

The equipment, consisting of the Echoscope 3D, a data unit and a cable were lowered through a hole in the ice and placed on the seabed to observe the underside of the ice and icebergs. An ROV (remotely operated vehicle) with a video camera was used to verify the readings.

"Preliminary results indicate that the Echoscope 3D imaging sonar lends itself well for measuring ice thickness and drift", comments Sandsven.

Further testing will be carried out in 2008 when the instrument will be operated from a platform on the seafloor. The project is scheduled for completion in 2009.

ICESONAR

New equipment for measuring ice thickness.

- **Institution:** The Nansen Environmental and Remote Sensing Center *(www.nersc.no)*
- **Partners:** UNIS, Statoil and CodaOctopus
- **Model testing:** From the research vessel *Lance* north of Svalbard and in the Hinlopen Strait

Going deeper and further for oil

Deep down in the ocean, far from the host platform, there is more oil. Plenty more. Hard to get? Not any more. With the award-winning multiphase pump Subsea MultiBooster, the life of oil fields can be extended on a large scale.

The new Aker Kvaerner pump is five metres long, 2.5 metres wide and five metres high. After years of development and testing, the 45-tonne Subsea MultiBooster has now come onstream.

In the Gulf of Mexico, at a record-breaking depth of 1700 metres and 29 kilometres from the platform, two pumps – and a third for backup – are being put to the test. No one has ever gone this deep with this technology, nor have they been further away from the host platform.

The MultiBooster was purchased by the oil company BP for Aker Kvaerner's King field in the Gulf of Mexico, proof positive that this is a definite commercial breakthrough.

"This technology is a milestone for Aker Kvaerner's subsea boosting technology" says Executive Vice President Raymond Carlsen of Aker Kvaerner Subsea. "We have been waiting for this for several years".

