Full speed ahead on Johan Sverdrup

NORWEGIAN CONTINENTAL SHELF

A JOURNAL FROM THE NORWEGIAN PETROLEUM DIRECTORATE NO 1 - 2017

Photo: Rune Solheim

Halfway The first development stage on Johan Sverdrup has reached its midpoint. Hilde Anita Arntsen (left) and Renate Eikeland are part of the workforce at Aker Stord, one of 20 fabrication sites for the platforms.


Photo: Sverre S Jarild

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The interview Petroleum and energy minister Terje Søviknes wants to change what he calls the "bad guy" image the industry has acquired.


Photo: Monica Larsen

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Student optimism
The downturn in applications for petroleum-related courses is flattening out as students take a brighter view of their prospects.

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Sub-surface
Johan Sverdrup was discovered with the aid of masses of existing geological data which were re-interpreted, says Hans Christen Rønnevik.


Photo: Alexey Deryabin

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Rockshot
The photo in this issue hails from Wilhelmøya – a remote area of Svalbard.


Photo: Monica Larsen

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NPD profile
Pressure from the NPD has been crucial for getting out the extra resources in Snorre, says Tomas Mørch.


Photo: Harald Pettersen/Statoil

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More resources
Snorre Expansion will yield almost 190 million extra barrels of oil – making this one of Norway's biggest improved recovery projects.


Photo: Nils Rune Sandstå/NPD

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Minerals
The search for metallic minerals in the world's ocean depths is under way.

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Immobile oil
A new study assesses methods which can help to recover large amounts of residual oil on the NCS.

More to gain

The 50th anniversary of the start to oil and gas production from the NCS is approaching with less than half the resources recovered. Overall resources, including the estimate for those as yet undiscovered, have increased by more than 40 per cent since 1990.

Over the past two months, we have presented two reports which underline the big remaining oil and gas potential.

In our latest resource report for fields and discoveries, entitled with good reason *Value for the future*, we point to the huge quantities of oil and gas already proven and awaiting production.

At 31 December 2016, 77 discoveries were being assessed for development. And more can be produced from existing fields through improved recovery measures. A huge potential exists for using enhanced oil recovery (EOR) techniques.

Further details and the size of the volumes involved can be found in the resource report, which has been published at *www.npd.no*.

What is required to realise this value? First, the companies must take investment decisions on projects which have already been identified.

Second, the industry must collaborate to exploit existing infrastructure and adopt available technology. The NCS has been a laboratory for testing new technical solutions. It must now become a front runner in applying them.

Our report on Barents Sea North-East was published in May. New mapping of this area has doubled the earlier estimate of resources for the whole Barents Sea. This report is also available on our website.

Our job is to maintain an overview of oil and gas resources across the whole NCS. So we also map areas not open for petroleum activities to provide a good factual basis for future decisions.

It goes without saying that future operations in Barents Sea North will be pursued in accordance with the Petroleum Act and the decisions taken by the politicians. Our job is to identify the potential.

Bente Nyland
director general

Out of the echo chamber

A mood of light euphoria grips Terje Søviknes after his first trip offshore, when he has literally looked down on Norway's oil wealth. That made a big impression on the new minister of petroleum and energy.

Bente Bergøy and Sverre S Jarild (photos)

Alliances. *"People often find themselves in circumstances where they stay in their own echo chambers," says Terje Søviknes. "If the petroleum industry is to have the future I hope it gets, it must build alliances with other social players."*

> *Technology represents the key to reaching climate goals, not prohibitions and restrictions.*

The Progress Party politician says he is not often to be found in his office. He prefers to be hands-on, out in the field, where things are happening.

"I'm so incredibly impressed by this industry," he cries. "We're a world leader in so many areas – subsea technology, rigs, clean production …

"I can't see how it's possible to run all this, the platforms and everything which happens far, far beneath the seabed. It's the ultimate in engineering skill. It leaves me gasping!"

Søviknes enthuses about his helicopter ride out over the Norwegian Sea to visit *Deep Sea Stavanger*. The Odfjell rig is drilling production wells on Maria at the moment.

This field will be produced in an intricate interaction with neighbours Kristin, Heidrun and Åsgard, where the wellstream is to be piped to the first of these for processing.

Heidrun will deliver water for injection in the Maria reservoir, while the processed oil is transferred to Åsgard for storage and offshore loading. Gas goes to Kårstø near Stavanger.

"Just imagine, the rig runs two operations simultaneously – that's so efficient, full speed ahead," says Søviknes. "Once the field's on stream, nobody can see it. Ships can sail right over the seabed facilities."

He is a declared technological optimist. "Technology represents the key to reaching climate goals, not prohibitions and restrictions."

Travelled

The minister has begun to settle in after 100 days in the job. He has travelled all over Norway, talking to ordinary workers and company executives.

Visiting suppliers, technology enterprises, government agencies and oil companies, he has seen, asked, listened and learnt about their work, challenges, expectations and concerns.

"If you're going to have a full understanding of the position, it's important to meet people and be hands-on where things are happening," he emphasises.

He has always been keen on the social perspective. "Politicians can't do it all. As council leader in Os, I often worked for tripartite collaboration with industry and volunteers.

"That's a good model. Cooperation with other players is extremely important, not least in the oil and gas industry. We mustn't get too shut off."

People often find themselves in circumstances where they stay in their own echo chambers, Søviknes observes. That can be secure and comfortable, but hardly forward-looking.

"If the petroleum industry is to have the future I hope it gets, it must build alliances with other social players," he emphasises.

As the minister for Norway's largest and most important industry, he has a responsibility for ensuring that the value created benefits the whole nation – including future generations.

In his view, the sector's poor reputation is undeserved. "It reflects the combination of a couple of factors which emerged at roughly the same time.

"After the oil price slump in 2014, many participants in the public debate seemed to think oil revenues were no longer so important for Norway. There was much talk about restructuring and the green shift."

Then came the Paris agreement and the big climate debate. "The result in Norway has been a very polarised discussion," Søviknes says. "People are either for producing fossil energy, or they want to save the planet."

He takes the reputational problem seriously. "We're dependent on recruiting skilled hands and wise heads to continue developing the expertise base we've built up over 50 years.

"This base is the really big asset – it's the one which allows Norway to lie among the front runners for technological progress and right in the lead within the oil and gas sector."

Concerned

Søviknes admits to being worried about the sharp drop in applications for petroleum-related courses. Few students mean it is only a matter of time before the teachers go too – which would be stupid, since the industry needs people in coming years.

He also worries about attitudes to oil among the young. "It's super that youngsters are involved with and concerned about the climate, and they're undoubtedly more idealistic than us older folk.

"But we must get across the fact that it's possible to have both. We can reach our climate targets – *and* explore for and produce oil and gas."

He appreciates that youngsters cannot be reached through traditional channels such as TV, radio and newspapers. "Both politicians and the industry must get better at being where young people are, and communicate more with then there."

Søviknes has taken one step through his initiative on establishing a youth panel, and is recruiting youngsters to help on the message and the channels.

The most important message the minister wants to get across is that if there is one place where people can really make a difference for the climate, it is the energy sector.

And that holds particularly true for oil and gas. Technological advances can have a huge impact.

"We must balance the debate and get the facts across," he emphasises.

Perspectives

Søviknes points to the recent report on *Perspectives for the energy transition. Investment needs for a low-carbon energy system* from the International Energy Agency (IEA) and the International Renewable Energy Agency (Irena).

"They've produced scenarios on what can be done about the world's energy position to achieve the climate goals set in the Paris agreement," he explains

"These agencies believe it's important to invest in wind, solar and other renewable energy forms, but underline that demand for oil and gas will remain high."

Declining production from existing fields means that the companies must continue to explore and bring new discoveries on stream.

"The IEA/Irena scenario for a low-emission society in 2050 assumes that as much as 40 per cent of the energy will come from fossil fuels.

"If that's the case, why shouldn't Norway also contribute? We have a tradition of being a front runner, and emissions from our production are among the lowest in the world."

Although the trend is towards more renewables, oil and gas will continue to be produced. Norwegian gas can replace coal in the EU. The UK, for instance, has a clear policy in this area to reduce emissions.

In late April, Britain experienced its first day without coal-fired energy since the industrial revolution, and the government is resolved to eliminate this source by 2025.

Proud

The minister is proud of Norway's achievements in the oil and gas sector, and wants to eliminate the "bad guy" image which the industry has acquired.

"We must get much cleverer at relating value creation to things which mean something for ordinary people – schools, care of the elderly, transport, health, police and hospitals," he says.

"Oil revenues finance the welfare state. Those working in the petroleum sector used to be regarded as heroes, now they're rogues. That's extraordinary and unjust."

He also finds the media debate is conducted between him as minister, a few politicians and the environmental organisations – not between the political parties and the voters. "That makes the exchanges a little rarefied," he argues.

Asked to sum up the status of the NCS, Søviknes praises the job done by the oil companies and the supplies sector in recent years.

"The industry has really got a grip in strengthening its competi-

On the go. *The minister is not often to be found in his office. He prefers to be out in the field.*

tiveness. We're constantly getting reports that planned developments are cheaper and drilling is going faster."

He emphasises how important it is that these savings last, and that the industry has learnt. "When the companies were hardly making money despite top oil prices, it was high time to reef the sails."

The Conservative-Progress Party coalition has been fully aware of the importance of giving the industry access to new exploration acreage to maintain activity on the NCS.

Since it took office in 2013, 241 production licences have been awarded and consultations held on the blocks proposed for the 24th licensing round.

The government has also announced the 2017 awards in predefined areas (APA) with a substantial expansion of the acreage on offer, particularly in the Barents Sea.

"Big reserves still exist on the NCS," Søviknes notes. "The NPD has doubled its resource estimate for the Barents Sea, which is exciting in a longer perspective. It's important to get across that we have assets to exploit for a long time."

The third success factor he highlights is the change in the player mix on the NCS. Statoil remains the heavy locomotive, but companies such as Lundin, Aker BP and other smaller participants have contributed different perspectives and new methods.

Campaign

"Following the exploration campaign in the Barents Sea this summer will be extremely interesting," the minister emphasises. "Much of the attention in coming years will be on these waters.

"The future lies in the far north. Two fields are on stream there after 40 years of exploration – Snøhvit and Goliat. Alta/Gohta are now in the offing, with more searching to come. That's exciting."

