Norsk olje&gass

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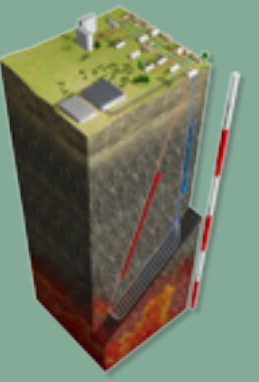

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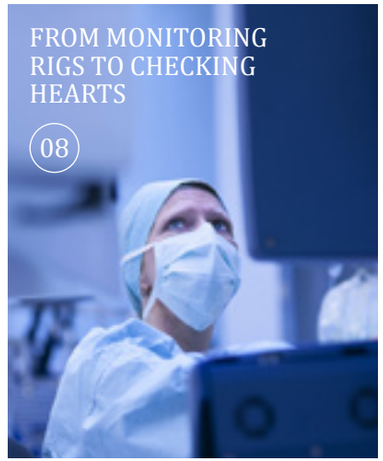

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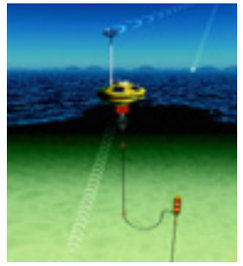

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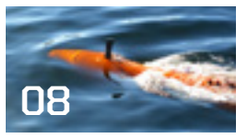

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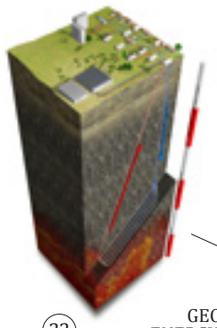

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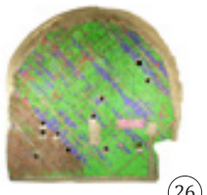

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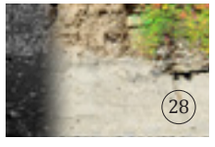

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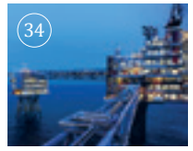

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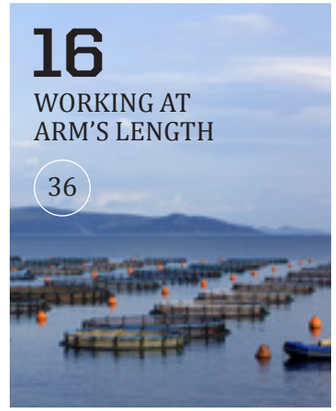

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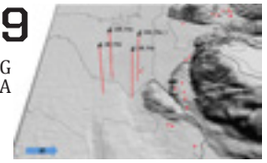

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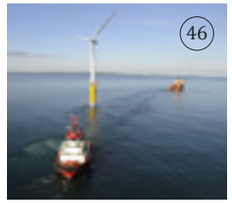

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WE BUST BOUNDARIES

DID YOU KNOW THAT TECHNOLOGY FROM NORWAY'S OIL AND GAS SECTOR CAN BE USED TO MONITOR HEART PATIENTS AND FINANCIAL TRANSACTIONS, CHARGE ELECTRIC CARS, PROVIDE FIELD HOSPITAL AND EXPLORE MARS?

We have compiled a report on *Technology transfers from the oil and gas sector* in cooperation with Rambøll, and present it through these pages.

They show some of the ways in which technology developed by the oil and gas industry is busting boundaries and contributing to other sectors. A total of 26 examples of such technology transfers are presented.

Norway's petroleum industry currently employs 250 000 people, directly or indirectly. The supplies – or oil technology – business ranks as the largest mainland Norwegian industry and the country's largest export sector after oil and gas.

It employs almost 200 000 people in 4 000 companies, and has annual sales of more than NOK 360 billion. Companies in this sector pursue extensive innovation and technology development, utilised both on the Norwegian continental shelf (NCS) and in the rest of the world.

Technology and solutions from these companies are not only exported to other countries and new markets, but have also been passed to other sectors. Examples include renewable energy, space exploration and health care.

Such transplanting of technology, knowledge and production methods from one industry to another is generally termed technology transfer. Ensuring that innovations benefit a broad range of products and people worldwide, it represents a very important tool for progress.

As with Tesla for electric cars, Apple for consumer electronics and Nasa for the space industry, the petroleum sector plays a key role in all scenarios for future energy supplies. We're part of a global technology industry which is moving the world forward.

Our technology and our expertise will and must play an important role in determining the best way to recover the resources both in deep water and in more extreme climates.

That's when the opportunities will come. That's when innovation will happen. That's when we become part of the solution. Because we bust boundaries.

We're boundary busters because we are Norway's most important technology industry and Norway is a leading offshore nation for developing new technology and new solutions.

We're boundary busters because clever and creative people and companies in our industry see opportunities to develop and apply advanced knowledge gained offshore in completely new ways and for entirely different applications than producing petroleum.

Many of the opportunities for continued development of the Norwegian knowledge society lie here: in offshore oil and gas, in industries of the kind described in these pages, and in applications we still don't know about.

Gro Brækken
Director-general
Norwegian Oil and Gas Association

01 FROM OIL SPILL COLLECTION TO FIELD HOSPITALS

Hard-wearing oil containment booms have proved to have far wider applications than originally imagined – including the provision of temporary medical facilities.

NorLense provides an example of a Norwegian petroleum-related business which has taken a step further to see new potential for its products. Established in Fiskebøl in northern Norway's Lofoten islands in 1975, this company has been a pioneer in developing modern oil-spill clean-up gear.

It is now a world leader not only in this field but also for inflatable tents as well as tarpaulins (including lift bags), and covers for outdoor hot tubs and winter storage of pleasure craft.

The hard-wearing inflatable oil booms proved to be useful well beyond their original purpose. Their durable material can accordingly protect boats and hot tubs from wind and weather.

And their inflatable function has been extended to easily installed tents for accommodation, command or communication centres, field hospitals and a wide range of other applications.

When NorLense won a contract from the Norwegian armed forces in 2000 to clean and maintain army tents, it quickly saw the potential for applying its high-pressure technology to develop a better solution.

The outcome is a temporary structure measuring six metres wide, which can be erected easily and efficiently by one person in less than 15 minutes.

These tents are very user-friendly and remain unaffected by climate or temperature. They function just as well in the Arctic as in the tropics.

Because of its wide range of applications, this NorLense product has customers worldwide – including the Norwegian army, civil defence and Red Cross.

02 FROM MONITORING RIGS TO CHECKING HEARTS

A system developed to keep an eye on offshore drilling has also proved effective for risk scrutiny at stockbrokers and observing cardiac patients.

A spin-off from the Norwegian University of Science and Technology (NTNU) in Trondheim, Verdande Technology originally developed its monitoring system for the petroleum sector.

This solution is based on tracking real-time data combined with knowledge transferred from earlier incidents, and has also been adopted today by several other sectors.

On drilling rigs, the system monitors such parameters as the amount of mud circulating and downhole pressure. Information is collected continuously and compared with a database of earlier cases and incidents.

The latter contains details of symptoms and subsequent events, so the continuous data-gathering makes it possible to recognise the development of symptoms and their previous consequences.

With 92 drilling rigs worldwide currently using the system, experience from the oil and gas sector indicated to Verdande that its solution could be useful in other sectors.

One of these is health care. The company is now developing a system in cooperation with Houston Methodist Hospital, which has one of the USA's leading heart clinics.

This version collects sensor data from patients before and after they have been operated on, monitors symptoms and compares them with earlier cases.

Verdande's approach has also proved useful in the financial services industry. It is used by stockbrokers, for example, to check if clients are taking inappropriate risks.

That partly involves looking for systemic errors which allow clients to buy more financial instruments – such as shares or options – than they should. It also identifies whether they are trading in illegal or unexpected ways.

And Verdande's solution has been used to monitor complex IT systems in order to spot problems before they arise by checking real-time hardware data. A human operator is notified if symptoms which previously led to downtime or system sluggishness are seen.

03

SLIPFORMING OF BRIDGE SUPPORTS

Knowledge and technology acquired from building concrete platforms in the 1970s is now benefiting the construction of river and fjord crossings on land.

Casting techniques originating in Norway's offshore sector are being used to install the 533-metre-long Hålogaland Bridge in the north Norwegian port of Narvik.