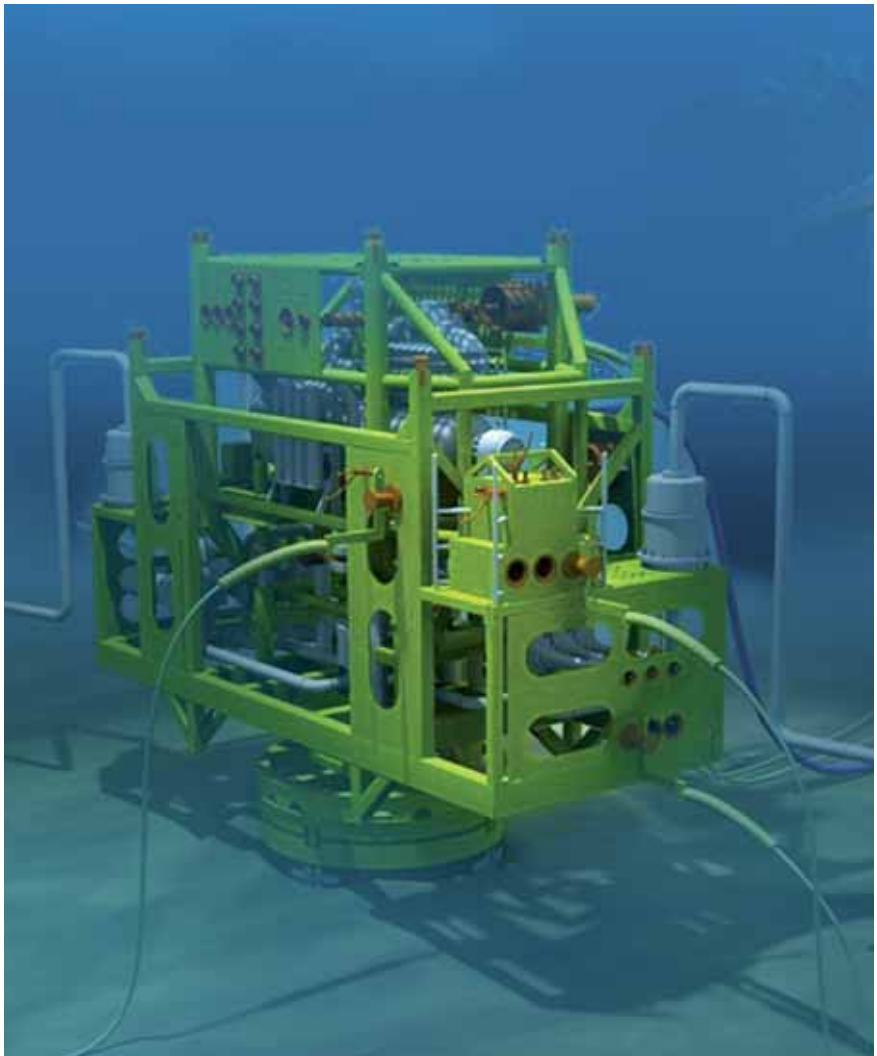
Pressure boosting technology

It all started 20 years ago when Kvaerner began developing its pressure boosting technology. First, they made a separation unit and a pressure booster which would separate sand, water, oil and gas on the ocean floor, enabling gas and condensate to be pumped through a pipeline to an onshore facility. This would eliminate the need to build expensive offshore installations.

Award-winning

In 1992, the Kvaerner Booster Station received the prestigious ONS Innovation Award. This was a bold decision by the Offshore Northern Seas foundation, ONS, as the construction had only been tested onshore. However, as it turned out, the ONS was wise in its decision: The successor, the Subsea MultiBooster, which is now at the bottom of the Gulf of Mexico pumping up oil, won the same award 14 years later, in 2006. ONS had been ahead of its time and welcomed a fully tested technology which promises to extend

IN USE: After years of development and testing, the 45-tonne MultiBooster is now in use. Photo: Aker Kværner



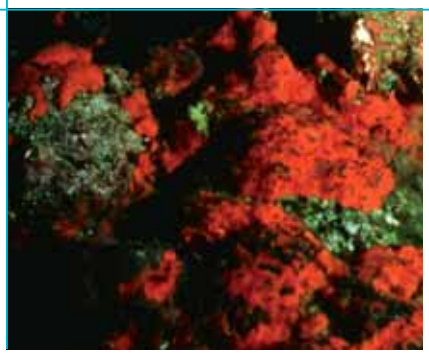


Photo: NOAA Fisheries

the production lifetime of existing oil fields.

That same year the MultiBooster was awarded another prestigious prize, the Spotlight on New Technology Award, at the Offshore Technology Conference in Houston.

"It came as a pleasant surprise that we have won an award for yet another of our innovative technologies. We see a great potential for multiphase pump technology", Raymond Carlsen at Aker Kvaerner Subsea said at the time.

The subsea multiphase pump – at last

With the Subsea MultiBooster, the industry has got another tool in its toolbox for increased oil recovery.

The pump adds energy to the wellstream, requiring less production pressure from the well heads. This leads to increased oil extraction from existing wells, which in turn makes it possible to make use of satellite discoveries further away from the oil installations.

>> Fields at great depths far from established platforms are no longer unreachable.

Two screws inside the pump make sure that the mixture of gas and liquid are given a pressure boost for increased flow through the flow line to a topside installation for further processing.

The entire unit is made of steel and tolerates pressure up to 250 bars.

Hence, the multiphase pump can be placed at ocean depths of 2500 metres.

Multi-million dollar development

The path from an idea to a prototype to a fully tested structure ready for production and commercialisation has been long. Collaborative efforts by Aker Kvaerner, Hydro, Statoil, ENI, CNR, Total, Shell, RWE-DEA, ExxonMobil and DEMO 2000 have made it possible.

"It is a well known fact that the maturity of many oil fields necessitates innovative solutions to continue production. The R&D funding available through DEMO 2000 has supported Aker Kvaerner's drive to create a technology to increase oil recovery. Now it is up to the oilfields' license holders to agree on strategies that facilitate further uptake of such technologies", says Raymond Carlsen.

The MultiBooster was first tested at Aker Kvaerner's subsea facility at Tranby, Norway. Following numerous tests under water, the module was shipped to Statoil's K-Lab (Metering & Technology Laboratory) at Kårstø for hydrocarbon tests before the yellow giant was finally piloted in the British sector.