He adds that the results of this year's campaign will affect interest in the 2017 APA and the 24th round. A window of opportunity is open for boosting activity in the Barents Sea.

"The job the NPD has done in mapping the resources is very important. More of this may be needed, and a political discussion will then begin on whether the time has come for an impact assessment and a possible opening process."

Søviknes emphasises that the Progress Party wants this to be achieved during the four-year life of the Storting (parliament) due to be elected this September.

He points out that Norway is blessed with oil, gas, water and wind. The country has always had a debate over utilisation versus conservation, and there is no reason for this to end.

"We must have that debate and apply the management knowledge we possess when deciding whether to open Barents Sea North for petroleum operations."

In his view, it is important to get the facts on the table in order to secure a genuine political decision on which areas are to opened, which will be left closed and what the terms should be.

"But the debate on what we should do with the Barents Sea could become relevant long before we've expected it," Søviknes warns.

"If the Russians start to drill and make discoveries, we must take care of Norway's interests. That we will – the boundary treaty specifies collaboration over producing fields with resources on both sides of the dividing line."

Busy

The minister has a lot he wants to do, and is busy. He was recently dubbed Terje "Full Speed Ahead" Søviknes in leading Oslo daily *Aftenposten* – a label he is happy to accept.

"I'm a man who gives my all in everything I do. I've won renewed trust as council leader in Os four times, and believe that has something to do with being committed and decisive."

Asked what he has managed to achieve during his first 100 days in his new job, his response is forthright:

"The government's been on the offensive with the 2016 APA, and we'll soon be announcing the 24th round. I've otherwise sought to talk up the industry and to boost optimism – both internally and among ordinary people. We have an incredible lot to be proud of."

What happened to the heroes? *The petroleum and energy minister wants to talk the industry up – its "rogue" image is undeserved, he says.*

> *"We must balance the debate and get the facts across."*

Looking brighter

Things seemed very bleak when Marie Hilander Gjerde applied to study petroleum technology in 2015. "There wasn't much positive feedback," she admits. Today, she is buoyant about her job prospects.

Alf Inge Molde and Monica Larsen (photos)

Now chair of Petroil, the association for petroleum engineering students at the University of Stavanger (UiS), Gjerde got little parental encouragement when she chose this course.

Both her mother, a nurse, and her father in the oil service business worried about the impact of the petroleum industry downturn and thought nursing would be a much safer path to follow.

Two years later, it is still too early to decide how sensible her decision has been. Several classmates are privately thinking of shifting to mechanical engineering.

But Gjerde remains convinced that she picked the right option. Although the labour market in Norway's petroleum sector is by no means off the sick list, she feels improvements can be seen.

"I've been in contact with a number of companies who're taking a positive view. Statoil is also launching a number of projects in the next two-three years. And the retirement bulge facing the industry will

Confident. *Petroleum technology student Marie Hilander Gjerde at the University of Stavanger is working hard to get the best possible marks, and has taken on the job of Petroil chair. She believes the job market will look a lot better in two-three years.*

create vacancies. We're going to be needed."

Vanished

More than 40 000 jobs have vanished in Norway's oil sector since 2014, and hardly a week has passed without new headlines on downsizing and gloomy prospects.

That outlook has also been reflected in declining interest in university-level petroleum studies. After three years of falling enrolments, however, the decline appears to be flattening out.

Overall, applications this year are down by a further 7.5 per cent from 2016 for a three-year engineering BSc, and 16.2 per cent for maritime subjects. But figures for a five-year engineering MSc have risen by 0.4 per cent.

Three years ago, the UiS had four applicants for every place on its BSc courses in petroleum technology. Almost everyone who applies gets in today.

Øysten Lund Bø, dean of the UiS science and technology faculty, is pleased that the fall in petroleum engineering applications has slowed. They were down four per cent from 2016.

Upturn

But the UiS is also seeing more applicants for the BSc in petroleum geology and the five-year MSc in petroleum technology related to industrial economics.

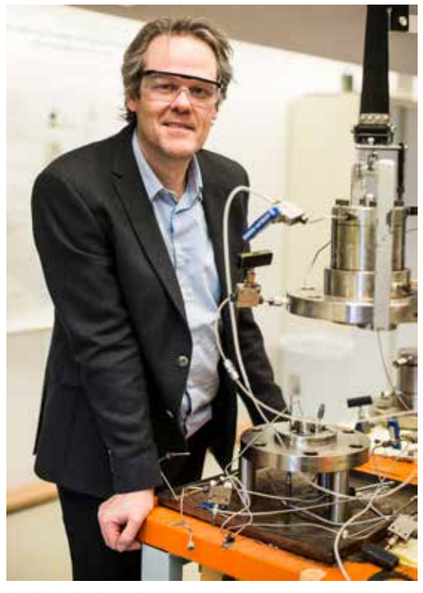
The biggest increase has been for the courses on offshore technology, industrial technology and operations management, where numbers applying were up no less than 68.9 per cent.

Overall, petroleum- and offshore-oriented MSc programmes experienced a rise of 7.4 per cent. The UiS is also seeing an increase in foreign applications.

Bø is hearing that changed acceptance criteria may be reflected in other types of questions being asked in lectures than before, which also exposes a slightly different starting point.

He nevertheless maintains that the quality of the petroleum courses and the students who graduate is high. The star candidates are still there.

However, he admits that new entrants collectively display a rather wider span of initial knowledge. That poses demands for the UiS in lifting the overall level during the period of study.



Optimist. *Dean Øystein Lund Bø in the science and technology faculty at the University of Stavanger wishes the oil industry was a bit readier to make a commitment to young people – even in tough times.*

Secure

Lise Lyngsnes Randeberg, president of the Norwegian Society of Graduate Technical and Scientific Professionals (Tekna), believes those who have opted for petroleum technology studies can look forward to a secure career.

"Norway's going to need petroleum expertise for a long time to come," she emphasises. "We are a world leader in this area, which must be maintained and further developed.

"At the same time, we face a change of generations as many of those who joined the industry when it first blossomed begin to retire. We need renewal."

And this is more than talk, she maintains. After several years of sharp growth in the number of cases related to downsizing and restructuring, the union's lawyers are now dealing with more issues relating to contracts of employment. The change has been particularly clear since Christmas.

Effect

The same effect is being seen by Norway's Labour and Welfare Service (NAV), reports Johannes Sørbø, senior adviser and labour market expert there.

For the first time in several years, the number of unemployed engineers and ICT specialists has declined over the first quarter of 2017.

Two factors appear to account for this – fewer redundancies in the oil and gas industry and more people securing a job, although the NAV cannot say exactly where.

"The signs are that they're finding work outside the oil and gas sector," Sørbø says. "We know this industry isn't doing much recruitment at the moment."

Sorry

Bø is confident of the job market facing students starting petroleum courses this autumn. But he feels sorry for those who fought for a place when they were hard to get, and who are now unemployed.

He wishes that the oil sector would think more counter-cyclically. "Students who've graduated to the dole queue in recent years meet very high quality standards."

Classroom

In any event, Gjerde still has three years in the classroom before she has completed her BSc and MSc courses and will be ready to look for work.

Like her fellow students, she is working hard to gain good marks – and hoping that voluntary posts like chairing Petroil will count in her favour.

Her dream is a job with Statoil, but she knows she has to compete with many others who have a similar education and several years of experience.

"It makes me a bit nervous," she admits. "But I hope some people will also see the favourable side of us new graduates – that we're positive and innovative. They need young people, too."

Upturn. *The University of Stavanger has recorded more applicants for its BSc in petroleum geology and five-year MSc study in petroleum technology related to industrial economics.*

Building it on a big scale

Work on the first development phase for the Johan Sverdrup field involves no less than 14 000 people at 20 different places around the world. *Norwegian Continental Shelf* has visited a couple of these sites.

Rune Solheim (text and photos)

Drone-eye view. *The quarters platform for Johan Sverdrup is under construction here at Kværner Stord. While the biggest structures are inside the workshop on the left, the three covered modules in the foreground are also for this field. On the right, the Statoil-operated Njord platform is in for maintenance.*

A huge blue crane capable of lifting more than 1 000 tonnes forms the gateway to Kværner's yard at Stord south of Bergen. Immediately behind it towers the grey floater carrying the Njord platform topside, which has been towed in for upgrading.

Located centrally on the site, the workshop itself is currently fabricating and outfitting the bottom deck for the Johan Sverdrup quarters facility.

The whole shop is mounted on wheels and can moved aside as the structure grows. Other modules for the platform's topside stand just outside it.

Giants

Much offshore history has been made at this yard, including work with a number of the giant structures on the NCS such as Statfjord A, Gullfaks A, B and C, Oseberg A and Troll A.

Also on the reference list are Snorre A and B, the Njord and Kristin facilities, and the Norne and Åsgard A production and storage ships.

But today's focus is on Johan Sverdrup, the field which has boosted optimism on the NCS. Kværner and US engineer KBR are building a topside with a nine-storey accommodation block.

This platform will also house the nerve centre for the whole field – the control room – and provide space for three helicopters on top.

One of these will be in a hangar on stand-by for search and rescue missions across the whole Utsira High area. And nine lifeboats will be available for the four field-centre platforms.

Activity

Johan Sverdrup is generating a high level of activity at Stord. The topside being built there will include the world's largest offshore accommodation unit to date.

With 560 berths, gym, cinema and sick bay, this "marine hotel" incorporates a set of modules being outfitted only

Top left
Multidimensional. *Hege Robberstad is a 3D modeller, creating detailed visualisations of the quarters platform at contractor Apply Leirvik.*

Top right
Forklift *Yard worker Borowski Bartlomiej operates a forklift as he helps to build Johan Sverdrup at Kværner Stord.*

Above left
Local spinoffs. *"Building Johan Sverdrup has benefitted not only Kværner but also the whole Stord community," says Edmund Skålnes, construction manager at Kværner Stord.*

Above right
Systematic. *Apply Leirvik has developed a special system to manage the accommodation block, report engineering leader Øystein Kvalvik (left) and design coordinator Odd Peter Ørjasæter.*

Outfitting. *The topsides for the Johan Sverdrup quarters platform is starting to look like an offshore installation.*

a few crane lengths away at sub-contractor Apply Leirvik.

Moreover, the support module for the drilling platform is taking shape at Aibel's yard in Haugesund about 60 kilometres further south.