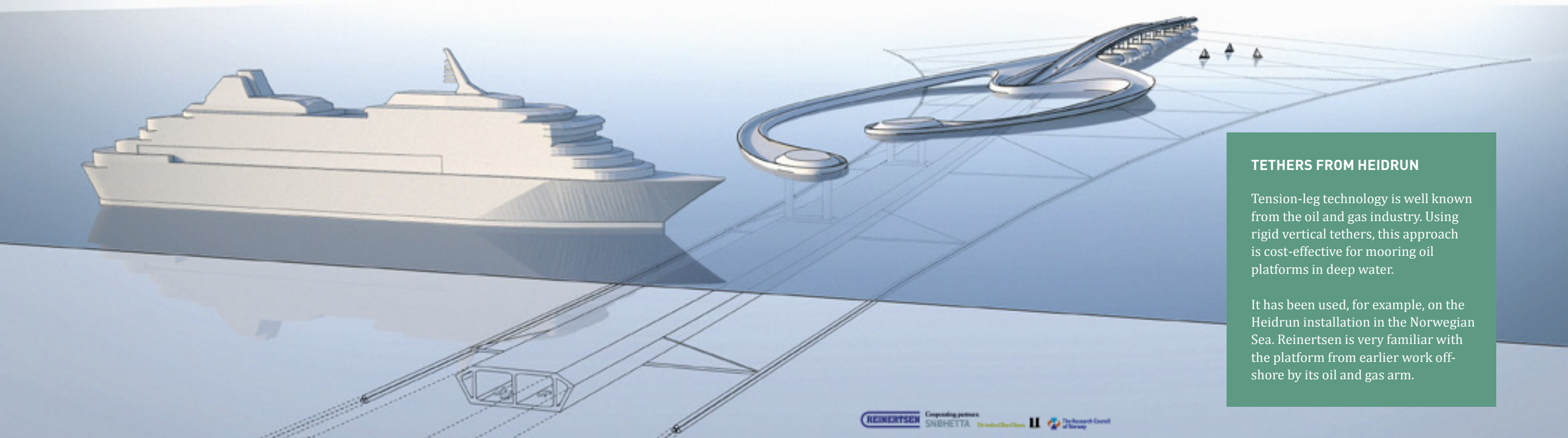
Norwegian Contractors developed this slipforming concept in 1973 for its Condeep solution, where huge concrete gravity base structures (GBSs) were built above water before being submerged.

The tallest of these facilities is Troll A, which stands in 303 metres of water and – at 472 metres from top to toe – is the highest floating unit ever built by humans.

Their mobility is one of the factors which make these massive concrete structures relevant for installing large bridge foundations.

NCC Construction AS will use the slipforming technique to cast the supports for the Hålogaland Bridge, which incorporates two submersible caissons for each of its towers.

These big concrete cylinders are built on a barge nearby, towed to the right position and then sunk by filling them with rocks. The towers will also be raised with slipforming to a total height of 175 metres above sea level.



TETHERS FROM HEIDRUN

Tension-leg technology is well known from the oil and gas industry. Using rigid vertical tethers, this approach is cost-effective for mooring oil platforms in deep water.

It has been used, for example, on the Heidrun installation in the Norwegian Sea. Reinertsen is very familiar with the platform from earlier work offshore by its oil and gas arm.

04 ANCHORING SOLUTIONS FOR FJORD CROSSINGS

Floating (pontoon) bridges could be the answer where conventional rigid crossings are impractical – and mooring technology from the offshore industry may then prove highly useful.

Many Norwegian fjords are crossed today by ferries, which carry people and cars across and save travellers from long diversions.

Bridges provide an alternative over fairly narrow sounds or in shallow waters, and have many advantages over ferries. They are available around the clock, cause few emissions and have little need for workers once built.

But what about fjords, lakes or rivers which are too wide and/or deep for conventional bridges, and where tunnels do not provide a good option either?

Norway's Reinertsen company is currently working on a solution to this challenge, which utilises offshore mooring technology to hold floating bridges of any length in any depth.

The problem of excessively deep water can be avoided with this approach, installing sections horizontally rather than in the vertical manner used for oil or gas platforms.

It will then be possible to anchor the floating bridge to these structures, which form an "artificial seabed" at the desired depth.

One of the challenges with floating bridges is that they represent a barrier for shipping – in and out of a fjord, for example.

This has also been incorporated in the concept, since part of the bridge can be constructed as a submerged tunnel which ships and pleasure craft then sail over.

05 SEABED MONITORING AND MAPPING

Tools for underwater inspection of oil and gas pipelines can also be used for traditional environmental surveillance or by the fishing industry.

A technology for monitoring and mapping the seabed has been developed by Ecotone, a company spun off from the Norwegian University of Science and Technology (NTNU) in Trondheim.

New camera technology based on hyperspectral imaging makes it possible not only to see what is on the sea floor but also to identify objects automatically.

Similar systems have been used on land for many years, but Ecotone utilises a solution specially tailored for underwater recording.

Its development was originally initiated to identify life on the seabed, but the technology will have its biggest application in the oil industry.

Making much of the technological progress possible, the petroleum sector will use the system for marine environmental investigations, seabed surveying and pipeline inspection.

Ecotone's methods will contribute to efficient and accurate information acquisition, helping in turn to minimise impacts on the subsea environment. The company aims to deliver new tools for inspecting subsea oil and gas pipelines.

But the technology also has a number of possible applications in other industries, and work is currently under way to commercialise it for these sectors.

They include traditional environmental monitoring, fish farming, and environmental studies and surveillance in connection with waste deposition in the sea.

Ecotone's solution helps to map everything from natural objects, such as corals, sponge colonies, and other seabed life, to human installations – pipelines, subsea facilities and mooring chains for floating installations.

This could be useful for the aquaculture sector in investigating the impact of fish farms on local environmental conditions.

The cameras can help to monitor and check developments over time and how living conditions in the habitats change. Similar functions could also be important in several areas of classic environmental mapping.

Waste deposition sites are another potential application. Dumping mining spoil in the sea has been under discussion, and the Ecotone technology could then help to investigate possible pollution of the seabed and the water column over time.

STATOIL TAKES A STAKE

It was revealed in December 2013 that Statoil Technology Invest is buying into Ecotone as part of its search for best available techniques in marine investigation and inspection.

The aim is to minimise impacts on the underwater environment and to secure the integrity of Norway's offshore installations, said Richard Erskine, head of the Statoil subsidiary.

Subsea imaging technology developed by Ecotone is promising because it can provide a big advance in understanding marine biology and be an effective inspection tool for seabed oil and gas pipelines, he noted.

06 OBSERVING CURRENTS AND WINDS AT SEA

Electronic monitoring systems developed for the oil and gas industry are also being used for surveillance of the climate as well as for tsunami and cyclone warnings.

Fugro Oceanor was part of the Sintef research foundation until 1984 and worked on acquiring meteorological data for the oil and gas industry along the Norwegian coast.

Used in part as input for designing offshore installation, this information was gathered with the aid of buoys which measured ocean currents, wave heights and wind strength.

Oceanor was established as this activity began to make money, and initially leased its buoys and data analysis services. But it later began to sell the hardware as well.

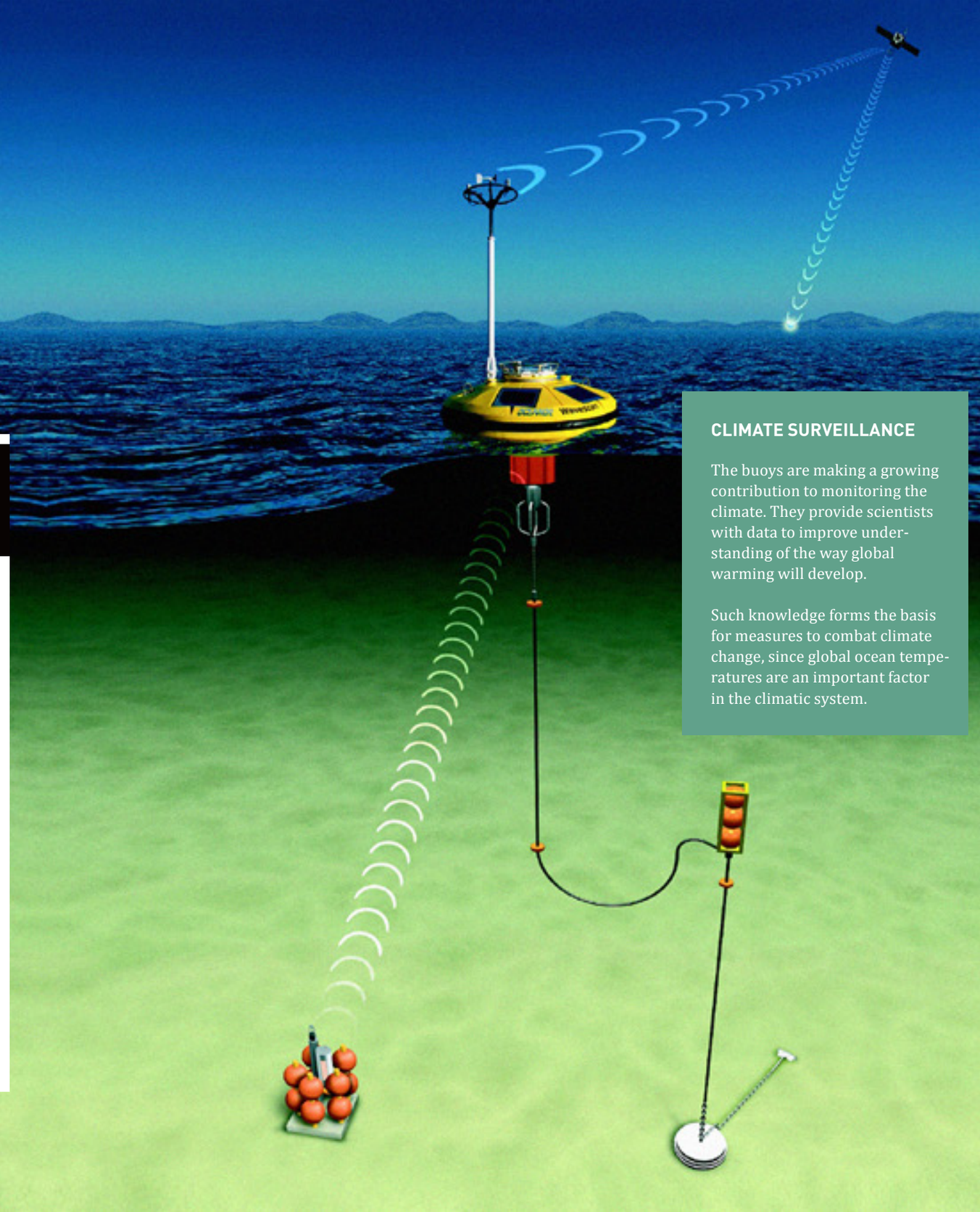
This company was acquired by Fugro in 2003, and the stock of buoys transferred to a UK subsidiary. The Norwegian arm concentrates today on the sale of buoys and monitoring services.

