DEEPSEA TREASURE HUNT

WITHOUT OIL, WHAT THEN?
A DIRECTOR GENERAL BOWS OUT

NORWEGIAN CONTINENTAL SHELF

A JOURNAL FROM THE NORWEGIAN PETROLEUM DIRECTORATE NO 1 - 2020

The Covid-19 epidemic means that this issue will not be appearing in a print version, but only as a web edition. Please note that the magazine went to press before the virus outbreak radically changed daily life.

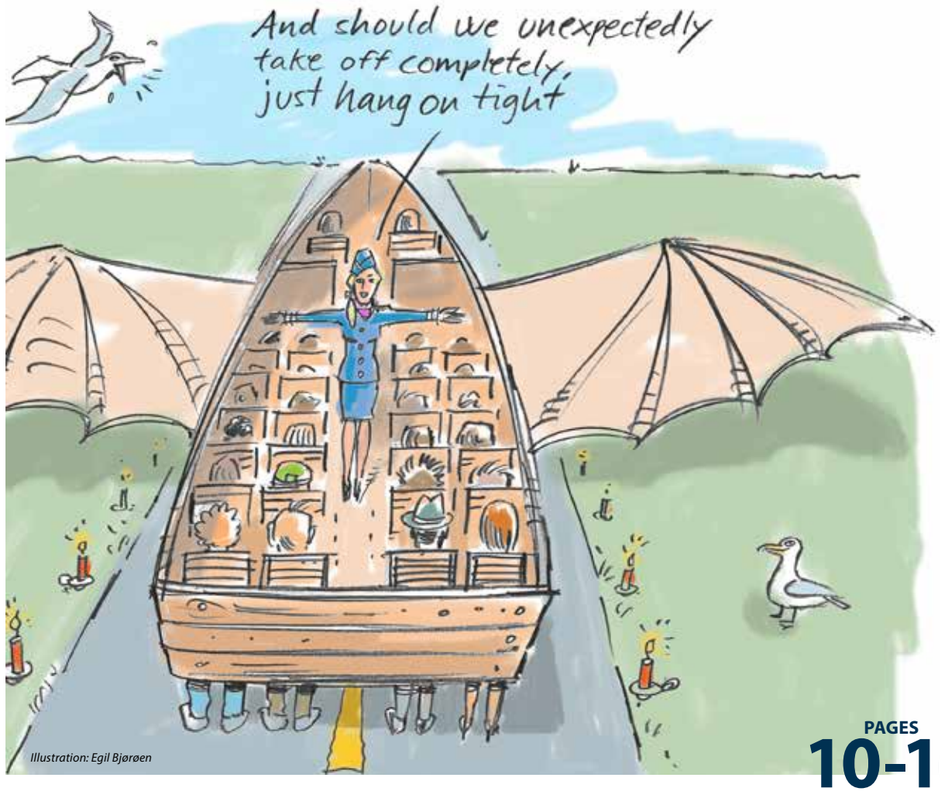

Illustration: Egil Bjørøen

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What if oil disappeared tomorrow?

Oil is an extremely energy-intensive and versatile liquid which humans have benefited from since the 1850s. Now, 170 years later, many are calling for production to cease altogether. What happens then?

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COVER PHOTO
Measurements on an active vent in the Fåvne sulphide field 3 000 metres down in the Norwegian Sea. (Photo: K G Jebsen Centre for Deep Sea Research, University of Bergen)

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Bente Nyland has stepped down after 12 years as NPD director general. It is a pity that the positive aspects of oil and gas often fail to emerge properly, she says.

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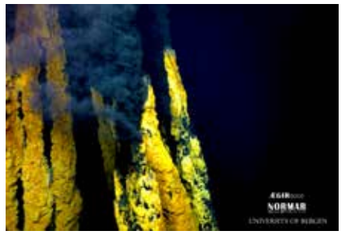
Crushed rock on the Gands Fjord.



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Success in seeking seabed assets

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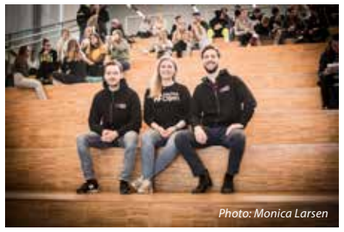

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Feelings and facts

How do young people view the oil industry? That differs according to where they live and how old they are.