Kværner's Verdal yard in mid-Norway has the job of building the three largest of the four steel platform jackets under an engineering, procurement and construction (EPC) contract.

The heaviest and most complicated jacket, intended to support the riser platform, is approaching completion and will be delivered this summer.

Design work for the drilling and process platform jackets was completed in the late autumn of 2016. Prefabrication and assembly of these are well under way at Verdal for delivery next year.

Proud

Construction manager Edmund Skålnes at Kværner Stord is pleased and proud that the yard proved sufficiently competitive to win fabrication contracts this big in an ever-tougher world market.

The job is worth NOK 6.7 billion to the Norwegian group. Its efforts to boost productivity and cut costs, combined with solid expertise and ability to deliver, help to explain why it won.

"We were facing a period of reduced activity when the Johan Sverdrup order was placed," says Skålnes. "That benefited not only us, but the whole Stord community."

The construction process has so far gone smoothly, reports Trond Ove Lerøy, who is the client's on-site supervisor.

"It's a great strength that well-known and tested components and building methods are being used. That both simplifies the work and makes it more secure."

No headaches

New technology often gives rise to headaches, cost overruns and delays for field developments. But that is not the case with Johan Sverdrup.

The challenge here is not the known technology, but the scale of the project and the many elements being built separately which need to come together at the right time.

"Fortunately, we're well on schedule and haven't had any serious incidents," says Skålnes. "Much of the necessary hardware was ordered even before we landed the contract. Along with good engineering work, that's given us positive start."

Specifications and drawings are closely followed up, Lerøy explains. "Checking that everything's been done correctly is a huge job.

"We have 70 000 sheets which have to be checked against the tag number for each component. It's also very important that things arrive at the right time and place."

Skålnes adds that changes are not welcome. "These usually mean that we must take a step back and amend both plans and methods, which presents extra challenges for fabrication."

Stories

A few kilometres away, Apply Leirvik is building six of 11 components for the accommodation block, covering seven of its nine stories. The other two are coming from Kværner.

Construction began in April 2016, but preparations for tackling the Johan Sverdrup job were initiated as early as 2012. Hook-up and outfitting of Apply Leirvik's modules started in May, with delivery due to Kværner in October 2018.

The company has long experience of building offshore quarters modules, extending from the

Team. *Construction manager Edmund Skålnes (right) at Kværner and Statoil's site supervisor Trond Ove Lerøy are collaborating over the process of completing the Johan Sverdrup quarters platform.*

Statfjord field in 1976 to the Gina Krog development last year.

Operator Statoil produced a rough design outline and then left it up to Apply Leirvik to fill in the details. It is providing engineering services as well as building the modules.

The last two of the latter structures are being constructed by Apply Emtunga, the fabricator's Swedish subsidiary in Gothenburg.

Control

"We've developed our own milestone system, a project management model, to maintain detailed control of both engineering and fabrication from start to finish," says Øystein Kvalvik.

Engineering leader for the accommodation modules at Apply Leirvik, he reports that 4 070 design documents and drawings for building and documentation have been produced.

Design coordinator Odd Peter Ørjasæter calls up detailed three-dimensional drawings of the quarters platform on a big screen.

He explains that specific requirements are set for hygiene, ergonomics, lighting and noise where people will be present on the platform, in addition to all the technical specifications.

The 11 modules are designed to be hooked up very quickly. They add up to 14 500 square metres of accommodation – the rough equivalent of two football pitches.

Reversible

The quarters platform will have 450 cabins, and 110 of these are fitted with a reversible bed. That allows shift workers to share a cabin while retaining their own personal berth.

Each cabin measures 7.6 square metres, with the bed placed crosswise to give more sense of space. All these units are delivered ready-built from Finland for immediate assembly.

Account has been taken of possible requirements for additional accommodation capacity, with mooring locations for three flotels provided on the field.

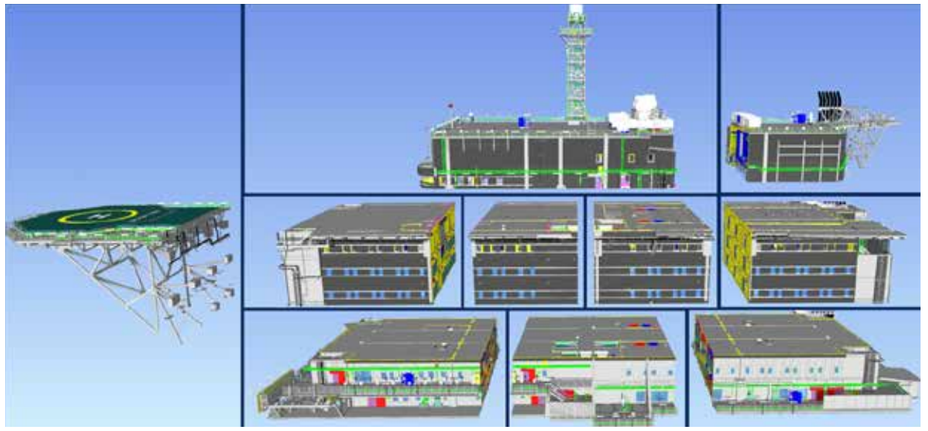
The need to house as many as 560 people on the platform will only arise occasionally, during maintenance turnarounds and modification work. Normal field staffing will be about 220 people.

Although the steel jacket might look a little flimsy in relation to the massive structure it has to support, all the weight calculations are in order.

The accommodation module is being constructed with the two lowest stories in steel and the rest in aluminium, which provides a weight saving of 1 000 tonnes.

If the cranes and helideck are ignored, this offshore hotel looks a bit like the superstructure of a cruise ship – with shiny aluminium surfaces pierced by rows of cabin windows.

It then remains to be seen whether the rest of the voyage will continue calmly towards the planned start of production in 2019.



3D model. *The various modules forming the quarters platform topside. (Illustration: Apply Leirvik)*

Keeping it all together

Construction work for Johan Sverdrup, the new giant North Sea field, is ahead of schedule at the midpoint and could be NOK 26-27 billion cheaper than planned. Making sure things stay that way could be a challenge.

Rune Solheim (text and photo)

Halfway is a milestone," accepts Trond Stokka Meling, Statoil's technical head for this phase-one project. "We're entitled to acknowledge it, but not to celebrate.

"Everyone knows that the challenges could well arise in the second half. We can celebrate when everything's finally put in place."

Although the field is being developed with known technology, some things have not been done before. That includes the first use of *Pioneering Spirit* – the world's largest heavy-lift vessel – for offshore installation.

This ship is due to install the topsides on three of the four platforms under construction, although its experience in this area is limited to removing such structures on Yme and Brent D.

"We've made pretty formidable technological preparations to ensure that this will go well," says Meling. "We also have a whole month's weather window in summer – far more than the job needs."

Platforms

The field installations will comprise four platforms, for drilling, risers, processing and quarters respectively.

Three large modules are due to be hooked up on the drilling platform topside during September, while others will be delivered by Aibel's yard in Thailand.

With a drilling rig from the Nymo yard in Grimstad and the drilling support module from Aibel's Haugesund yard, this platform is scheduled for towout to the field in the summer of 2018.

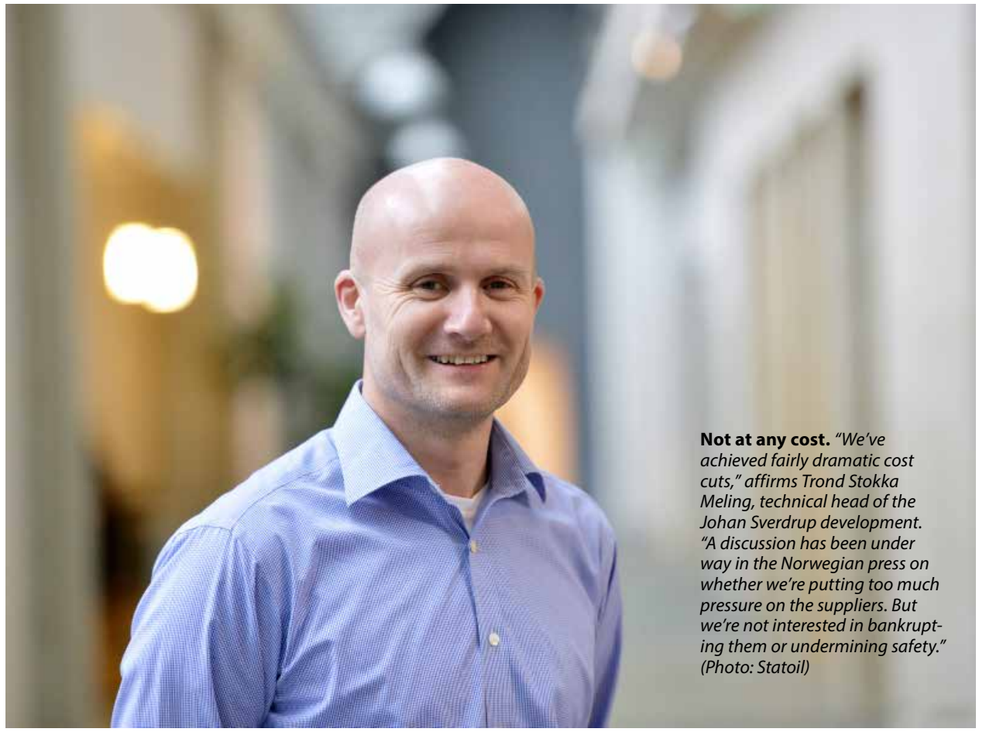
The riser and process platforms are under construction at the Samsung yard in South Korea and set to sail for Norway next year and in 2019 respectively.

Power

A high-voltage direct current connection (HVDC) facility supplied by South Korea will be installed on the riser platform as part of delivering power from shore to the facilities.

Preparations for the transformer station at Haugsneset, just to the east of the Kårstø terminal north of Stavanger, are well under way.

This installation will convert



Not at any cost. *"We've achieved fairly dramatic cost cuts," affirms Trond Stokka Meling, technical head of the Johan Sverdrup development. "A discussion has been under way in the Norwegian press on whether we're putting too much pressure on the suppliers. But we're not interested in bankrupting them or undermining safety." (Photo: Statoil)*

alternating to direct current, with the HVDC turning it back to alternating on arrival – a process which minimises power losses in transmission from land.