Its technology has increasingly been used by sectors other than the petroleum industry, including data acquisition for marine construction of such facilities as breakwaters and ports.

Other applications include weather forecasting services and the renewable energy business, with services such as design data for offshore wind power developments.

Information can also be acquired for the planning of loading and discharging operations and for climate monitoring – such as tsunami and cyclone warnings. And collecting pollution data makes it possible to measure water quality.

The technology used by Fugro Oceanor is still primarily the same as that developed at Sintef before 1984, but solutions have also been created to support the expansion into new markets. That includes a new wind buoy used to map design data for offshore fabricators.



CLIMATE SURVEILLANCE

The buoys are making a growing contribution to monitoring the climate. They provide scientists with data to improve understanding of the way global warming will develop.

Such knowledge forms the basis for measures to combat climate change, since global ocean temperatures are an important factor in the climatic system.

07

SUBSEA SOLUTIONS HELP TO HARNESS THE TIDES

Many renewable energy sources are available, but not all have been tapped. While wind, wave and water power are being exploited, little has been done with one of the most reliable – tidal flows.

Established in 2002, Norway's Flumill company is working on converting ocean currents into electricity with the aid of screw turbines attached to generators.

Tidal flows offer a very stable source of power if they can be properly exploited. Unlike other renewables, such as wind and water, they operate continuously and are highly predictable.

When the turbines are rotated by the current, the electricity generated is transmitted to land via submarine cables.

The technology has been analysed and model-tested at up to 25 per cent of full scale over the past three years, with good results. A two-megawatt full-scale system is the next step.

This will be installed in Rystraumen in northern Norway, and a preliminary project was pursued in the autumn of 2013 with Siemens supplying the electromechanical system. Results were again very good.

Given that this development involves a subsea energy technology, drawing on experience from the oil industry has been a natural approach.

The turbine itself was developed independently of the offshore sector, but Flumill reports that lessons from the latter have been essential in readying the device to work in the sea.

Everyone involved in the project has offshore experience, which has contributed to a broad range of solutions – including turbine seals and preservation methods.

The key lessons have nevertheless related to mooring. For the turbine to function as intended, the project depends on stable and reliable attachments to the seabed.

Work on underwater mooring has been under way on the NCS for many years, and Flumill has drawn most of its anchoring technology from this source.

Technology and experience from Norwegian subsea operations play a key role in turbines which can convert tidal currents into green energy.

08

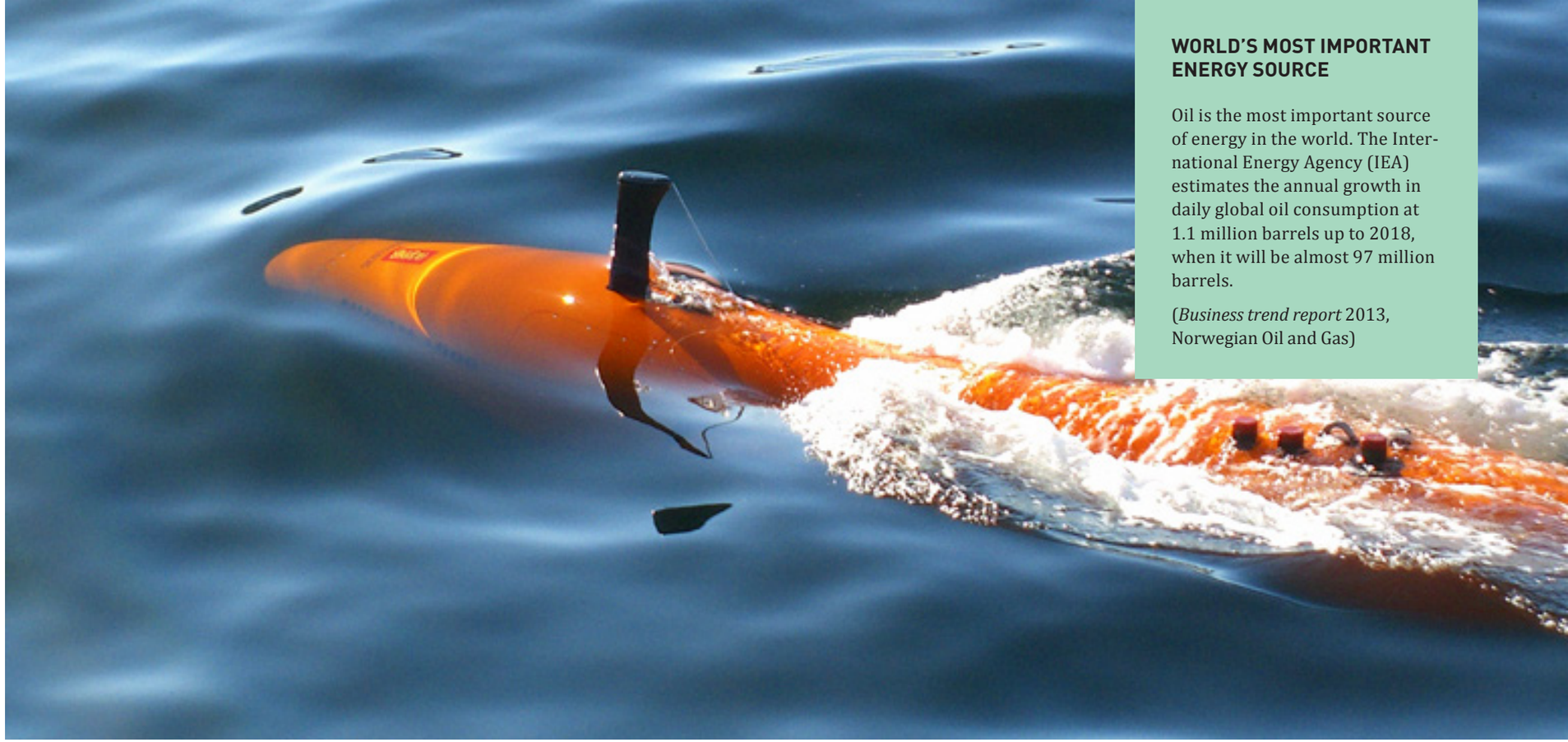
MINEHUNTING AND SEABED MAPPING

The Norwegian armed forces and the oil industry have jointly developed an autonomous underwater vehicle (AUV) which can be used both to map the seabed and to search for mines.

This Hugin device provides an example of the way the oil and gas industry has common interests with other sectors, and can jointly develop technology which is useful for several users.

It has been created by a collaboration between Kongsberg Maritime, the Norwegian Navy, Statoil and the Norwegian Defence Research Establishment.

Work began in 1995, and the first Hugin unit began commercial operation in the North Sea two years later. The solution has also been used subsequently for military purposes.



WORLD'S MOST IMPORTANT ENERGY SOURCE

Oil is the most important source of energy in the world. The International Energy Agency (IEA) estimates the annual growth in daily global oil consumption at 1.1 million barrels up to 2018, when it will be almost 97 million barrels.

(*Business trend report* 2013, Norwegian Oil and Gas)

As an AUV, Hugin can operate without the need for remote control from a surface vessel – in other words, as a kind of underwater robot.

Unlike remotely operated vehicles (ROVs), an AUV must have both sufficient power reserves and enough artificial intelligence to perform its mission.

The vehicle must be able to determine its location, where it is heading, how it is going to get there, what it is to do on the way and how to react to the unexpected.

For navigating and mapping the seabed, Hugin is equipped with a number of different sensors to support inertial navigation, measurement of its speed over the seabed, and mapping and imaging the sea bottom. In addition come advanced positioning systems.

Hugin is operated for the petroleum sector by leading offshore survey companies, and ranks as the market leader with detailed seabed mapping for field development and deepwater pipelaying.

Bottom conditions have been investigated by the vehicle ahead of the development of Åsgard, Snøhvit and Ormen Lange on the NCS, and for most deepwater oil fields worldwide. Detailed mapping can be done in water depths down to 4 500 metres.

The first Hugin 1000 prototype was installed for military use on the KNM *Karmøy* minehunter in 2004, safeguarding the crew by exploring potential minefields at a secure distance. It also enhances the efficiency of minehunting, and makes it possible to determine the type of mine involved.

In this way, the unit has provided benefits for both offshore and military users. It yields a big improvement in efficiency for the oil and gas sector, and more accurate survey results.

Hugin is also used for hydrography (the creation of marine charts) and marine research, and has been sold to government agencies in six countries.

Both offshore and defence sectors have secured mutual benefits from their collaboration, and the development would not have been possible without participation by both sides.

The commercial market would not be large enough on its own to make the development process profitable, so collaboration with the navy was crucial.

Efforts are currently under way to develop Hugin for new markets and applications, including pipeline inspection and environmental monitoring.

09

TAPPING GEOTHERMAL ENERGY FOR HEAT AND POWER

Water injected deep beneath the ground comes into contact with hot rocks and, on returning to the surface, can be used for heating and electricity generation.