Huge market

Now the MultiBooster is ready to extend the productive life of oil fields. Fields at great depths far from established platforms are no longer unreachable. Subsea pump technology can help here too.

The market for multiphase pumps consists of small satellite fields gathered around pre-existing offshore facilities and infrastructure. In the North Sea alone, Aker Kvaerner has identified 60 projects where this technology may be of use. Counting international projects, the number is around 550. The fact that the MultiBooster can go so deep makes oil fields in the Gulf of Mexico and off the coasts of Brazil and West Africa potential areas of interest for the application of this technology.

At the King field in the Gulf of Mexico, the application of the MultiBooster is expected to boost recovery by 10 to 20 per cent.

In other words, chances are that the millions spent on the development of the Subsea MultiBooster will pay off with interest.

MultiBooster™

A complete subsea multiphase pump module that adds energy to the wellstream and makes sure that the mixture of gas and fluid is given a pressure boost for increased flow through the flow line.

- **Company**: Aker Kværner *(www.akerkvaerner.com)*
- **Partners:** Hydro, Statoil, ENI, CNR, Total, Shell, RWE-DEA, ExxonMobil
- **Pilot:** Lyell (UK)

Better than all the rest

What is actually inside a pipeline? How much oil, gas and water are flowing through it? And how? The oil industry is screaming for this information. The Norwegian company MPM may be able to give them accurate answers thanks to its new instrument.

"The performance of the MPM Meter was significantly better than that of any of the other multiphase metres tested", said a Statoil employee on Gullfaks A, following the final round of tests in February 2007. Once again, the new metre made by the Stavanger-based company Multi Phase Meter AS (MPM) demonstrated exceptionally good results, despite very challenging flow conditions.

Today, both the topside and subsea versions of MPM's high performance flow metre have been qualified and are in production. StatoilHydro and two other oil companies have bought the new metres, and Managing Director Hans Olav Hide is beaming with satisfaction.

>> Our system is so accurate that it satisfies the oil companies' requirements for fiscal accuracy.

"We have developed something that the oil industry has been waiting for for a long time", he says. "A metre for multi-phase flow which measures accurately and efficiently, and thus increases the recovery rate, reduces costs and makes recovery simpler and safer".

LABORATORY: Managing Director Hans Olav Hide in MPM's flow laboratory in Stavanger. Photo: MPM

Accurate

It is a real challenge to measure how much oil, water and gas are in a multiphase flow without separating the liquids. The mix can vary and is often impossible to predict. Multiphase measurement is complex.

"Developing this technology has been a tougher nut to crack than anyone could have foreseen", states Hide.

However, with support from six oil companies and DEMO 2000, development has nonetheless been possible through a series of costly development and qualification processes. Precision is currently one of the MPM Meter's most important advantages.

The metre is based on the patented 3D broadband technology for high-speed measurements of flow rates. Like tomography in the field of medicine, this technology scans the flow in the pipeline, producing a 3D image of it. The difference is that this takes many pictures every single second.

Better income distribution

"Qualification tests we've performed recently indicate that the system can measure multiphase flows with a margin of error compared with the reference point of only one to one and a half per cent. With ordinary measuring equipment, a margin of error of 10-30 per cent is not unusual", comments Hide.

Photo: Arve Henriksen, Aftenposten

"Our system is so accurate that it satisfies the oil companies' requirements for fiscal accuracy. For fields involving many different licences, this will make calculations of production volumes and taxes far easier and more accurate".

All in one

The 3D technology allows the MPM Meter to bridge the gap between conventional multiphase metres and wet-gas metres.

It used to be necessary to decide in advance what kind of metre should be used in a pipeline. You also risked having to replace the multiphase metre with a wet-gas variety, or vice versa if the flow was different from what was expected.

The MPM Meter has eliminated all those problems.

"The High Performance Flowmeter is a true all-in-one", confirms Hide.

A must have

MPM and the oil companies which have taken part in the process believe there is a bright future in store for the new metre. This can translate into significant value added for the oil industry.

» The High Performance Flowmeter is a true all-in-one, bridging the gap between conventional multiphase metres and wet-gas metres. It has also been honoured for its good design.