The process generates a good deal of heat and radiation and therefore takes up a certain amount of space. Johan Sverdrup is to receive 100 megawatts from shore.

Control

The offshore control room will run all four field-centre platforms (set to rise to five in the second phase). These facilities will have a combined staffing of about 280 people.

In addition, the control room will manage the subsea systems, a possible unstaffed wellhead installation, and the power supply facility on land at Haugsneset.

Part of an organisation of about 130 people linked to the field centre, the onshore operations centre will deploy real-time data and expert tools for support and decision-making.

Taking power from shore eliminates the need for big diesel or gas-turbine generating sets on board. But boilers needed by the process plant usually run on waste heat from the generators.

In the first stage, this heat will be provided by gas, with power from shore taking over in the second phase. The quarters platform will also carry a diesel-driven emergency generator.

Size

The challenge for the project is its size. Everything must fit together even though construction has been pursued at 20 sites around the world.

Meling underlines the importance of information being conveyed in a precise manner and interpreted in the correct way.

"All the equipment must work when it comes offshore. Interfaces, design and construction have to be done well. The preconditions must be the same at all the yards."

He recently visited a supplier in Poland providing seven cranes. Follow-up is important to ensure that they work properly offshore. Correcting anything out at sea is more expensive.

A challenge arose after a bridge across an Italian motorway collapsed. Driving heavy vehicles over such structures was banned for a while in northern Italy, making it impossible to get equipment to the docks for shipping out.

"We were locked in," says Meling. "Fortunately, we found roads which could be used and sent the freight by river barge to the coast and onto the cargo ship."

Share

Asked how much of the Johan Sverdrup development is being constructed in Norway, he says it depends on how the domestic share is calculated.

About 70 per cent of the contracts have gone to companies with a Norwegian address. However, some of these are allocating part of the work to their foreign branches.

An example is drilling platform contractor Aibel. It has an office in Oslo and a yard in Haugesund, but is using its Thai facility for some

Phase one. *The chosen solution for the first development phase is a field centre with four specialised platforms for quarters, process, drilling and risers respectively. They will be linked by bridges. (Artist's impression: Statoil)*

work because of a lack of capacity in Norway.

Palfinger provides another case in point, with an office in Bergen while manufacturing its cranes in Poland. So the picture is nuanced, Meling points out.

"The suppliers have looked at how they can be competitive in an international market. They can often compete on engineering and hook-up, but need to weld steel in other countries.

"When the company is Norwegian, we communicate with its management here. That's clearly an advantage. In technical terms, however, we've no grounds for saying that Norway does things better than elsewhere as long as the specifications are met."

Construcion

Around 14 000 people will be employed on the Johan Sverdrup project at peak, and the whole construction period involves 51 000 work years. But Meling is unsure how many of these are Norwegian.

A decision is due this summer on permanent monitoring of the Johan Sverdrup reservoir with the aid of four-dimensional seismic surveying.

This involves repeating three-dimensional surveys at regular intervals to check developments in the formations once production is under way.

While the cost of such surveillance has been included in the field's plan for development and operation (PDO), it must be approved by the partners before 1 July.

Meling notes that opportunities to acquire sub-surface data on an annual basis will provide increased understanding of reservoir behaviour during production and water injection.

"That in turn allows us to improve the planning of new wells and methods for boosting resource recovery. Our ambition is to get out 70 per cent of the proven hydrocarbons."

Operator Statoil and its partners have a 50-year production time frame, and need robust data to reduce uncertainty. That can improve the recovery factor and extend the field's commercial life.

Fantastic

Meling describes the economics of Johan Sverdrup as fantastic. "When sanctioning phase one, the bill was put at NOK 123 billion. We're now down to NOK 97 billion.

"We've achieved fairly dramatic cost cuts, and a discussion has been under way in the Norwegian press on whether we're putting too much pressure on the suppliers.

"But we're not interested in bankrupting them or undermining safety. We take great heed of health, safety and the environment. A project isn't a success if we suffer a serious incident.

"Our positive experience is that we're getting what we ordered, to the right quality and by and large on schedule, so that we don't have to spend heavily on repeating the work."

Noted. *The Utsira High discoveries are very significant for the further development of specialist expertise in Norway's oil sector, believes Hans Christen Rønnevik. He says they will "occupy a key place in efforts to reduce the crisis in the industry and to secure jobs for the future." (Archive photo: Emile Ashley)*

Getting to the bottom of it

"Integrating all available data to detect possible degrees of freedom for formulating new hypotheses was the key to success," says Hans Christen Rønnevik. This approach allowed him to spot the geological potential of the Utsira High in the North Sea.

Alice Ølberg Bore

"We took cores, analysed and tested. That was essential for acquiring a quick grasp of the local geology."

The southern part of this area had been sporadically investigated by most of the big companies since 1967," explains Rønnevik, former exploration manager at Lundin Norway.

"This meant large amounts of geological information were available, which we were able to utilise as the basis for a new interpretation."

He adds that the subsequent discoveries on the Utsira High introduced broadband geophysics to the NCS, and this methodology has since become standard there.

The first big find in the area was made in the Luno prospect during 2007, renamed Edvard Grieg when the plan for development and operation (PDO) received approval in 2012.

With estimated recoverable oil reserves exceeding 200 million barrels (32 million standard cubic metres), this discovery converted the nearby Avaldsnes structure to a low-risk prospect.

Lundin's 16/2-6 ("Avaldsnes") well in 2010 discovered the giant field now called Johan Sverdrup. Holding some 2.8 billion barrels of oil, its peak daily output could reach 660 000 barrels.

Concept

Rønnevik explains that the exploration concept for Utsira High South was a big accumulation with a oil zone 40-50 metres thick under a gas cap less than 1 950 metres beneath sea level.

The Edvard Grieg and Johan Sverdrup discoveries have shown oil/water contacts down towards this level. They have no gas cap and are thereby undersaturated.

However, the level of undersaturation in the Johan Sverdrup crude is considerably greater than for the genetically similar oil in the Edvard Grieg formation.

Predrilling analysis indicated that the Johan Sverdrup structure was formed 1.5 million years ago. The discovery shows that oil-filling has been very rapid and is still under way.

Edvard Grieg comprises land-deposited Jurassic/Triassic sandstones and conglomerates with relatively good properties. Such reservoir rocks have not been encountered before on the NCS.

Wells drilled in Johan Sverdrup have found very good reservoir properties in the Upper, Middle and Lower Jurassic sandstone sequences deposited in shallow seawater and along the shoreline.

Extensive

"This discovery covers a very big area and called for extensive appraisal drilling," says Rønnevik. "We took cores, analysed and tested.

"That was essential for acquiring a quick grasp of the local geology and to provide a solid factual basis for the models on which the development plans were to be built."

He emphasises that each well has been very significant for amending and adjusting the models. A crucial factor is that the people who formulated the hypotheses were also involved in updating during the operational work.

"Putting together technically diverse teams of people with the ability and commitment to reach a collective result is important," Rønnevik emphasises.

"Operational activity must rest on fact-based learning and steady improvements in practice. Relationships between the people involved are crucial."

He says that the Utsira High discoveries are very significant for the further development of specialist expertise in Norway's oil sector. They will "occupy a key place in efforts to reduce the crisis in the industry and to secure jobs for the future."

Age no barrier

Hans Christen Rønnevik has passed his 70th birthday and is no longer a full-time Lundin staffer, but remains active in the company's geological team as an adviser.

With the NPD from 1972-83, he then served as vice president for exploration at Saga Petroleum from 1984-99 before helping to resurrect Det Norske Oljeselskap in 2000.

He joined Lundin Norway on its creation in 2004. This company contributed to revitalise activity on the NCS with the Alvheim, Edvard Grieg, Johan Sverdrup, Gohta and Alta discoveries in 2003, 2007, 2010, 2013 and 2014 respectively.

How value can be created by understanding the geological images of the sub-surface is a question which continues to concern Rønnevik.

"Concepts, theories, tools and methods are always inadequate," he says. "Accepting that is essential for learning and new value creation.

"Concepts are created by geotechnical integration of people ahead of mathematical modelling. Reality is revealed more through activity than by predictions."

Facts about Johan Sverdrup

- Oil field on the Utsira High in the Norwegian North Sea, 40 kilometres south of Grane and 65 kilometres north-east of Sleipner.
- Scheduled to come on stream on 1 December 2019.
- 70 per cent of the contracts awarded to companies with a Norwegian address.
- Profitable at an oil price as low as USD 20 per barrel.
- Will yield NOK 1 350 billion in revenues over a 50-year producing life.
- Tax revenues will total USD 670 billion.
- Peak daily production will be 440 000 barrels (70 000 scm) of oil and six million scm of gas for phase one, and 660 000 barrels (105 000 scm) plus 10 million scm for the full field.
- Water depth on the field is about 110 metres.
- Reservoir depth is about 1 900 metres.
- Covers about 200 square kilometres.
- Chosen solution for the first development stage is a field centre with four dedicated platforms for quarters, processing, drilling and risers, all linked by bridges.
- Drilling platform with 48 well slots is designed for simultaneous drilling, well intervention and production.
- Power from shore will be used throughout the field's producing life. Phase two, due on stream in 2022, includes power from shore for other developments in the Utsira High area.
- Oil resources being developed in phase one lie in continuous Upper Triassic and Lower Cretaceous sandstone reservoirs. However, the bulk of the crude is found in Upper Jurassic intra-Draupne sandstones originating from the basement high in Utsira High South. The remainder lies in the Statfjord and Vestland Group as well as in Viking Group spiculites. Oil has also been proven in Zechstein carbonates.
- Water injection will be utilised as pressure support and gas lift in the production wells, along with other measures for improving oil recovery. Producers will be placed high in the thickest parts of the reservoirs, with injection wells close to the oil/water contact. Producers and injectors are four-five kilometres apart.
- Stabilised oil travels from the riser platform to the Mongstad terminal near Bergen through a new pipeline tied into rock caverns. Gas goes from the same platform to the Kårstø terminal north of Stavanger via a new pipeline tied into the rich-gas arm of the Statpipe system west of Karmøy island.

Sandstone on Wilhelmøya

Text and photo: Alexey Deryabin

"Where have these sand grains come from and how did they turn into rock," is the question inquisitive geologists ask themselves when they look at sandstone outcrops.