Energy needs

Norway is a different country. Nature has been generous with us. Our ability to exploit natural resources has put us in a unique position with a very high standard of living, a technology industry which ranks as a global leader, and a sovereign wealth fund of more than NOK 10 000 billion. That benefits the whole of Norwegian society.

We are more than self-sufficient in energy. Hydropower has supplied us with renewable electricity for more than a century.

And we have oil and gas. In a world which constantly needs more energy and the consumption of petroleum is expected to remain high for many decades, we should exploit these natural resources in the best possible way with the lowest possible carbon footprint.

These resources create revenues which fuel the welfare state we live in, and are necessary for others who cannot meet all their own energy needs.

Oil and gas are also used to a great extent in producing products we surround ourselves with in our daily lives – and which cannot readily be replaced by other raw materials.

Petroleum is very much a world business, and we should view it from that perspective. Although this industry is big in Norway, we are a small part of it in a global context.

Our production of oil and gas amounts to two per cent and three per cent respectively of the world figure, while greenhouse gases released from this output are a thousandth of the total.

We must nevertheless do all we can to keep emissions as low as possible. So it is gratifying that Norway's united petroleum sector recently unveiled ambitious plans to cut carbon emissions from oil and gas production to "net near zero" by 2050.

Forecasts and scenarios of the future energy mix make it clear that petroleum will continue to be important in this context for several decades to come.

Norway has signed up to the Paris agreement. Combined with the national carbon tax it pays, our oil and gas industry is thereby encouraged to do its utmost to reduce production emissions.

Moves there include extending the use of electricity, improving energy efficiency and keeping flaring to a minimum at petroleum facilities.

We face a lot of tough – and intelligent – work to fill our place in the energy mix in a way which meets the goal of a sustainable future emissions.

Ingrid Sølvberg
Director general

"What we're going to live on after the oil is still unclear"

Big assets remain to be recovered from the NCS, says Bente Nyland on stepping down after 12 years as director general of the NPD. That is fortunate for Norwegian prosperity, since no genuine alternative exists at present.

Bjørn Rasen and Monica Larsen (photos)

Checking out. *"It's up to others to deal with the future now," says Bente Nyland after completing two terms over 12 years as director general of the NPD.*

Nyland has just started clearing her office when we meet in a grey, rainy Stavanger, the day after Sylvi Listhaug became the eighth petroleum and energy minister appointed during her watch.

But it is likely to be her successor who welcomes the Progress Party politician to the NPD. Listhaug's seven predecessors during Nyland's time in office began with Odd Roger Enoksen.

She was then acting in the job. He was followed by Åslaug Haga, Terje Riis-Johansen, Ola Borten Moe, Tord Lien, Terje Søviknes and Kjell-Børge Freiberg. The first four belonged to the Centre Party, and the last three to the Progress Party.

Nyland joined the NPD as a geologist in 1989 and, including her service before taking the top job, she has experienced 21 different petroleum ministers.

She feels her time with the NPD has been fantastically interesting, and says she has "never felt any reluctance over going to work".

It has also been a value-creating voyage for the NCS, with the government pension fund - global (the "oil fund") swelling from NOK 2 000 billion to NOK 10 000 billion over the period.

Although this can sound like a continuous upward journey, it has not gone entirely smoothly.

Clouds

When Nyland was confirmed as director general at the end of 2007, she called attention to dark clouds looming over Norway's oil sector.

Her concern at the time was with declining oil production and a reduction in the size of new discoveries. And the climate debate was gaining greater prominence – of which more later.

When Nyland was given a second six-year term in 2013, she told *Norwegian Continental Shelf*: "[It] has begun with fresh clouds. The biggest worries for the companies now are costs and capital."

And they had good grounds for such concerns. Costs were being driven up while oil prices fell, yielding a sharp downturn. The question today is whether history is repeating itself.

Nyland's answer is unhesitating: "New clouds can usually be seen on the horizon. But they're followed by sunshine. That's the way this industry is – up and down.

> *"I think it's a pity that the positive aspects often fail to emerge properly. It's challenging to explain where this country's wealth comes from."*

Cash in hand. *Bente Nyland has participated in a period of substantial value creation on the NCS. During her term in office, Norway's "oil fund" has risen from NOK 2 000 billion to NOK 10 000 billion.*

> *"Our role at the NPD is to tell politicians, the industry and others what the country can expect to find in terms of profitable resources."*

"The picture today is characterised by a high and stable level of activity," she maintains. "The clouds hanging over it are of a different kind."