The temperature of the Earth's crusts rises with depth by an estimated 15-50°C per kilometre, depending on local geological conditions.

Typical dry rocks, such as granites, gneisses and basalts, located 3-5 000 metres down, could vary in heat from about 60°C to 250°C. That represents a huge amount of energy to be tapped.

A number of countries are thought to have the potential to increase their geothermal energy output with the aid of deep wells.

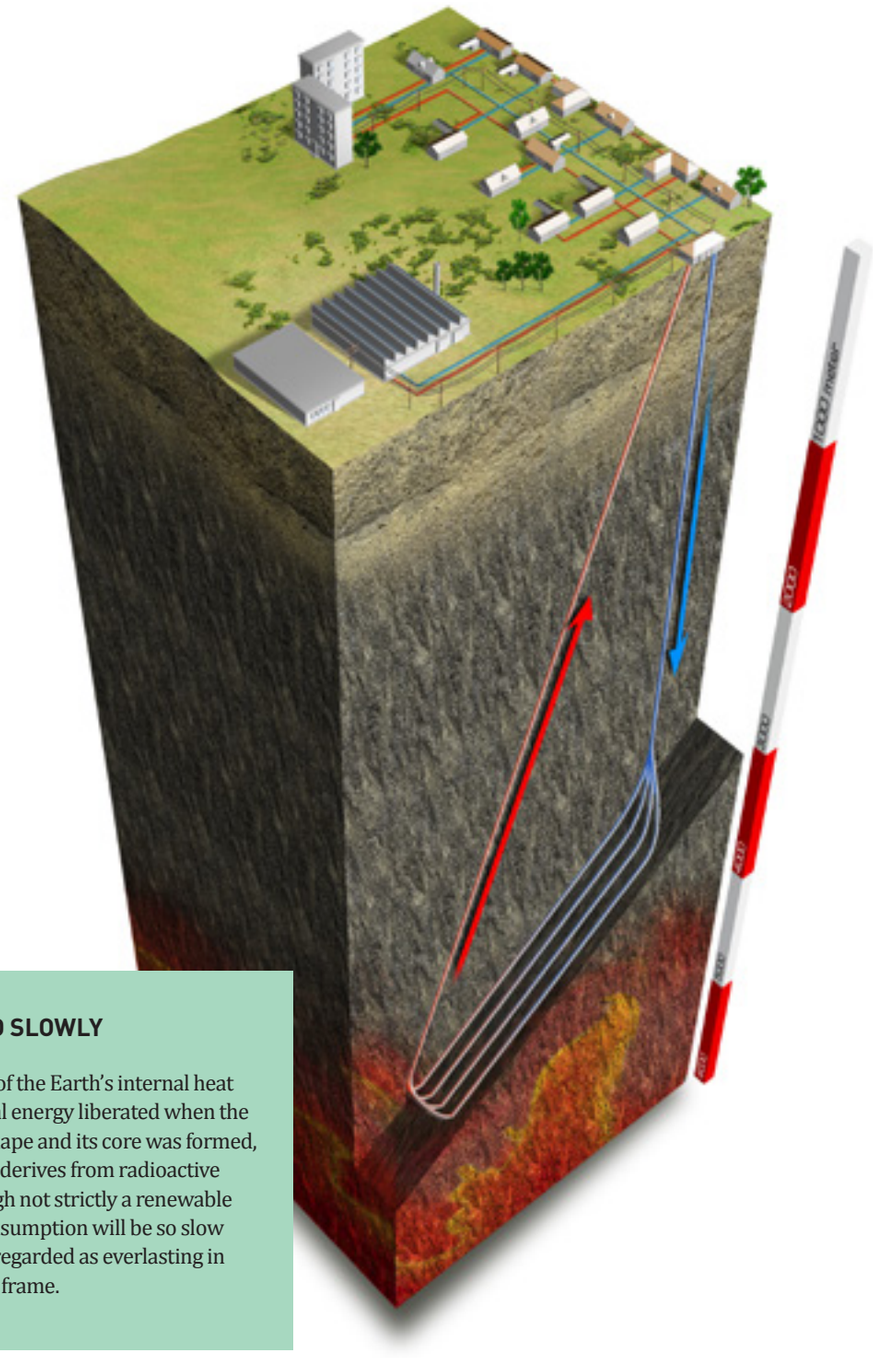
Norwegian players with an offshore oil and gas background are playing a key role in this development, particularly in terms of drilling technology and geological investigations.

Rock Energy, for instance, aims to develop, build and possibly own facilities for deep geothermal energy based on its patented technology (see illustration).

This solution has been designed with the aid of advanced drilling technology and experience built up by Norway's petroleum sector over many years.

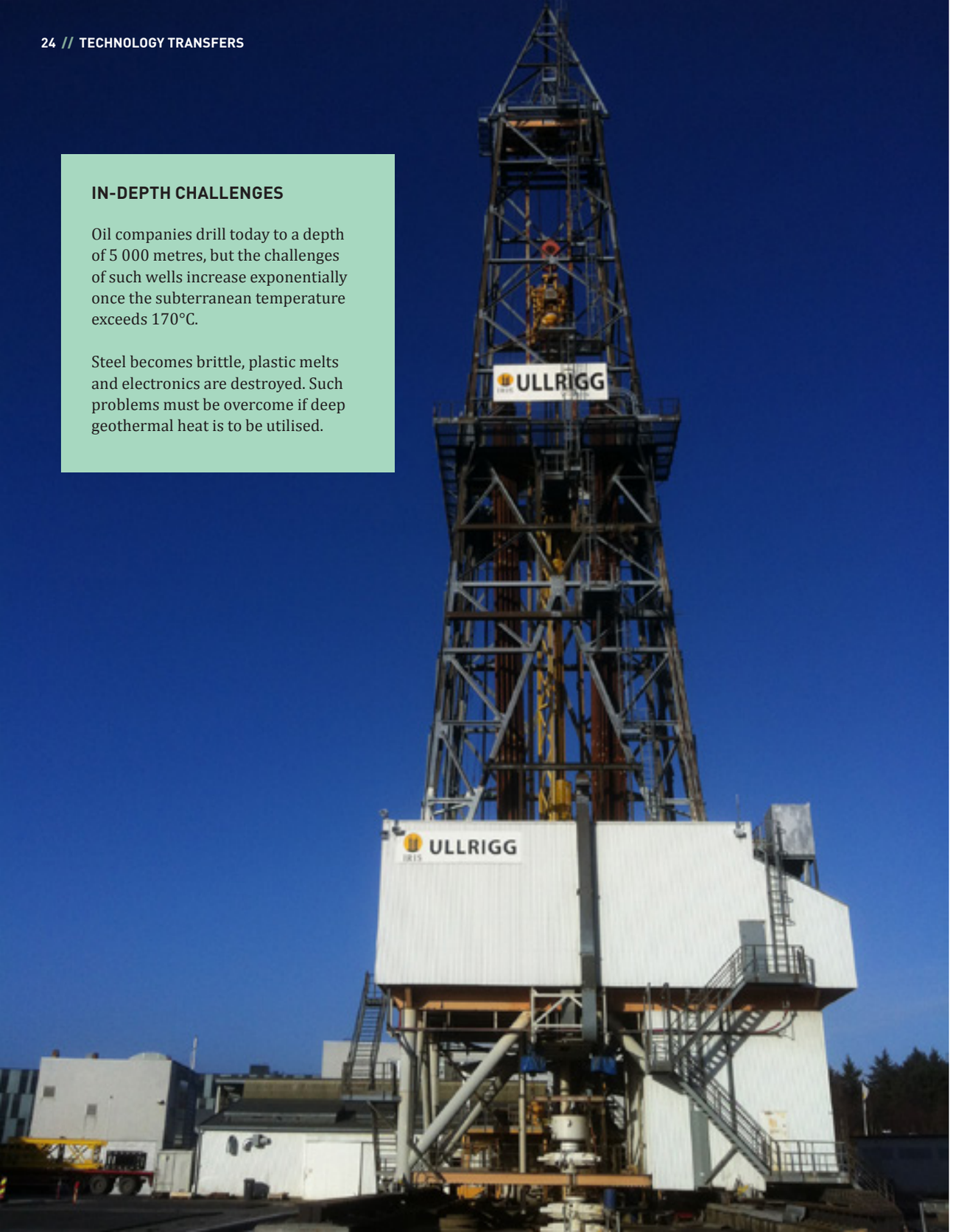
The key principle involves injecting cooled water into a well system. This is warmed and returned to surface for use in heating, cooling or electricity generation for the commercial market.

With the technology scalable for two to 50 megawatts, the aim is to be able to supply energy on competitive terms in three-four years. Rock Energy is now designing its first pilot plant.



CONSUMED SLOWLY

A proportion of the Earth's internal heat is gravitational energy liberated when the planet took shape and its core was formed, while the rest derives from radioactive decay. Although not strictly a renewable source, its consumption will be so slow that it can be regarded as everlasting in a human time frame.



IN-DEPTH CHALLENGES

Oil companies drill today to a depth of 5 000 metres, but the challenges of such wells increase exponentially once the subterranean temperature exceeds 170°C.

Steel becomes brittle, plastic melts and electronics are destroyed. Such problems must be overcome if deep geothermal heat is to be utilised.