NPD geologist Andreas Bjørnestad is seen here on Wilhelmøya – a remote part of the Svalbard archipelago where rocks analogous to the sandstone reservoirs on the NCS can be studied.

These sediments belong to the Svenskøya formation and were deposited in a shallow sea around 200 million years ago. The cliff has some horizontal layers at its base, overlain by strata formed in a nearshore deposition environment.

Sandstone is fairly unconsolidated and can easily be scratched with a fingernail. Some fragments of fossile trees and bits of coal can be found at this location.

Wilhelmøya, Svalbard. (Illustration: Norwegian Polar Institute)

Doubling. *Tomas Mørch, an assistant director for development and operations in the NPD, describes Snorre as "a fantastic journey," with a doubling in its estimated resources. "This makes it one of the biggest improved recovery projects on the NCS."*

Patience is a virtue

Working with oil and gas calls for long-term thinking – and endurance. Tomas Mørch's first job when he joined the NPD in 1992 was to produce reservoir models for Snorre. He is still keeping an eye on this North Sea field.

Bjørn Rasen and Monica Larsen (photos)

All the signs are that a decision on the Snorre Expansion project will be taken before the end of this year by operator Statoil and its partners.

They are due to submit a plan for development and operation (PDO) which calls for the installation of six or seven large subsea templates providing up to 28 new well slots.

"That could allow Snorre to stay on stream until well after 2040 – 30 years beyond the original PDO forecast," says Mørch, who is an assistant director for development and operations.

"Resource extraction will increase by at least about 190 million barrels [30 million standard cubic metres] of oil – equivalent to a Goliat field."

Fantastic

He describes Snorre as a "fantastic journey", with its estimated resources more than doubled since the start. "This makes it one of the biggest improved recovery projects on the NCS. It remains among the Norwegian fields with the most remaining oil."

The NPD earlier believed that a third platform would be needed on Snorre, but this became "financially demanding" after oil prices slumped.

Many people have described the abandonment of the platform concept as a loss of prestige for the NPD, but Mørch rejects that view.

"Our most important consideration is – and has always been – to achieve a solution which takes care of the big resource potential on the field. In other words, more wells.

"Sanction for the new solution would be a victory for us. It provides the same level of resource utilisation and as many wells as a platform – with lower costs and improved profitability."

Where does this resoluteness stem from? The spark was ignited back in 1992 when Mørch and colleague Bjørn Anders Lundschien produced reservoir models for Snorre.

Their aim was to determine whether water alternating gas (WAG) injection could drive out more oil. The pair wrote a paper on this issue which they presented at seminars.

That led in turn to a good dialogue with Saga Petroleum, the then Snorre operator, which had reached other conclusions in its WAG study. Mørch says the NPD model fitted the actual outcome.

Difficult

Qualified as a reservoir engineer, he has continued to work with Snorre through various roles at the NPD and explains that its reservoir is difficult.

Many solutions have been proposed to improve recovery from the field, which lies at a depth of 2 000-2 500 metres beneath the seabed.

The reservoir comprises Jurassic and Triassic riverine deposits from around 200 million years ago, and covers roughly 10 by 25 kilometres.

Mørch and his colleagues have also studied this formation at close hand a number of times by visiting Ainsa in the Spanish Pyrenees, where it is exposed to the light of day.

"You can walk around and see what Snorre looks like," he says. "These analogues at Ainsa are used in the models we produce to improve our understanding of the field."

Mørch calculates that he and Lundschien have given courses in this Spanish location more than 30 times – and will be heading down again in September.

"You get an insight into what the reservoir looks like, and can learn how wells should be placed and oil recovered. That's useful when each well costs several hundred million kroner."

He points out that advances in drilling technology have helped a lot. "These include horizontal wells, well completion, and guiding gas and water in the reservoir zones to where they do best at driving oil to the production wells.

"More wells have been drilled on Snorre than anyone could have imagined when the field came on stream in 1992."

Battles

Tough battles have been fought over Snorre in meeting rooms at the operator and the NPD. But Mørch nevertheless describes the dialogue as good.

"Positive collaboration with Statoil as the present operator and the other licensees mean we have jointly arrived at good solutions.

"We've made it clear throughout what we think and expect. Unambiguous signals have been given and conditions set on what we consider prudent recovery."

Generally speaking, the broad picture is a battle over investment cash and with senior management in big groups who believe they can

Force. *"We're a driving force for getting out even more oil," says Tomas Mørch, an assistant director for development and operations in the NPD.*

> *"We've made it clear throughout what we think and expect. Unambiguous signals have been given and conditions set on what we consider prudent recovery."*

get a better return elsewhere than the NCS.

"That's their job, but they also have a clear responsibility to utilise Norwegian resources to the full," emphasises Mørch. "Our job is to manage Norway's oil and gas.

"Pursuant to the Petroleum Act, all profitable resources must be recovered. The government won't allow the companies simply to skim the cream."

He believes that the NPD's encouragement has been crucial in ensuring that the additional resources in Snorre and elsewhere are recovered.

"These developments involve major capital spending, to be sure. But such investment pays off – with interest."

Portfolio

Mørch has not worked full-time on Snorre – few NPD staffers stick solely with one task or project. His portfolio extends much wider, and he is currently responsible for the Barents Sea.

Earlier jobs include assessing players who want to enter the NCS, project coordination for a number of development projects, and area studies to persuade companies to cooperate across licences.

His knowledge of the NCS is also applied internationally through the Norwegian Agency for Development Cooperation (Norad). The Oil for Development programme supports other countries in achieving the best management of their petroleum resources.

But Snorre has been his biggest single involvement – so much so that colleagues seldom succeed in finding holes in what he knows about the field and its history.

In what he describes as "weak moments when I got a bit confused," he has actually had bigger problems remembering family birthdays and his own wedding anniversary.

A somewhat overeager commitment also brought Mørch into local politics in Randaberg local authority outside Stavanger, where he sits on various committees and is an alternate council member.

His inability to keep quiet drew him into the Christian Democrats. He told the politicians that Randaberg was the local authority in the region which paid most in road tolls for the smallest return. "That did it."

Social issues interest him. He wants tax revenues to provide the largest possible value creation for society. "And that also applies to oil issues."

His fixed term as an assistant director expires this autumn – he is actually on overtime. "I'm looking forward to new opportunities in the NPD, and will certainly work with vigour."

At the same time, he will be letting go of Snorre. "That'll be like a divorce, and one that leaves me with a heavy heart."

Saga continues

Snorre was originally expected to be shut down three-four years ago. The government is now awaiting new plans to extend the producing life of this North Sea field until 2040 or beyond.

Bjørn Rasen

The Snorre reservoir is regarded as complex, and has given many an expert headaches since its discovery in 1979. Developing the field has been difficult and exciting, with three operators – Saga Petroleum, Norsk Hydro and now Statoil – and much conflict.

But all the discussions and disputes resulted in calculations and plans which have more than doubled estimated reserves since production began in 1992.

The original plan for development and operation (PDO) put recoverable oil at almost 750 million barrels (119 million standard cubic metres).

Steady drilling of new wells has helped to boost that figure to just over 1.7 billion barrels, and the new PDO due in late 2017 should boost this above 1.9 billion. That makes Snorre unique in improved recovery terms.

Saga's initial PDO expected production to cease in 2012-14. As with so many Norwegian fields, however, the Snorre operator and licensees have learnt more, acquired better technology, become familiar with the subsurface and identified new opportunities.

Saga applied for only one operatorship during Norway's eighth licensing round in 1983, covering block 34/7 in the North Sea west of the Sogne Fjord.

It secured that job, but on condition that it joined forces with an experienced oil company to act as guarantor for the selected development solution. The choice fell on Esso Norge.

A single installation was originally proposed, and Saga secured acceptance for the Snorre A tension-leg platform (TLP) tied to a subsea template.

Two options were initially in line for the next phase – either redeploying the A unit to produce the northern part of the field or installing more templates on the seabed.

Big volumes. *The forthcoming Snorre Expansion development will boost recovery from the field by almost 190 million barrels – equivalent to reserves in the Goliat field in the Barents Sea. (Photo: Statoil/Harald Pettersen)*

But neither course was chosen. Instead, the Snorre B semi-submersible came on stream in 2001. In 2010-11, Statoil – now the operator – proposed installing just one template in the north.

Bigger

This would improve recovery, but the government felt a much bigger solution should be considered. Simply "skimming the cream" did not meet the Petroleum Act's requirement that all commercially profitable resources are recovered.

A Snorre C platform was chosen as a third concept in 2013 and gave birth to the Snorre 2040 project. Then industry costs rose as oil prices plunged. It was back to the drawing board.

Few fields on the NCS, if any, have probably occasioned more meetings between operator, licensees and government than Snorre. Ministry, cabinet and Storting (parliament) know it well.

An important milestone was reached in the late autumn of 2016, when the licensees resolved to continue the project under its new name of Snorre Expansion.

The platform concept has been abandoned and the solution will now be a big development with six or seven templates tied back to Snorre A to provide capacity for up to 28 new wells.

While a total of 93 wells were originally planned for the field, more than 120 production and injection wells have actually been drilled so far.

It is no secret that the companies and the government have been at odds over the best way to manage the Snorre resources, with the authorities largely relying on objective arguments.

But they have also turned to stronger measures by setting conditions for the companies, which have been dependent on getting the production licence extended.