Again we turn the clock back – to early 2008, when the newly appointed director general noted that climate change was putting the petroleum industry's reputation under pressure.

"Perhaps the biggest challenge in relation to the world at large is to explain what the petroleum sector is," she observed to *Norwegian Continental Shelf* at that time.

"I think it's a pity that the positive aspects often fail to emerge properly. It's challenging to explain where this country's wealth comes from."

Downside

But she was also very clear over the downside related to the industry's operations, and gives a confirmatory nod when asked whether it remains the same today.

"Regardless, petroleum remains an important product which the world needs," she says. "As long as the demand is there, this sector retains an important role.

"It's clearer than before that we've picked up speed on introducing electric-driven ships and cars. We've acquired a more diversified energy picture, which is sensible and necessary.

"But even if transport-sector requirements are reduced or phased out, demand for petrochemicals will persist. An unimaginable number of products are petroleum-based.

"The customer base is also expanding – just think of the population growth we've experienced globally. And what we're going to live on after the oil is still unclear."

Nyland notes that opinion is also split on the oil industry's biggest project during her term – the massive discovery which became Johan Sverdrup in the North Sea, due west of her office.

Some have maintained that this field should never have been allowed to come on stream, and are calling for it to cease production as soon as possible.

"In the event, this would be the first time a profitable field is shut down," Nyland observes. "If that's the outcome of a democratic process, are people willing to pay the price?"

Nuanced

She still believes that an improvement potential exists for communicating a more nuanced picture of the petroleum industry.

"The model Norway's politicians chose for taxing and regulating the oil and gas sector has resulted in prosperity being spread nationwide," she says.

"Our role at the NPD is to tell politicians, the industry and others what the country can expect to find in terms of profitable resources."

And a good deal of oil and gas remains in place – about half the total, according to the resource estimates published by the NPD. So the industry's workforce needs constant renewal.

But clouds can be seen on the horizon there, too. Today's media picture draws a more pessimistic picture on recruitment of young people.

They see dilemmas, but Nyland points out that worrying about such problems has been characteristic of the young throughout the ages.

"As a student in the 1980s, I was also concerned with environmental issues. Attention then focused on industrial discharges, hydropower development and pollution of nature.

"The issue today is rather different. If youngsters want to help reduce the environmental footprint, however, the petroleum industry could be a good choice. Remember that Norway's a pioneer in health, safety and the environment, and in good management."

Long-term

Today's young people may be uncertain about what will be happening in the distant future, but the industry which is to employ them should be thinking and planning for the long term.

Nyland believes that the great majority are on track here. A long-term approach is essential for those in this industry – even though the era of the big discoveries may (perhaps) be over.

"We've now got to reap from what we've got," she says, and registers that this is precisely what the companies on the NCS are doing.

That includes, for example, exploring close to existing infrastructure so that possible small discoveries can be

Grateful. *"I've been backed by a fine organisation with dedicated and technically able colleagues," says Bente Nyland. "The quality of the information I've received has never been in doubt."*

made commercial by tying them back to existing infrastructure.

She points to several examples which show that determination and long-term thinking can pay off.

"It's only a few days since the government received a revised plan for development and operation of production licence 001 on the NCS, covering the Balder field.

"And don't forget that Johan Sverdrup – Norway's last really big discovery – was found in an area which had already been explored.

"The 50th anniversary of the Ekofisk field is now being celebrated, and Statfjord is still on stream. All this is happening in the North Sea.

"Hundreds of billions of kroner may not be left, but several tens of billions can still be earned. The major investments have been made, now the maximum return must be reaped."

Nyland adds that constant technological development contributes to increasing the return, and compares this to a space odyssey.

"Subsea factories on the seabed, inspection drones, repair robots and digitalisation which lets you sit on land and control production – we talked about this 12 years ago, now it's reality."

Wins

Nyland is asked whether the NPD has scored any big wins – or, to put it another way, pushed through good solutions which helped to maximise value creation for society – during her time in charge.

In response, she highlights the goal set in 2013 of improving recovery by five billion barrels of oil over and above the original plans. That target has now been raised further for 2023.

"This is a case of the many small drips," Nyland explains. "But we're managing to achieve it through what we call active encouragement."

She also looks back with satisfaction on the decision over a new Snorre development plan, which keeps this North Sea field on stream beyond 2040 and offers large quantities of extra oil.

"Snorre has worn out many case officers over a number of years. But a good solution has ultimately been achieved."