10 GREEN ENERGY FROM ADVANCED DRILLING METHODS

The possibility of retrieving thermal power from the Earth's interior is being tested by the Ullrigg drilling rig at Ullandhaug in Stavanger.

Existing infrastructure at this experimental facility can be utilised to develop new opportunities for advanced drilling technology.

Ullrigg has been used in research and development work directed at the petroleum sector for more than 25 years. But it has now become very significant in developing solutions related to harnessing geothermal energy.

One of the biggest challenges in exploiting this source of renewable energy is reducing drilling costs, and Ullrigg has been devoted for many years to more cost-efficient offshore drilling.

This installation also makes it possible to test new methods without needing to invest in large new facilities – the necessary machines are already in place.

In addition to exploiting geothermal energy, lessons learnt with Ullrigg could be beneficial for underground storage of carbon dioxide.

Existing drilling technology makes it possible to guide a well along any desired path, and permits more efficient utilisation of thermal energy from hot rocks deep in the Earth's crust.

The borehole can also be directed at sealed formations for permanent carbon storage, while the risk of leaks from such structures is minimal.

11 DETECTING THE DANGERS

A method for scrutinising rock surfaces to understand how oil reservoirs are constructed can also be used to check the safety of tunnel walls and identify the threat of landslips.

This development involves light detection and ranging (lidar) scanning, an optical technique for remote measurement of a physical object's position.

It is being pursued by Norway's Centre for Integrated Petroleum Research (CIPR) as one of a number of projects to extend petroleum industry technology for other applications.

One use of lidar scanning is to study reservoir analogues, or geological formations exposed on land. Information they yield can be transferred to similar sub-surface structures which form hydrocarbon reservoirs.

The technique maps extensive rock surfaces with millions of points in order to show variations in the distances between these points and the scanner.

Combining these points with high resolution photographic images creates a three-dimensional picture of the bedrock which can be used to analyse structures and geometries.

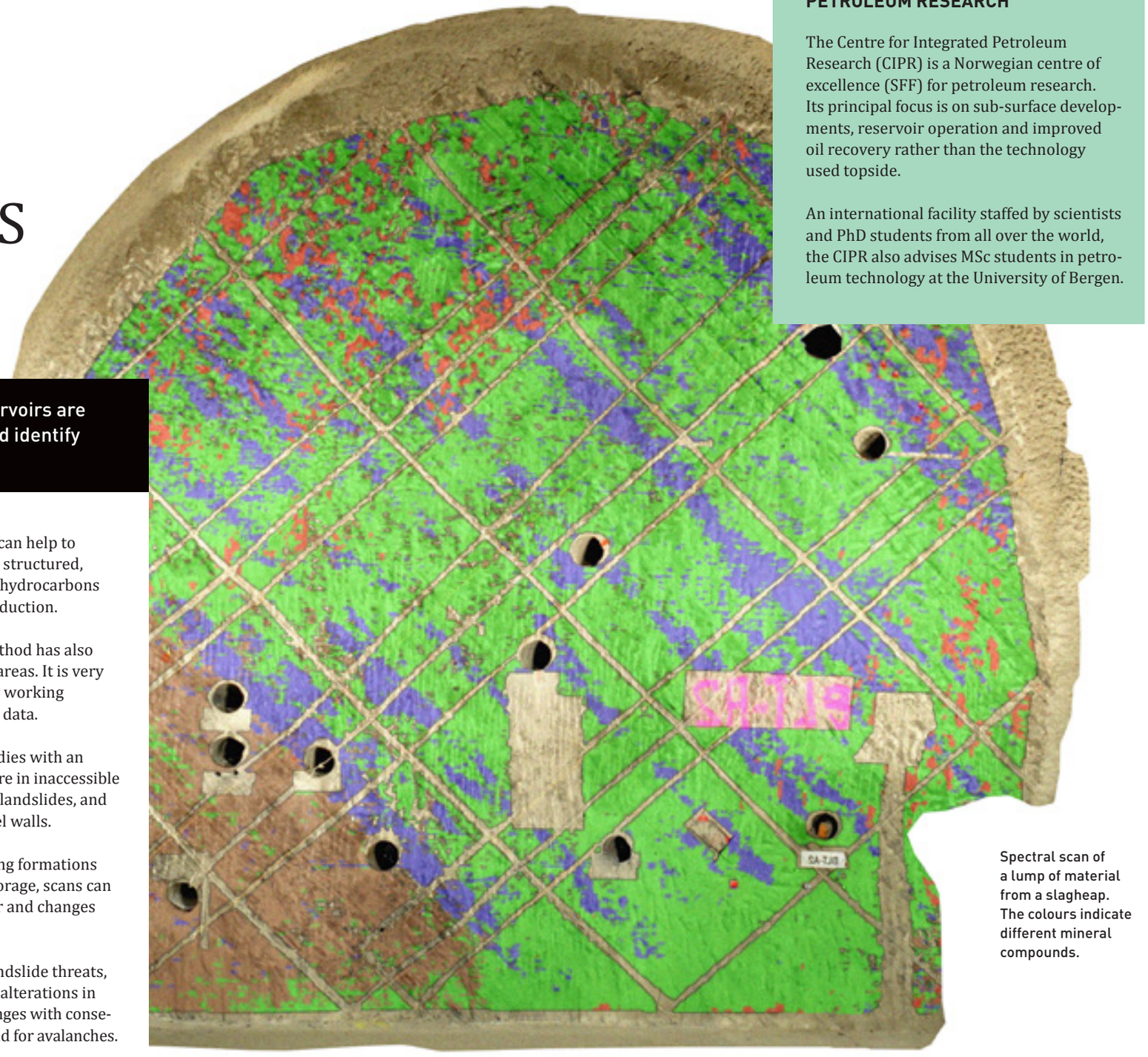
So lidar scanning of analogues can help to understand how reservoirs are structured, and to build models of the way hydrocarbons move through them during production.

As applied by the CIPR, this method has also proved to have value for other areas. It is very efficient compared with earlier working methods for acquiring bedrock data.

Lidar scans can be used for studies with an accuracy down to one centimetre in inaccessible areas, for gauging the threat of landslides, and for checking the safety of tunnel walls.

Also applicable to understanding formations being considered for carbon storage, scans can be superimposed on each other and changes over time detected.

That is useful with regard to landslide threats, for example, but can also show alterations in glaciers and help to expose changes with consequences for the environment and for avalanches.



Spectral scan of a lump of material from a slagheap. The colours indicate different mineral compounds.

PETROLEUM RESEARCH

The Centre for Integrated Petroleum Research (CIPR) is a Norwegian centre of excellence (SFF) for petroleum research. Its principal focus is on sub-surface developments, reservoir operation and improved oil recovery rather than the technology used topside.

An international facility staffed by scientists and PhD students from all over the world, the CIPR also advises MSc students in petroleum technology at the University of Bergen.

Several aspects of lidar and spectral scanning of rock surfaces. To the left is a hyperspectral scan, in the centre is a lidar image, and on the right a photograph has been stripped away to expose the 3-D grid measured by the laser scanner.

12 HELPING TO HANDLE WASTE

An analysis method developed for the petroleum industry can be used to map possible underground sites for storing nuclear waste and recovering metals from old slagheaps.

Most people have seen infrared images and know a little about the way colours and contrasts can make it easier to separate out heat sources in the landscape, for example.

Analysing selected parts of the infrared spectrum – known as hyperspectral analysis – permits detailed mapping of the composition of the material which is reflecting the rays.

The Centre for Integrated Petroleum Research (CIPR) originally intended to combine this technique with lidar scanning to identify the mineral content of reservoir analogues (see previous article).

But this petroleum-centred application has now been greatly expanded for such uses as determining the composition of opencast mines and possible radioactive waste storage.

Hyperspectral analysis is being used in Germany to check the quantity and quality of coal exposed to the air in opencast workings, which would have taken much longer to do manually.

The Swiss are applying the technique to analyse clay minerals in the walls of nuclear waste storage facilities, since these could comprise possible leak points or weak zones.

This method is also being used for more environmentally conscious measures, such as extracting residues from old slagheaps.

Miners have become ever better at getting the maximum out of metallic ores, but large volumes of metals could be left behind because earlier processing methods were unable to extract them.

These can be recovered today, and hyperspectral analysis is used to map these old spoil deposits with an eye to cost-effective recycling.

13 CLEANING UP OIL SPILLS

Technology developed by students at the Norwegian University of Science and Technology (NTNU) to collect spilt oil 10 times more effectively than with manual labour is now finding new markets.

After several ships had been wrecked off Norway in 2007, a spotlight was focused on the heavy and time-consuming job of removing oil in the shore zone.

These clean-up efforts once a spill reached land involved hard manual toil, usually combined with high pressure jetting which displaced the problem rather than removing it.

Three NTNU students had the idea of making this job easier and more effective by developing a vacuum-assisted brush which removes oil from hard surfaces such as rocks or ship decks.

The Norwegian Clean Seas Association for Operating Companies (Nofo) initiated a multi-year development programme for oil-spill clean-up technology in 2009.

Norwegian and international industry was invited to overcome these technological challenges, and the student inventors were one of 20 projects selected for this Oil Spill Response 2010 effort.

Their Mose technology has been documented to clean up oil 10 times more effectively than manual workers, achieving a level of cleanliness exceeding 99 per cent.

Mose Innovation is now entering new markets after a number of inquiries from land-based industries where oil spills need to be dealt with in ports, ship-yards, roads and so forth. Its technology has been extended for such applications in cooperation with Norway's Hafslund company.