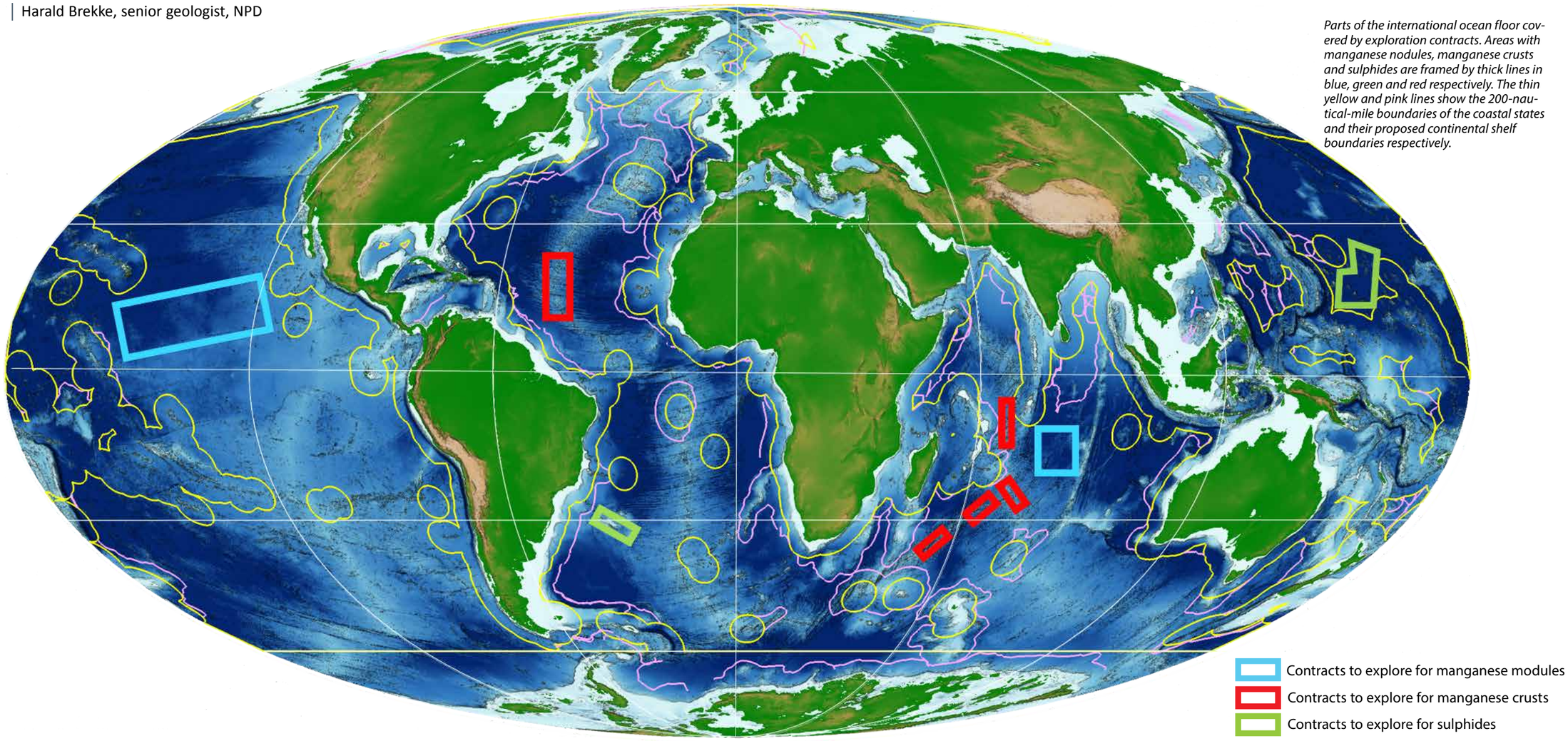
That is because Snorre was initially expected to have a much shorter producing life – and the government has exploited this opportunity to get progress and the necessary project decisions.

These commitments have been adopted at the same time as Snorre's operational regularity has steadily improved in recent years.

The latest temporary licence extension expires in June 2018, and a new PDO must be approved by then. If it is, the two licences covering Snorre will be extended.

Seabed search for metals surging ahead

Harald Brekke, senior geologist, NPD



Parts of the international ocean floor covered by exploration contracts. Areas with manganese nodules, manganese crusts and sulphides are framed by thick lines in blue, green and red respectively. The thin yellow and pink lines show the 200-nautical-mile boundaries of the coastal states and their proposed continental shelf boundaries respectively.

Exploring for minerals on the ocean floor has been under way in international waters for more than 15 years. Interest in these resources is also growing in Norway.

The presence of metallic seabed minerals in the world's oceans has long been known. In some areas, these accumulations are of a size which may make them commercial – and thus to be regarded as ore deposits.

These seabed resources were a key driving force behind negotiations on the UN International Law of the Sea treaty in 1973-82, which now regulates the rights to exploit them.

A total of 27 active exploration contracts have been awarded for international sea floor areas, split between the three types of mineral deposit.

These are manganese nodules, manganese crusts and sulphides. Each of them in turn contains a number of metallic elements and lies in water depths of 1 500-6 000 metres.

Under the UN Convention on the Law of the Sea (Unclos), a coastal state controls the resources on and under its whole continental margin – even where this is extends further than 200 nautical miles from land.

The convention defines this area of national jurisdiction as the coastal state's continental shelf – in other words, a legal rather than scientific definition of the term.

It means that the NCS is not confined to the relatively shallow areas where oil and gas are found. It also includes waters several thousand metres deep and far from land, where exploring for other types of resources could be relevant.

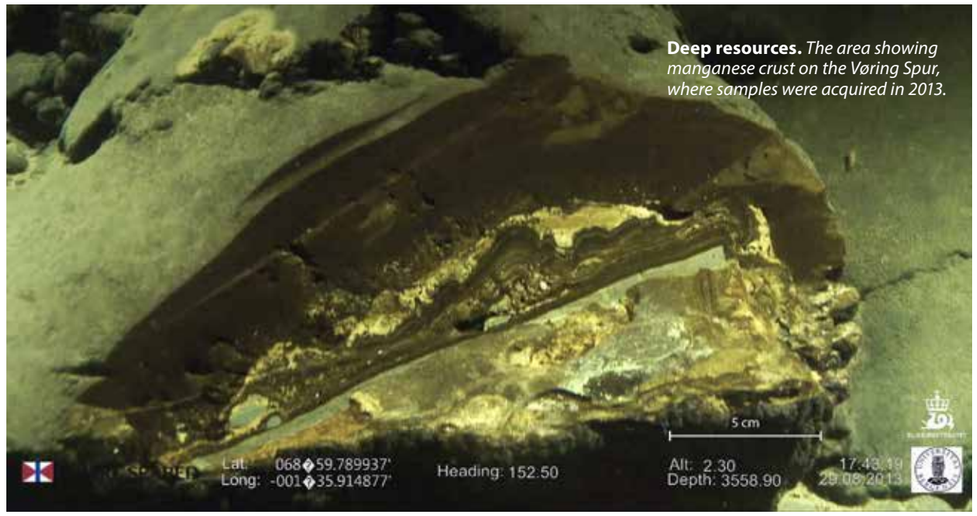
Quantities

Found on soft seabeds in the deep ocean, manganese nodules contain large amounts of manganese and iron with smaller quantities of copper, nickel, cobalt, titanium and platinum.

Manganese crusts also consist largely of manganese and iron, plus titanium, cobalt, nickel, cerium, zirconium and rare earth elements (REEs). They grow as laminated deposits on bare bedrock exposed at the seabed in water depths of 1 500-3 000 metres.

Sulphides primarily comprise lead, zinc, copper, cobalt, gold and silver, and are linked to hot springs in volcanic spreading ridges beneath the oceans where "black smokers" form.

These vents continue to spew out hot material for several thousand years before dying out and leaving behind mounds which con-



Deep resources. *The area showing manganese crust on the Vøring Spur, where samples were acquired in 2013.*

tain the bulk of the sulphide ore resources.

Sought

Such resources have been sought in the international parts of the ocean seabed for more than 15 years under contracts awarded by the International Seabed Authority (ISA).

The first of these areas went to seven pioneering investors in the 1990s, but their contracts only came into force in 2001 when exploration regulations for manganese modules were put in place.

Little happened until 2012, when the number of applications for the contracts suddenly rose substantially and remained stable for the next three-four years.

The jump in the number of applications coincided with the completion of the regulations governing the search for sulphides and manganese crusts.

It also occurred at a time when China was becoming the monopoly supplier of a number of strategic minerals which are important for introducing "green" technology.

Manganese crusts are expected to be a future source of such strategically important metals, including REEs.

Copper

Moreover, the world's copper reserves on land – put at roughly 720 million tonnes by the US Geological Service (USGS) – appear to be running out.

They will last for only 40 years at today's level of consumption, but demand is expected to rise substantially in the next few years in response to green technology needs.

That gives a much shorter timeframe for identifying further supplies. In that context, the USGS has put global copper resources in manganese nodules at about 700 million tonnes – roughly equal to current land-based reserves.

While the USGS has not published figures for copper resources in deep-ocean sulphides, others have put them at less than a 10th of the USGS forecast for manganese nodules – probably a very conservative estimate.

Exploration

Most of the contractors involved with the 27 active contracts are state-owned institutions, such as France's Ifremer and BGR of Germany.

Private companies have also joined the hunt in recent years, including UK Seabed Minerals, Belgium's G-Tec Sea Minerals and Keppel from Singapore.

All contractors must have official support from their own government, and 20 countries are currently backing exploration for these minerals. Five are developing countries – small island states in Asia and the Pacific.

The contracts run for 15 years, with the contractors originally expected to convert subsequently to a production phase. That has not happened.

Instead, all seven of the pioneer contracts have been given a five-year extension. At the same time, the ISA is working on regulations to govern extraction.

First

Production of minerals from international waters could begin during the next decade, with manganese nodules set to be the first target.

Long before then, however, Canada's Nautilus company is likely to start output from the Solwara 1 sulphide ore field in 1 700 metres of water off Papua New Guinea's continental shelf.

The mining equipment has already been designed and built, and a production ship will be ready in 2019. This activity could have great influence on the industry's development elsewhere.

Present

Where the NCS is concerned, seabed minerals are known to be present in deep parts of the Norwegian Sea. The University of Bergen (UiB) found black smokers there more than a decade ago.

Drawing in part on the NPD's large multibeam bathymetric data set, acquired for boundary mapping, the university has identified a number of sulphide deposits.

Including both smokers and gravel heaps, these are located along the volcanic Mohns Ridge between Jan Mayen and Bear Island and northwards on the Knipovich Ridge.

Samples have since been taken from a number of sulphide deposits and manganese crusts while mapping the Norwegian Sea in a long-running research partnership between the UiB and the NPD.

This is part of the university's internationally acclaimed study of the volcanic processes leading to sulphide deposits, and of their unique fauna.

Where the NPD is concerned, the work is part of its general mapping of resources on the NCS – which forms one of its main duties.

The Norwegian University of Science and Technology (NTNU) has also recently begun work on seabed minerals, making its own investigations of the sulphide deposits identified by the UiB.