Where Johan Sverdrup is concerned, too, guidelines have been established which will safeguard opportunities to increase recovery beyond today's planned level.

"A lot has been put into motion, but we won't see the outcome until many years have passed," Nyland comments.

But one important issue was resolved during her time in office – the outer limits of the NCS. "It was good to get the median line between Norway and Russia in place," she says.

"That also opened new opportunities for making big discoveries. These have unfortunately failed to materialise so far, but I remain an optimist over the Barents Sea."

She does not spend much time wondering whether something should have been handled differently: "What's done is done. It's more important to learn the lessons and look ahead."

Minerals

One future opportunity involves something other than oil, but is also far out and deep down. Nyland feels it would be "exciting and fun to get a new leg to stand on with seabed minerals".

Mapping these resources is under way, with positive results so far. But when they can start to be exploited is a more open question.

To Nyland, this is about demand: "Materials crucial to a green transition are involved. Reserves of these on land aren't inexhaustible, and the search will thereby shift offshore."

For her part, she is now shifting to a new everyday life. Her last day as director general fell on 31 December. She feels successor Ingrid Sølvberg will have "an enjoyable job".

"I've been backed by a fine organisation with dedicated and technically able colleagues. The quality of the information I've received has never been in doubt."

The role as NPD director general confers great influence over the industry, and Nyland says that this involves a kind of "stick and carrot" approach.

"But we haven't had to use the stick often," she affirms. "Good arguments always carry the day."

In her view, the companies themselves see the benefit of collaborating offshore. Disagreements may arise, but they are always resolved.

"Others will have to decided whether our performance is good or not," Nyland concludes.

After stepping down, she intends to take a proper break for a few weeks. Impatience and a desire for a meaningful job are then likely to take over – but where that will lead remains to be seen.

> *"These opportunities have unfortunately failed to materialise so far, but I remain an optimist over the Barents Sea."*

What if oil disappeared tomorrow?

Mineral oil is an energy-intensive and versatile liquid which humans have been exploiting on a large scale since the 1850s. After 170 years, many are calling for its production to cease completely. The question is what would happen then.

| Rune Solheim (text) and Egil Bjørøen (illustrations)

Some people predict that phasing out oil rapidly might create a doomsday scenario. Others believe it would usher in idyllic conditions.

Norwegians may think they could adapt to such new circumstances, given electric cars, wind turbines and so forth. But would they manage without imported food?

Numerous other things which might have to be foregone include air travel, cosmetics, contact lenses, trainers, sportswear and shampoo – not to mention key medicines and hypodermic syringes.

Hydrocarbons are extremely energy-intensive. One barrel of crude oil, or 159 litres, equals 1 300 kilowatt-hours – enough to meet the energy needs of a Norwegian detached house for a month.

A litre of petrol contains roughly 9.1kWh – sufficient to heat eight full buckets or 80 litres of water from room temperature at about 23°C to boiling point.

Rests

Modern society rest on oil, emphasises chief economist Eirik Wærness at oil company Equinor: "Our entire prosperity, economic progress and economic system, and the whole communication system which allows us to visit each other in a completely different way than we did before, for example, are based on an economy with access to very efficient energy sources."

He lists these in order of importance as coal, then oil and finally gas and notes that all three are currently used simultaneously.

"If oil disappeared tomorrow, that's what would go – a society completely different from what it was in 1850 when we seriously began to exploit hydrocarbons. We've got so used to this that we don't even think about it."

The Norwegian Oil and Gas Association has calculated that shutting down Norway's petroleum industry from 2020 would mean the loss of NOK 140 billion in annual government revenues.

It also estimates that around 300 000 people employed in the country directly and indirectly by the industry would lose their jobs.

Transport

"If oil disappeared tomorrow, it would have global consequences for transport," says Kjell Werner Johansen, deputy head of the Norwegian Institute of Transport Economics (TØI).

He points out that this sector is crucial for trading goods and services, and that no distribution network not dependent on the internal combustion engine exists.

"We've got electric trains, of course, but rail freight depends on motor vehicles at each end of the track. Without oil, aviation, shipping and road haulage would cease. Global trade would face major difficulties as a result."

Food

The sudden absence of oil is also certain to present big problems for food production, Johansen adds. "The raw material position would become critical."

He points to halted farm tractors and other equipment, while fishing boats could not put out to sea without fuel for their diesel engines.