"On a field currently under development, the operator has estimated that using multiphase flowmetres will increase recovery by two to four per cent of the oil in the reservoir", continues Hide.

At the opening of MPM's flow laboratory in Stavanger in 2005, Alan Burns, R&D manager at the oil company Total, stated that "This is a piece of technology that is about to make the leap from being 'nice to have' into one that offshore oil and gas operators will soon be treating as a 'must have' ".

"We are most definitely at that point today", asserts Managing Director Hide.

MPM Meter

A multiphase flow meter based on the patented 3D BroadBand™ technology for high-speed (tomographic-like) measurements of the flow rates.

- **Company:** MPM AS *(www.mpm-no.com)*
- **Partners:** Conoco Phillips,ENI, Hydro, Shell, Statoil and Total
- **Pilot:** Gullfaks A, Norway

Foto: MPM

Norwegian activities

OG21 – Oil and gas in the 21st century

OG21 is a Task Force established by the Ministry of Petroleum and Energy (MPE) of Norway in 2001 to help the petroleum industry to formulate a national technology strategy for added value and competitive advantage in the oil and gas industry. The objective is to develop a more co-ordinated and focused approach to research and development throughout the oil and gas industry. The initiative has received strong support from the industry.

To meet OG21's vision of a sustainable petroleum industry for the next 100 years, players will make joint efforts concentrating on knowledge and technology will be made, and eight Technology Target Areas have been identified. Most of the TTA groups are led by oil companies to ensure the commitment of the industry. OG21 is an umbrella organization providing strategic directions and alignment for the PETROMAKS and DEMO2000 programmes.
www.og21.org/

Optimal management of petroleum recources – PETROMAKS

PETROMAKS is the umbrella for most of the petroleum-oriented research supported by the Research Council of Norway. The programme covers both long-term basic research and applied research, resulting in the development of new competence as well as innovation. This is the largest single programme run by the Research Council of Norway.
www.forskningsradet.no/petromaks

International connections

The petroleum service industry operates globally and faces common challenges across oil and gas offshore provinces of the world: ever deeper water, remote and harsh areas, increased recovery, reduction of costs and above all request for clean energy. Supported by the DEMO 2000 programme, new products and systems can be accepted as field proven in new markets. Assisted and facilitated by INTSOK, several workshops and conferences have been conducted in key export markets. The network of international connections includes related R&D programs in UK, USA and Brazil:

Norwegian Oil and Gas Partners – INTSOK

The Norwegian Oil and Gas Partners was established in 1997 by the Norwegian oil and gas industry and the Norwegian Government. INTSOK's objective is to work with companies throughout the industry to expand the business activities in international oil and gas markets using the industry's experience, technology and expertise. DEMO 2000 works with INTSOK in several of its key markets.
www.intsok.no/

The Industry Technology Facilitator – ITF, UK

Established in 1999, ITF is a global, non-profit organisation based in the UK, owned and governed by operators and service companies. ITF's key objectives are to identify technology needs, foster innovation and facilitate the development and implementation of new technologies.
www.oil-itf.com

DeepStar, USA

DeepStar is a US-based joint industry technology development organization focused on advancing technologies to meet its members' deepwater business needs to deliver increased production and reserves. DeepStar participants represent a strong mix of large and mid-size operators, based inside and outside the US, drawing on a rich array of diverse expertise to address common deepwater challenges.
www.deepstar.org/

The Research Partnership to Secure Energy for America – RPSEA, USA

RPSEA is a non-profit corporation formed by a consortium of premier US energy research universities, industry and independent research organisations. RPSEA's mission is to play a stewardship role in ensuring focused research and the development, and the deployment of safe, environmentally sensitive technology. RPSEA has established and coordinated a public benefit research programme to identify and develop new methods and integrating systems for exploring, producing, and transporting energy, or other derivative products from natural gas, in ultra-deepwater and unconventional onshore hydrocarbon resources.
www.rpsea.org

Petrobas and PROCAP-3000, Brazil

Petrobras is a major oil company and one of the industry leaders in advanced deepwater technology. Their PROCAP-3000 Programme aims at developing technology for safe production at water depths down to 3000 m.
www.petrobras.com

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