Norway's continental shelf areas are expected to contain manganese crusts in parts of the deep Norwegian Sea and around the Yermak Plateau in the Arctic Ocean and Bouvet Island in the South Atlantic.

On the other hand, manganese nodules are not likely to exist in these waters, with the possible exception of the areas around Bouvet Island.

Commercial

The question now is whether these minerals are found somewhere on Norway's continental shelves in such quantities and of such quality that mining them could be commercial. A lot more work and investigation is needed to provide a reliable answer.

To get the ball rolling, the NPD has carried out an initial series of chemical analyses of thick manganese crusts on steep slopes of the Jan Mayen Ridge and the Vøring Spur.

These have revealed interesting differences compared with such deposits in the rest of the Atlantic and in the Pacific.

Manganese crusts in the Norwegian Sea fall into two groups in terms of their lanthanide content. One has twice the amount found in Pacific and other Atlantic sources, the other has less.

Both categories contain substantially more lithium (20-80 times as much) and scandium (four-seven times). These are interesting "green" metals.

The group with a high lanthanide content also has a greater proportion of yttrium, and is therefore richer in the whole series of REEs.

These findings are extremely interesting. The question now is why these chemical characteristics

For the common good

The UN Convention on the Law of the Sea (Unclos) specifies that resources on the international seabed belong to all humankind. According to the treaty, the International Seabed Authority (ISA) is responsible for managing these assets.

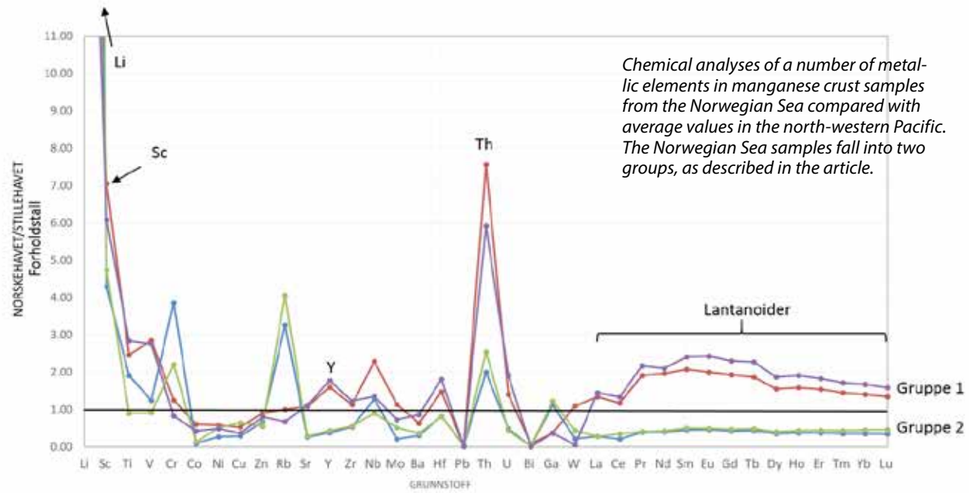
With its secretariat in Kingston, Jamaica, this agency comprises all the Unclos signatory states. Norway is represented on the ISA council through the Ministry of Foreign Affairs.

In addition, the council's technical and legal commission (TLC) has a Norwegian member – previously from the Geological Survey of Norway (NGU), and currently from the NPD.

Companies or institutions seeking exclusive rights to explore for and/or produce seabed resources in international waters must apply to the ISA.

Such applications have to be backed by the formal support of the applicant's government. The rights are regulated under a contract with the ISA.

Metal content in manganese crusts from the Norwegian Sea compared with the Pacific.



Chemical analyses of a number of metallic elements in manganese crust samples from the Norwegian Sea compared with average values in the north-western Pacific. The Norwegian Sea samples fall into two groups, as described in the article.

have arisen and how this knowledge can be used for continued mapping of the quality and extent of the resources.

Similar studies are also needed for the sulphide deposits, which include testing methods for recording various types of data and sampling techniques.

Reliable

Only when good progress has been made here will it be possible to provide reliable estimates of the resources involved.

Good management also requires that such calculations come from responsible institutions committed to recognised standards for reporting resource figures. This is crucial for possible future decisions by both government and the private sector.

Although a number of results are available, little exploration for minerals has taken place on the NCS. Nor does current legislation take account of such activity.

The government is therefore drafting new and modern legal provisions governing mineral exploration on and exploitation of the NCS. These are currently the subject of a public consultation.

Value

The position today is roughly the same as when oil and gas exploration began on the NCS. What has made the petroleum industry a big success in Norway is that these resources have been converted into value for the whole society.

From the start, it has been clear that the state owns the petroleum resources and will manage them for the benefit of the entire population.

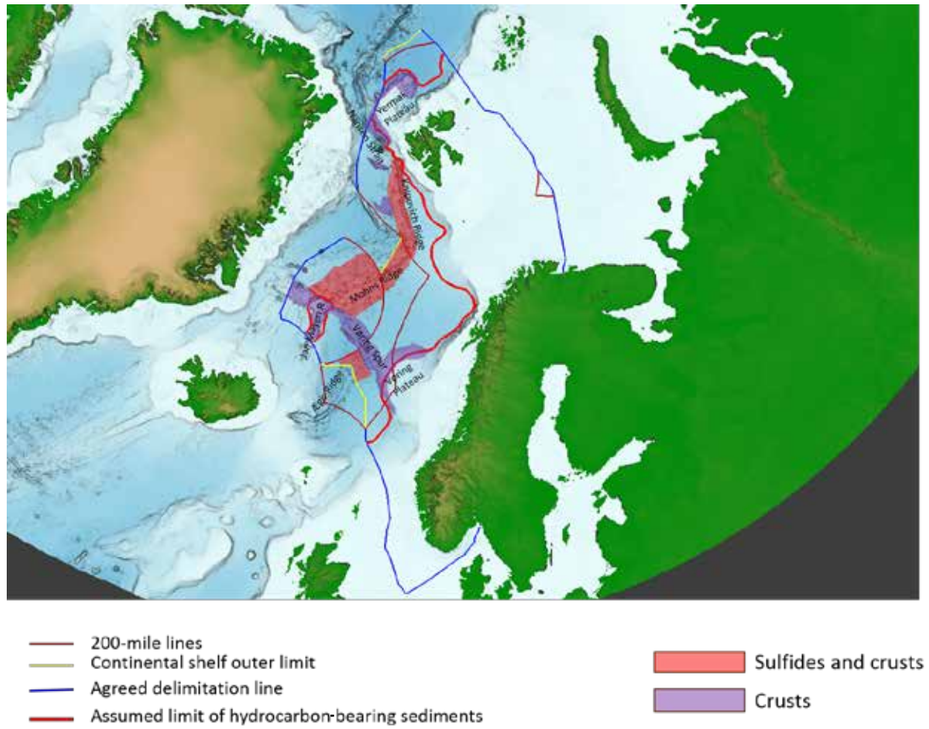
The country also had a shipbuilding industry and world-class maritime technology expertise. Combined with legislation and statutory regulations, this know-how was crucial in managing the resources and the revenues they yielded.

Norway's qualifications for repeating this success have not diminished, even if it now has fewer shipyards. Its expertise on maritime technology has developed further, and the country is a world leader for industry, research and education in this area.

In addition come 50 years of experience in all aspects of marine geological mapping and management of the continental shelf's resources.

So Norway does not need to build up much in the way of additional structures to look after the possible new resources which might exist in the ocean depths.

The original Norwegian version of this article has previously appeared in the* GEO *geology journal.



Anticipated extent of seabed minerals on the NCS.

Positive prospects for producing more

A very significant potential for enhanced oil recovery (EOR) on the NCS has been identified by a recent technical screening study of various available technologies.

Performed by experts from London's Imperial College, this work addressed which EOR processes would be most suitable for the NCS and what incremental improvement could be achieved.

The study compared seven potential approaches with conditions in a number of Norwegian offshore reservoirs to determine how appropriate each of them would be for the respective formations.

High

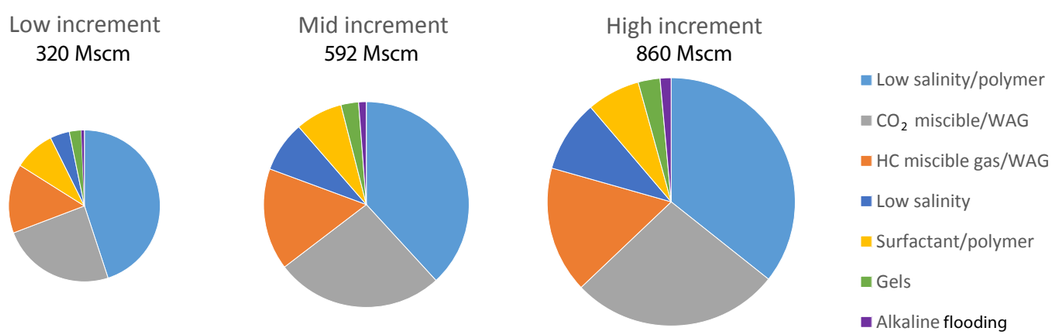
The recovery factor - or the proportion of oil originally in place extracted from fields on the NCS - averages 47 per cent, which is high compared with average global figures of slightly less than 40 per cent.