Even more seriously, perhaps, artificial fertiliser production would run into difficulties, given that this depends on hydrogen from natural gas reacting with nitrogen.

"The gas used for this purpose could undoubtedly be replaced by something else, but not overnight," Wærness observes.

Cars

If oil goes, it might be comforting to think that Norway has so many electric cars. Although we are world leaders in this area, however, Johansen reveals that less than seven per cent of the country's passenger cars are electrically powered.

Moreover, over 99 per cent of

utility vehicles such as lorries and buses run on diesel or petrol. These will come to a halt as service stations run out of fuel.

You might think the answer is simply to buy more electric cars – but these contain many oil-based products and need to be freighted with the aid of petroleum.

The car industry is also a global industry. Fossil fuels are needed to transport the components used in vehicles to the actual manufacturing site.

"These parts come from every continent through product channels which would face problems," says Johansen. "Nor do the manufacturers have the capacity to convert to making electric cars alone – at least not in the short term."

Products

The flow of products to shops would stop without oil, and Johansen predicts that the shelves would quickly empty. Working life would largely cease because people could not get to and from jobs.

"Service provision would stop," he forecasts. "That's bad enough, but the consequences of halting the flow of goods are much more dramatic.

"It'll take time to adapt if we're going to start cultivating carrots in flower pots or keeping pigs and chickens in the back garden."

Agriculture could continue on a smaller scale, following the old ways and with a more seasonally based, local range of foodstuffs.

Converting to living without oil for maintaining basic everyday life would require at least 10-20 years, Johansen estimates.

He notes that even the scenarios related to the 1.5°C goal from the UN's intergovernmental panel on climate change assume substantial oil and gas consumption up to and beyond 2050.

Alternatives

Without oil, we would face a world as far outside our ordinary experience as it is possible to get, observes Johansen, and sees no adequate alternatives to fossil fuels.

Eliminating air, sea and long-distance road freight means that goods could be neither bought nor sold on any scale. Short-range transport, which might use electricity, could suffer bottlenecks.

He points out that local transport distributes the food, medicines and other products we need to keep us fit and healthy.

Biofuel

In an oil-free future, Norway would have some capacity for biofuel production. Chemicals group Borregaard, for example, produces 20 million litres of bioethanol per annum.

According to its communication adviser, Tone Horvei Bredal, that entire output is used today for blending with conventional petrol.

This could be used in theory directly for fuel, but the amount involved is small compared with petrol and diesel oil production. The choice would probably lie between using it for fire engines or for food lorries, rather than for private motoring.

Norwegian biofuel output is very limited, and international demand would rise enormously in such circumstances. A rapid conversion to producing biofuels would be difficult and again require the use of fossil sources.

"You've got to go out into the woods and harvest what you're going to make biofuel from – algae, seaweed or timber," observes Johansen.

"It then needs to be transported and processed, and none of this can be done with electric vehicles running on hydropower or battery-driven power saws."

Plastics

One of the most important substances derived from oil – plastics – would be impossible to produce on today's scale if petroleum output were to cease abruptly.

The petrochemical industry absorbs about four per cent of global oil and gas output. Norway manufactures some 800 000 tonnes of plastics annually, primarily using American ethane.

In our daily lives, it is almost easier to think of what does not contain plastics – which takes a variety of forms used in countless different products.

Polyethylene (PE), for example, is utilised to make packaging, building and agricultural film, shrink film, paper and cardboard coatings, carrier bags, sacks and hoses.

In addition come piping, bottles, canisters, buckets, electrical insulation, household items and technical articles, certain pleasure boats, foam plastics, toys and much more.

This material is also found in a form known as ultrahigh molecular weight PE, so wear-resistant that it can be used as a biomaterial for artificial human joints.

It is also utilised to produce new fibre grades with unusually high strengths and soles for the skis worn by many Norwegians.

High proportions of oil-based plastics are also used in furniture, building materials, paint, computers, mobile phones and cars.

Sports equipment is another application, along with clothes, carpets and all possible other types of textiles such as curtains. Think of all the ropes containing nylon, which derives from oil.

Look around the room you are sitting in, and think how many things there contain plastics. The answer is almost everything. This material has revolutionised our daily lives.

And many of the innovations which make cars and aircraft lighter and more fuel-efficient today are produced from plastics.

Biomass

If petroleum vanished, it is reassuring to know that "everything which can be made with oil can be produced from trees", as the Research Council of Norway has claimed in a newspaper article.