14 MEASURING VIBRATION IN A SMALL WAY

A compact sensor developed for the petroleum industry also has applications in every sector which makes extensive use of machinery.

Heavy rotating machines have a big impact on daily life on North Sea installations. Critical for Norway's petroleum output, they depend on good maintenance and predictable operation.

This was originally achieved with hand-held monitoring devices, and involved considerable manual labour.

Big and expensive sensors with many measurement points were attached to the largest and most critical machines to ensure continuous control.

ABB saw the potential for improving this technology in terms of cost, sensor size and more efficient manual processes, and developed a small-scale device.

This sensor can be attached to machines relatively easily and acquires data automatically at exact intervals in place of checks with varying regularity.

It is connected up in such a way that data can be transmitted to land. Analysis of the information acquired can thereby be done ashore, with a further efficiency gain.

The new device is also cheaper and eliminates a great deal of cabling, and can be used both on small machines previously checked manually and on big units which utilised more complex sensors.

It meets the explosion-proof (EX) standards required in the North Sea, and has an expected operating life of more than five years.

In other words, this represents a very durable product which could also be applicable in other sectors. Rotating machinery is by no means exclusive to the oil industry.

Virtually every sector utilises such vibration sensors, with papermaking as a good example. That uses a lot of machinery and can now benefit from the device developed for the North Sea.

DEMANDING JOB

The sensor is just 10 centimetres high, weighs a mere 200 grams, has a range of about 20 metres and can easily be attached to rotating machinery for wireless condition monitoring offshore.

Sintef, Statoil, BP, ABB, Kitron and SKF are among participants in a demanding development process, and have helped to make the product compact and cost-optimised.

15

SIMULATED REALITY

A simulation tool intended for use with oil industry control systems is found today in applications ranging from nuclear power stations to paper-making, metals and mining.

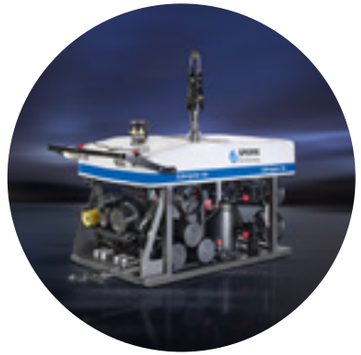
ABB has developed simulators for the Statoil-operated Sleipner A platform, for instance. This experience is now being used to create similar solutions for other sectors.

The company ranks today as a world leader for such deliveries to the process industry, where they have a wide range of applications.

Simulators make it possible to test a system's functionality, for example, and can also be used for thorough training of employees ahead of actual operation.

Good use of simulation also provides a solid basis for making improvements before a system comes on line. Faults and deficiencies can be spotted and dealt with without halting operations.

A simulator can also be used to test changes in existing systems before they are implemented in real life.



16

WORKING AT ARM'S LENGTH

Remotely operated vehicles (ROVs) developed for subsea use offshore can carry out a number of other jobs today – such as washing fish-farm cages.

Controlled from a ship or platform, ROVs are now used for countless operations – from detailed seabed mapping, via inspection, maintenance and repair of subsea facilities, to search and rescue.

The US Navy financed most early ROV development in the 1960s for salvage operations – such as the 1966 crash of the nuclear-armed Palomares B-52 bomber in the Mediterranean.

This technology was later adopted and further developed by the offshore sector, when many of the developments in the 1980s passed beyond the reach of divers.

Progress in the area has subsequently accelerated, and ROVs now do many jobs in and beyond the petroleum industry.

Norway's Sperre AS has long experience of developing and manufacturing such systems, which are used in fields like archaeology, research and aquaculture in addition to offshore.

The company's ROV solutions can take over from divers for maintaining and cleaning fish cages, and for inspecting the condition of these facilities and their moorings.

Sperre currently offers five basic systems, with working depths which range from 500 to 11 000 metres of water.

17

STAYING IN PLACE

Vessels operating in the rough North Sea need to remain in exactly the same position without anchors. Known as dynamic positioning (DP), systems for doing this can now be used in many other areas.

A DP solution is basically designed to hold a ship or semi-submersible rig over the same spot on the seabed with their own propellers alone.

Initially developed in the Gulf of Mexico during the late 1960s for drilling units, DP technology found even wider applications when oil was discovered in the North Sea.

It was needed on various types of units required for field development and operation – starting with diving support vessels (DSVs) and then supply, construction and maintenance ships.

Oil produced from the Statfjord field was shipped to land in shuttle tankers, which took on their cargoes from loading buoys out on the field. This process was expensive, time-consuming and not least hazardous.

Norway's Kongsberg Maritime had already developed a DP system, initially used primarily by DSVs. But the company quickly realised the potential for North Sea shuttle tankers.

It now has more than 30 years of experience with this technology, and ranks as the world leader with more than 2 000 DP systems in operation.

These are still used mostly by vessels for the offshore industry, but have also been applied in recent years to cruise and research ships.

The technology is no longer confined to maintaining a fixed position. It can also be used to move relative to another mobile object, such as a ship or a subsea vehicle.

Following a given track – when laying pipelines or cables, for instance – is another application. Opportunities for using DP systems in the fishing industry are also being investigated.

18

PROVIDING POWER FOR AUTONOMOUS MONITORING

Battery packs from the North Sea are being used for remote-controlled measurement stations on land, while oil industry know-how has been applied to maintaining Segway electric vehicles.

Established in 1995, Norway's Aquadyne company works primarily on product development and deliveries for the oil and gas industry – not least meeting special battery requirements. But it also exploits this experience to deliver solutions to other sectors.

Instruments installed on the seabed need energy and, since running cables to provide power is very expensive, they are often equipped with battery packs.

Examples include carbon, current, saline and sonic speed meters, transponders and devices for measuring ice thickness. Aquadyne has long worked on meeting their need for batteries.

A key aspect is the stringent standards set for such power packs. Their very high energy density makes them potentially hazardous when exposed to high pressure in very deep water.

The batteries are accordingly encapsulated in containers which can cope with an external pressure equivalent to a depth of 4 000 metres.

These packs can be fitted with electronics and valves for pressure reduction to prevent them from exploding if anything goes wrong inside the container.

In principle, Aquadyne's expertise will be useful for all batteries above a certain size which must be charged at high speed.

Measurement stations on land are among the devices currently powered with battery packs developed by the company on the basis of principles developed for North Sea use.

The offshore sector's requirements for compact packaging and safety are also important for remotely controlled stations of this kind on land.

Petroleum-industry experience has allowed Aquadyne to offer maintenance in Norway for Segway battery-powered, self-balancing two-wheeled vehicles.

These units are approved for road use in the EU and the USA, but not at present in Norway. However, the government has promised to end the Norwegian ban on them.

Segway utilises Bluetooth wireless communication between the ignition key and the actual engine, which means that the receiver is always on.

So users who forget to charge the battery will drain it, and have to revive it. Backed by its offshore experience, Aquadyne provides such revivers as well as other maintenance.

The company has long worked on inertial navigation equipment for the oil and gas sector, along with high-capacity rechargeable lithium batteries for the same industry. Knowledge of the latter devices underpins its reviver solution.

Similarly, work for the petroleum sector has given the company expertise with the gyro technology which forms the core of the Segway balancing method.

When the US vehicle manufacturer was seeking a dealer in Norway, its choice fell on Aquadyne. The company sells all Segway models and is authorised to maintain them.