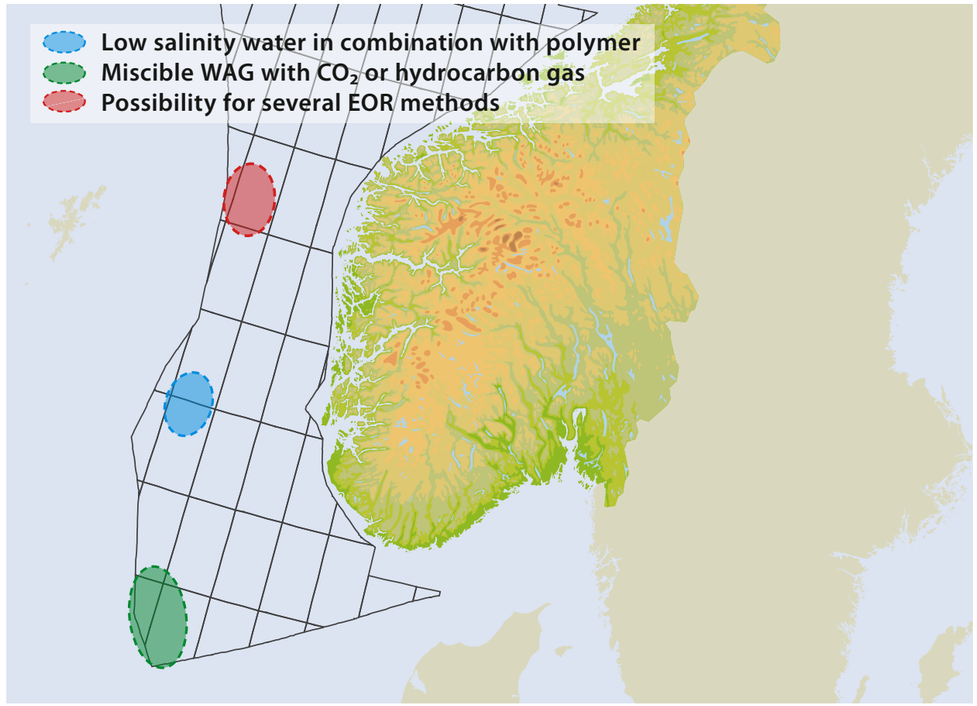
Various technologies can be deployed to enhance this recovery factor even further, and the following approaches have been used in or proposed for oil fields globally.

- **Gas injection**. The principal gases used are hydrocarbons, CO_2 or nitrogen (or nitrogen-rich flue gas). Injected gas may be miscible – where the gas and oil dissolve in each other to create a more mobile fluid – or immiscible, with the oil and gas remaining separate phases.

  Both miscible and immiscible injection are usually implemented in alternation with slugs of water. Such water alternating gas (WAG) processes are more effective at producing oil, since the water improves gas sweep through the reservoir.

  Hydrocarbon gas injection has already been used successfully on the NCS (in Statfjord and Oseberg, for example). CO_2 injection has the added attraction that some of the gas will remain in the sub-surface permanently and thereby contribute to carbon capture and storage (CCS).
- **Alkaline flooding**. Alkaline substances added to injected water react with the oil to produce surfactant compounds which reduce interfacial tension with oil and alter wettability. Both these outcomes can mobilise more oil from the pore spaces.
- **Polymer flooding**. Water-soluble polymers added to injection water increase its viscosity and thereby improve water sweep through the reservoir.
- **Surfactant flooding**. Surfactant added to injected water alters the wetting state of the rock and reduces oil-water interfacial tension, thereby mobilising more oil from the pores.
- **Low salinity flooding**. Oil recovery during waterflooding can be improved by lowering the total salinity of injected water to less than 5 000 parts per million (ppm), and thereby making the rock more water-wet.
- **Surfactant/polymer and low-salinity/polymer flooding**. In these processes, surfactant





or low-salinity flooding (which improves microscopic displacement efficiency) is augmented by adding polymer to improve injected water sweep.

- **Gels and thermally activated polymers (TAP)**. These improve sweep by shutting off specific water flow paths close to producer or injection wells (gels), or deeper in the reservoir (TAP).

Each of these EOR processes has specific envelopes of conditions within which they will perform optimally, or outside which they will not work at all.

In the current study, 53 reservoirs and segments were evaluated in 27 fields, using such screening criteria as lithology, depth, pressure, temperature, oil API gravity, viscosity, oil acidity, oil wetting behaviour, and reservoir porosity and permeability.

Reservoir thickness, fracturing, heterogeneity, clay content, clay type, formation water salinity, injection water salinity, remaining oil and current recovery process were also taken into account.

These screening criteria cover a wider range than those used in other published studies, which thereby enhances the sensitivity of the method. Reservoir data contributed by field operators were screened using the criteria above with the aid of a specially constructed software toolkit.

Effectiveness

Viable EOR processes were assigned recovery increments as a function of the generic effectiveness of the recovery process derived from global EOR project data, a suitability score and the field oil in place.

The suitability score quantifies the applicability of a given EOR process in a specified field. These scores were generated by the screening toolkit using the technical criteria, weighted for importance.

They vary between 0 and 1, where a score of zero means that the process is not viable and one means the process is optimal for that field. EOR processes with a zero score are assigned a zero recovery increment.

The EOR potential was estimated as the recovery increment for the top EOR process in each field – in other words, the one with the largest recovery increment.

When applied across all 27 fields studied, that gives an EOR potential of 590 million standard cubic metres (scm). This is the mid value in a range of possible outcomes based on an estimated technical potential of 320-860 million scm. The NCS clearly contains a very significant EOR potential (see figure on page 33).

Applicable

Four EOR processes are widely applicable and have mid-case technical potential recovery increments of over 40 million scm.

- Low salinity/polymer offers the largest large potential increment, mainly from fields in the Utsira High and Tampen areas of the North Sea.
- Surfactant/polymer suits similar fields, but only performs better than low salinity/polymer in a few fields from the Tampen area and the Halten Bank in the Norwegian Sea.
- CO_2 injection is promising in fields where this gas is expected to be miscible at reservoir conditions. These are mainly the chalk fields in the greater Ekofisk area and fields in the Tampen area.
- Hydrocarbon gas injection/WAG is potentially viable in many fields, and is already the most widely deployed EOR process in the North Sea.

Clear geographic trends for the applicability of EOR processes can be seen, and these could have important implications for economies of scale and injectant supply. The figure on page 34 shows two areas where the same EOR method is the top opportunity for all the fields within them.

Other EOR processes (low salinity, gels, alkaline flooding) are viable for niche conditions in certain fields.

While low-salinity flooding, for example, is not as effective without added polymer, it is viable on fields which are either too hot for polymer deployment or have very low-viscosity oil where polymer would add no benefit.

Gels and thermally activated polymers are viable in very mature fields to improve sweep and control water production.

Factors

All the fields in the study have some EOR potential. The amount of incremental recovery for a specific field depends on two factors – first, the existence of an EOR process which is fully optimal for that field with respect to its screening criteria and, second, the remaining field oil in place.

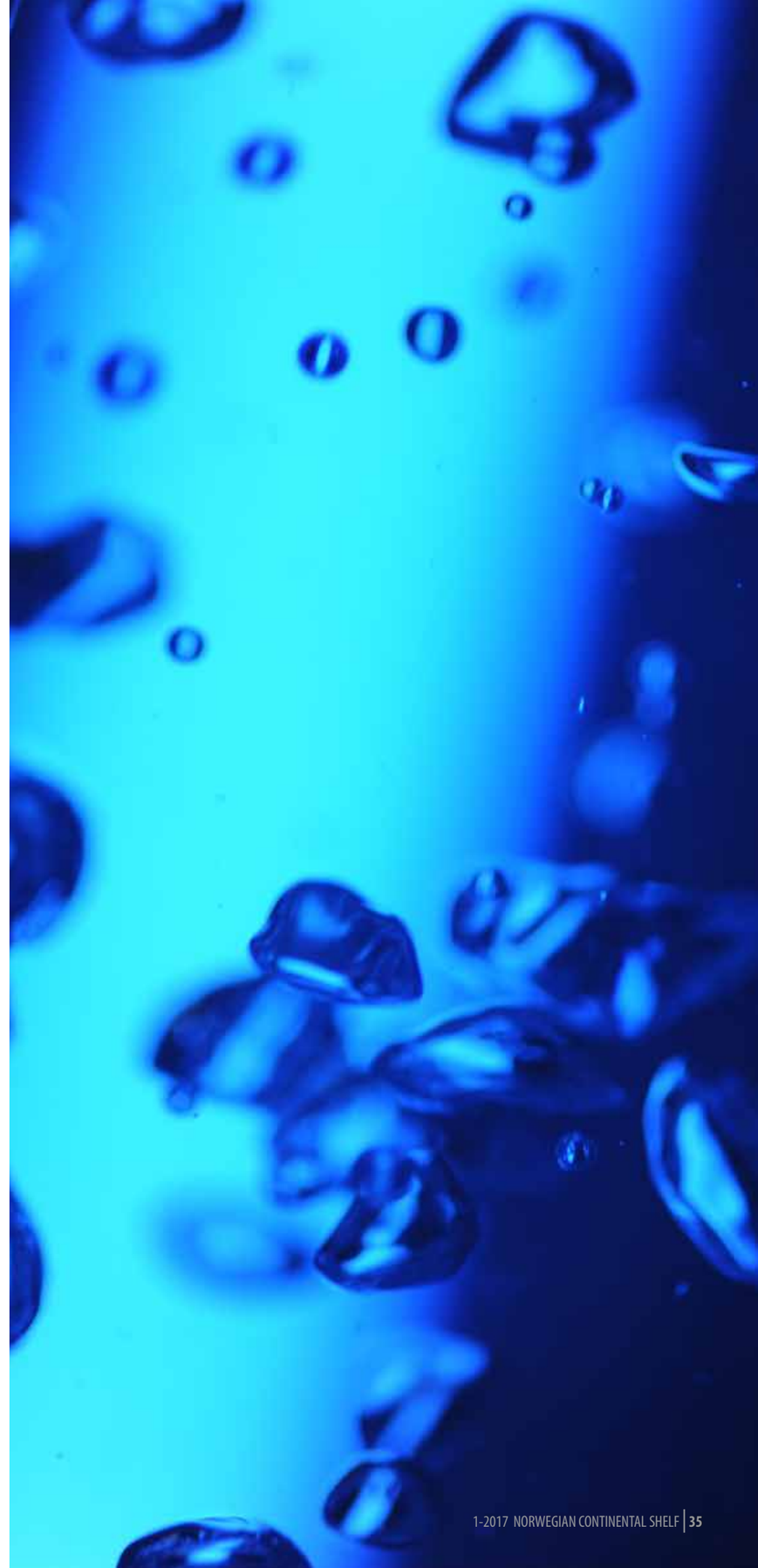
The amount of remaining oil, in turn, depends on the initial oil in place and the amount produced from the field so far.

Potential

This screening analysis gives an indication of the *technical* potential for EOR. The next steps are to apply rigorous operational, commercial and environmental screening criteria to determine more accurately the size and location of the *practical* potential.

The study recommends that the current work be followed up by a gap analysis to determine the main barriers to implementing EOR processes and an in-depth analysis of the most promising fields using a reservoir technical limits type of approach.

Further research may also be needed to develop some of these processes for the more testing conditions found in certain of the offshore fields, and to investigate the potential synergies between EOR processes and CCS.



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