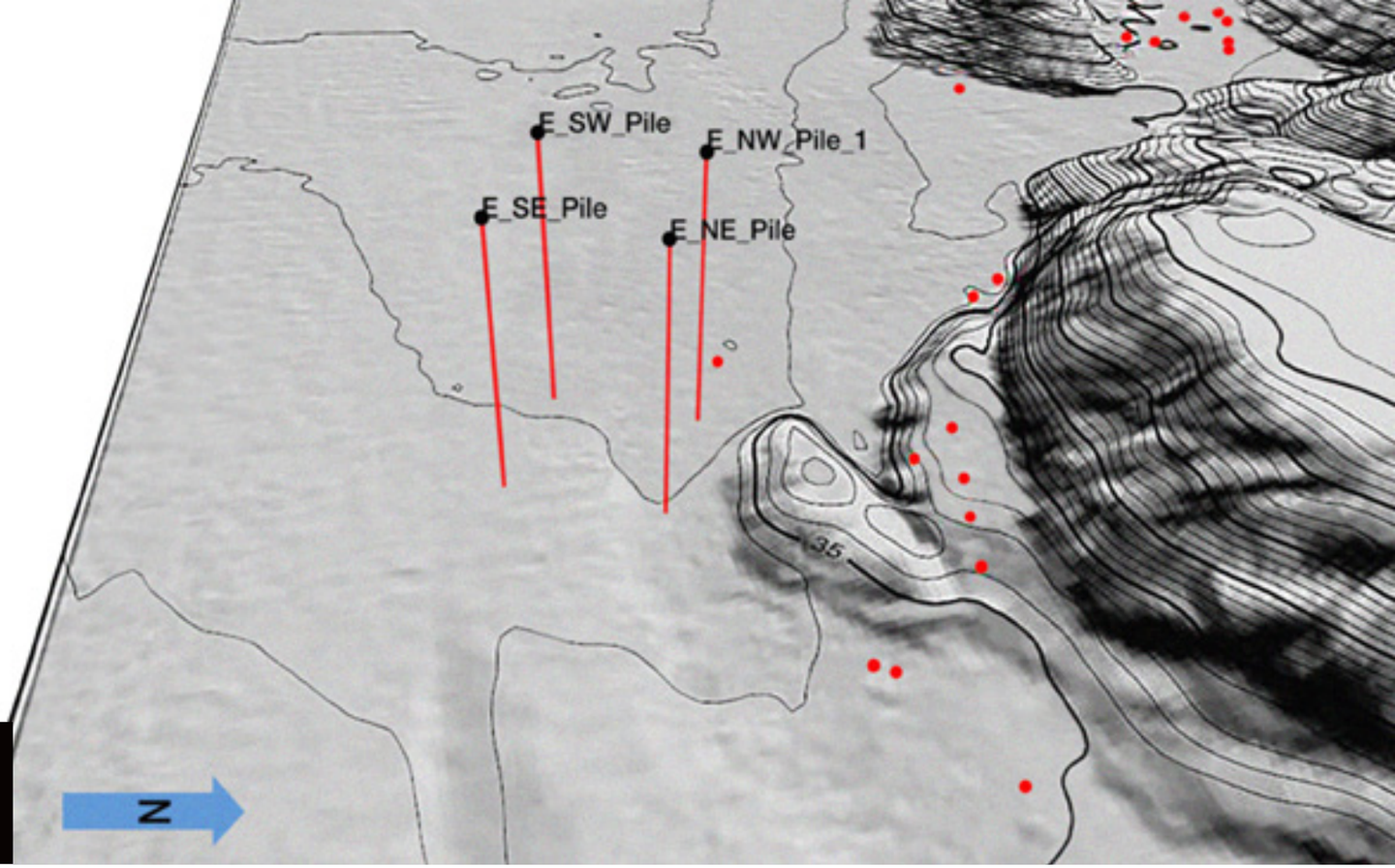
WITHSTANDING SHOCK AND VIBRATION

Aquadyne's battery packs must be designed to cope with shock and vibration, and they often feature watt/second meters which give full control over the amount of power remaining.

While the voltage of a lead battery is measured in volts, this is meaningless in the lithium type since cell voltage remains at around 3.6V until the battery is fully discharged.

Failure could produce a potentially hazardous overpressure in the battery container, so many offshore packs are equipped with safety valves or pressure meters.

19 HARNESSING THE WIND AT SEA



A well-established workflow for mapping and describing reservoirs when designing offshore production installations is also useful in modelling platforms for wind farms at sea.

Integrated models describing all aspects of a reservoir are used for planning by the oil companies. These have a high transfer value for positioning offshore wind turbines.

Plans for the latter are drawn up today using a range of tools for such aspects as water depth, waves, currents, meteorology, marine biology and infrastructure.

The lack of a coherent modelling platform often makes it difficult to achieve an integrated understanding of environmental conditions in sea areas where wind farms are to be installed.

Norway's Centre for Integrated Petroleum Research (CIPR) is making active use of oil industry experience in creating a simple model which includes all relevant variables.

Existing procedures for mapping the sub-surface in planned wind farms build on experience from established Danish and German projects.

But a far more complex seabed off Norway in terms of water depth and geological variation represents a critical difference, which makes direct transfer from Denmark and Germany difficult.

Several types of geological judgements must accordingly be made when a whole Norwegian offshore wind farm is to be modelled, compared with only one kind in the neighbouring countries.

These analyses are moreover complicated by the need to take account of many factors – shipping channels, local authority guidelines, biological conditions, conversation areas and the like.

A complete system which incorporates all relevant variables of this type will make the workflow in the design phase far more efficient.

The approach can also be used to map areas which suit different kinds of turbines, and then produce recommendations on where these types could be positioned.

One area might be well suited for foundations piled to seabed with hammering and drilling, while a gravity base structure which stays in place under its own weight would be better in another.

WIND AND SOLAR ENERGY ALMOST DOUBLED

A wind power capacity of more than 100 megawatts is expected to be installed in 75 countries by 2018, with growth for solar energy also expected to be high but from a lower base. Sixty-five countries should have more than 100 MW installed by 2018, up from 30 in 2012.

20 SECURING EFFECTIVE SUPPORT

Small, simple platforms resting on a single column, developed to cut costs on the NCS, have proved very useful since the concept of offshore wind farms emerged in the late 1990s.

Rambøll has designed platform support structures since the 1970s. When oil prices slumped in the mid-1980s, the company had to think innovatively to survive in the offshore business.

It came up with small, cost-effective “monopile” structures, featuring a single support column. These could be installed directly from the drilling rig once the wells were completed.

The first was put in place in 1989, and it became clear in due course that the design could be an appropriate foundation for an offshore wind turbine.

Rambøll was the first to apply monopiles for this purpose, and thereby to engineer turbine supports at sea. By then, these structures had already been tried and tested over many years.

Software for the structural analysis of such designs were also available, and Rambøll had experience of fabricating, transporting and installing large offshore facilities.

Even such small details as access by ship to an offshore wind turbine have been directly copied from the oil and gas industry.

21

ELECTRICITY AFLOAT

Lessons learnt from the oil and gas sector have been actively applied by Statoil in its on-going project to install floating wind turbines offshore.

The first prototype was installed in 2009, and generated almost twice the expected output the following year. It comprises floater, turbine, mooring and transmission cable to land.

During this project, Statoil has been able to draw on knowledge and experience from its North Sea operations to secure a number of benefits in the development process.

Earlier work on offshore mooring came in useful, for example, since the turbine unit is moored to the seabed. This applied to assessing soil stiffness on the bottom as well as other factors which contribute to stability and good turbine durability.

Coatings and sealants developed over a long period for oil platforms have been used to avoid corrosion. Good initial solutions here reduce maintenance and operational requirements.

Other lessons derived from the petroleum sector relate to such aspects as work processes, knowledge of water motions and analysis methods.

Benefits have also been obtained by drawing on experience of relations with other industries and sub-contractors, including the significance of standardised solutions.

The petroleum sector has learnt the advantages of standardising as much as possible in order to reduce its vulnerability to deliveries from sub-contractors.

Since offshore wind turbines represent a relatively new sector, this offshore experience has proved extremely valuable.

22

FIXED CONVERSION FACILITY FOR WIND POWER

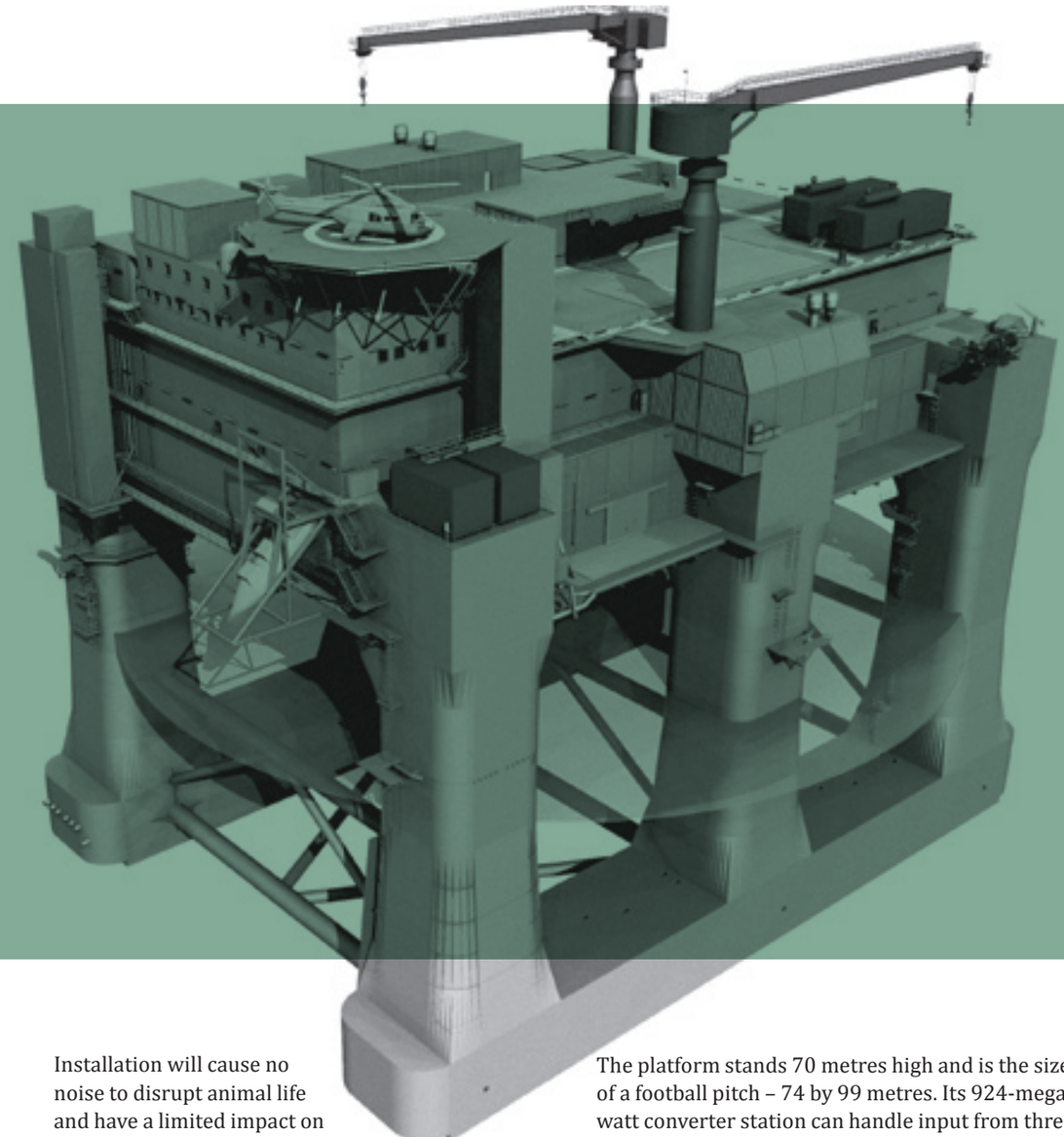


ABB and Aibel have utilised technology from the oil and gas sector to develop a platform which supports an AC/DC converter station for offshore wind farms.

In its search for alternatives to the nuclear power stations it has resolved to shut down, Germany has developed big facilities for exploiting wind energy at sea.

Transmitting electricity over more than 100 kilometres – from offshore generators to land, for example – requires it to be changed from alternating to direct current.

Needed in order to limit energy losses en route, this job can be carried out on a fixed platform using a compact converter station.

ABB and Aibel have drawn on gravity base structure (GBS) technology utilised over decades in the offshore sector to develop their concept.

The Dolwin Beta platform, now under construction through a collaboration between the two companies, will be floated to its location and lowered to the seabed.

It is due to stand in 29 metres of water in the Dolwin wind farm area near the island of Helgoland in the German North Sea sector.

Towing the platform, which resembles a semi-submersible, into position before installing it on the seabed offers considerable environmental benefits.

Installation will cause no noise to disrupt animal life and have a limited impact on the seabed, while the structure will be easy to move and remove when its working life ends.

In addition, major cost benefits will be achieved by eliminating the need for expensive floating cranes during transport and installation.

Dolwin Beta will receive alternating current from nearby wind farms and convert it to direct current for transmission to land via a submarine cable.

The platform stands 70 metres high and is the size of a football pitch – 74 by 99 metres. Its 924-megawatt converter station can handle input from three wind farms with 240 turbines.

Once in place, this facility will cut carbon emissions by three million tonnes per year and be able to supply 1.5 million households with green electricity.

Dolwin Beta represents a solid addition to wind power development in Germany, and a secure and sustainable alternative to nuclear energy, for example.

23

NEW HYDRAULIC-BASED INSTALLATION SYSTEM

Positioning offshore wind turbines is not a simple operation, and it must therefore be conducted in the most secure, controlled and cost-effective manner possible.

Such procedures have so far been performed from ships or jack-up rigs (pictured), with raising and lowering based on rack and pinion systems.

Norway's Aker Solutions group saw a big potential for improvement here, and has developed a solution utilising hydraulic cylinders to replace the former approach.

Using hydraulics – energy transfer with a fluid – offers a number of advantages over the existing system. These include greater robustness and stability, which ensures more reliability and predictability.

Installing, moving and raising turbines will be a regular activity in future offshore wind parks, and the more reliable and predictable the process, the better.

The cylinders can be connected directly to existing hydraulic systems, both conveniently and cost-effectively. The whole system does not have to stand idle when not in use.

Aker Solutions has applied experience and technological solutions from the oil and gas sector in developing its new system.

ASIA LEADS FOR RENEWABLES

New renewable energy developments are increasingly taking place in non-OECD countries. The latter are expected to account for 58 per cent of renewable energy output in 2018, compared with 54 per cent in 2012.

Magnetometer-based detection equipment will be useful in any sector dealing with buried cables and pipes, particularly in wetlands.

24 DETECTION SYSTEM SHIFTING FROM SEA TO SHORE

Technology developed by the oil and gas industry to locate concealed cables and pipelines under water is now being adapted for use on land.

This job is being spearheaded by Aquadyne, a Norwegian company established in 1995 which works primarily on product development and deliveries for the petroleum sector.

ABB in Karlskrona, Sweden, is among the companies which wants to benefit in new areas from Aquadyne's detection equipment for offshore cables and pipelines.

In technical terms, this solution is based on a triaxial magnetometer – put simply, a kind of three-dimensional compass which identifies magnetic fields created by cabling and piping.

Its original purpose was to identify underwater cables and pipelines, which are often buried, in order to meet stringent oil-industry requirements for annual inspections.

Aquadyne's detection equipment makes it possible to locate such concealed installations in a cost-effective manner.

The same technology is also used in the oil and gas sector to detect the "pigs" driven through pipelines to clean out deposits of asphalt, paraffin waxes and similar substances.

These devices can get stuck, and the Aquadyne solution is then used to find where they are in the pipeline. Much of the cost of developing this system has been met by Kongsberg Oil and Gas.

During its development work, Aquadyne has borne in mind that this equipment could also add value in any sector dealing with buried cables and pipes – particularly in wetlands.

Cables installed many years earlier are often inadequately identified on maps, and the detection system can then be used to find them in an effective way.

With an eye to technology transfer, Aquadyne has utilised open source software to simplify such processes. It is now tailoring the equipment for use on land at the request of ABB.

25 FROM CONTINENTAL SHELF TO OUTER SPACE

Advanced drilling and robot technology developed for Norway's offshore sector could be important in future exploration of the Red Planet.

The international Mars Institute opened a branch in Norway during 2012 to promote research and technology exchanges between the oil and space industries.

These two sectors have many features in common. Their equipment must be developed for use in inaccessible locations under fairly extreme conditions.

They are conservative industries which cannot tolerate equipment failures, and everything must be very carefully developed and researched before being taken into use.

And both sectors need robots which can be remotely operated or are able to act autonomously.

America's Nasa space agency has made great strides in robotics, but nobody has come further than Norway with drilling technology.

A mutual need accordingly exists for exchanging experience between these two industries – and the Mars Institute has taken that requirement seriously.

It wants to exploit Norway's extensive offshore drilling experience to develop a new technology which can be used for Martian exploration.

Petroleum engineering student Christopher Hoftun is taking part in a development programme at the Mars Institute where he collects drilling data from Arctic Canada.

No methods are currently available which permit drilling up to several kilometres beneath the surface of the planet, but the goal is to find a long-term solution to this challenge.

So far, the institute's Norwegian arm has worked on a conceptual study covering various concepts for drilling on Mars, and has identified a technology which could be relevant. This study was published in late 2013.

The purpose is to find life on the other planet. This is known to be impossible on the surface, as a result of strong radiation, low temperatures and excessive salinity.

In addition, the Martian surface is too cold for water to exist in liquid form – essential for life of the kind known on Earth. But ice does exist under the surface.

The aim of a drilling project would accordingly be to penetrate into the crust of Mars, where temperatures rise, and thereby reach liquid water.

FOLLOW THE WATER

Plans to drill on Mars derive from Nasa's "follow the water" strategy. Since all life on Earth depends on it, searching where water exists to find living things makes sense.

The surface of the Red Planet is too cold, and the pressure too low, for water to be present in liquid form. But scientists believe large aquifers may exist in the Martian crust. They then have to look deep down – probably a couple of kilometres below ground.

If that can be found and sampled, the theory goes, very simple micro-organisms might be detected and thereby prove that life does exist on the planet.

26 SMALL IS BEAUTIFUL

Miniaturised power electronics developed to cope with tough conditions encountered in North Sea drilling and wells have proved useful for space research and charging electric cars.

Small, light, robust and intelligent, this solution was originally developed for use in tools which require more power and higher voltage when working downhole in oil wells.

Stavanger-based company Zaptec AS has achieved a good dialogue over the past year with manufacturers of electric cars, and the response has so far been very positive.

Infrastructure for battery charging is a big challenge in the electric vehicle sector. Zaptec's miniaturised electronics can help to overcome this by adapting to the grid voltage and thereby ensuring swift and simple charging.

Furthermore, the charging stations can communicate with power companies, homes and cars, and thereby become part of an intelligent power network.

Zaptec's goal is to help produce the world's best charging stations, and plans call for these to be introduced during the first half of 2014.

Nasa has also shown interest in the company's technology, since the high voltage from the transformer is incorporated in a plasma-based drilling system.

The US agency wants to utilise this to drill on the Moon, on asteroids and on Mars – initially to map minerals, geology and water resources on the Red Planet and to search for life below ground.

In the next phase, drilling could be relevant for producing and processing resources in outer space, particularly from the Moon and asteroids.

Work with Nasa is currently at the conceptual development stage, but Zaptec's chief executive has worked a lot in recent years with the US and other space organisations.

He reports that Nasa's drilling team nominated the company's concept in late 2013 for the agency's innovation advanced concepts programme.

The Space and Energy innovation network has also been an important springboard in this process.

KNOW OF OTHER TECHNOLOGIES? LET US KNOW

The potential for technology transfer from the oil and gas business to other industries is substantial. Norway's oil technology companies represent a high-tech sector with a strong concentration on research and development, and a big volume in a Norwegian context. It employs almost 200 000 people in 4 000 companies, with an annual turnover of more than NOK 360 billion.

With so many companies involved, it is not easy to get a full overview of all the technology transfers which have taken place. This report, written by Rambøll on our behalf, has presented a selection identified and described during the autumn of 2013.

We are keen to be tipped off about possible additional technology transfers from Norway's oil and gas sector to other industries in order to get the most complete picture possible.

Send any tips you have about such transfers to Kolbjørn Andreassen, our editor, at **ka@norog.no.**

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