Carried by leading daily *Aftenposten*, this covered producing plastic from biomass. Borregaard converts roughly a million cubic metres of timber every year into a variety of substances.

Norway's forests grow at a gross rate of 25 million cubic metres per annum, with 10 million being felled. So annual carbon-neutral output could be boosted by 15 million cubic metres.

But it would take a long time to scale up production of bioethanol, for example, or the raw materials for making cement, paint and cosmetics and other products.

That is still a long way short of

what the oil industry provides. And it would be impossible without diesel to fuel lorries for freighting the timber.

Plastics produced from wood are often just as little degradable as those from oil. Only a tiny proportion of plastics based on biomass degrade quickly in nature.

Heating

The disappearance of oil would cost part of Europe's electricity output. Much is said about gas in relation to power generation, but that only consumes about 30 per cent of the Norwegian gas exported to the continent.

No less than 40 per cent is utilised directly for cooking and domestic space heating in the UK and other European countries, according to Norwegian Oil and Gas.

"One of the most important consequences of a sudden halt to petroleum production is that most Europeans would be unable to cook or heat their homes," says Hildegunn Blindheim, the association's director for climate and the environment.

The remaining 30 per cent share of Norway's gas exports is used for industrial purposes – achieving extreme production temperatures, for example, or direct conversion to fertiliser.

In the case of oil, about 10-15 per cent of Norwegian production is used to manufacture various products, and Blindheim says this share is rising. Norwegian Oil and Gas expects it to double to about 25-30 per cent by 2050.

Energy

A sudden loss of oil supplies would make it impossible to meet world energy needs. Countries have very varying stocks of natural gas which they could tap, and Johansen says such resources would be quickly depleted. "We're talking about weeks."

Many industrial sectors depend on oil and gas, and competition will be intense over what remains after production has ceased. Coal could become resurgent in such areas as power generation.

"Power generation from renewable sources is growing faster than we can manage to predict," says Blindheim. "But energy demand is increasing at the same time.

"The rise in consumption was covered by renewables for the first time only in 2018, but 80 per cent of demand is still met from fossil fuels."

If oil vanished tomorrow, renewables would have to meet that four-fifths as well as any further growth. That is not possible in the short term, Blindheim affirms – regardless of whether solar cells and wind power get cheaper.

"We'll remain dependent on petroleum for several decades – rather less on oil than on gas," she says. "Technological advances which reduce greenhouse gas (GHG) emissions from these fuels is therefore essential if we're to meet the climate goal."

Sensible

According to the experts, it would be sensible – if oil did not vanish overnight but was phased out slowly – to reduce Norwegian emissions from both industry and power generation.

One approach could be carbon capture and storage (CCS), where a number of trials are currently under way. Another is to use hydrogen produced from natural gas or via electrolysis as an energy bearer.

The oil industry has a clear role to play in both these areas. Preliminary work is being done on two full-scale CCS plants, and a CO_2 store on the NCS will be completed this autumn.

Few people believe demand for petroleum will fall drastically in the near future. So efforts to cut emissions from air, sea and heavy road transport could be positive, since oil replacements are particularly hard to find in these areas.

"To reach the climate goals, the whole toolbox of measures must be used," says Blindheim, and notes that oil industry expertise can contribute to finding solutions.

Shell and Total as well as Equinor are working on solutions for carbon storage and transport, while the latter is also pursuing opportunities to convert natural gas to hydrogen.

Combining this with CCS would allow the resulting product to be used as clean energy in such applications as fuelling large ships, which have no way to cut GHG emissions sufficiently today.

Drawback

One drawback with generating electricity from renewables is that output varies with the amount of sunshine or wind – not only during a day but also over weeks.

Energy consumption can also fluctuate greatly between summer and winter, for example – as is the case in the UK, where gas is widely used for space heating at present.

Seeking to overcome this challenge by building infrastructure which ensures that enough renewable power is available at all times would call for huge investment.

Natural gas has been highlighted as a means of smoothing out these supply fluctuations. Equinor and some partners are pursuing a Dutch project to see whether hydrogen could be part of the solution for a power station.

If such a facility can use this as a fuel, rather than natural gas, it could serve as a massive battery for electricity output when the wind does not blow or the sun shine.

Conventional batteries in themselves cannot operate much beyond hour by hour – in other words, levelling out daily variations.

Since splitting hydrogen is an energy-intensive business, this could be done with surplus solar or wind power, storing the result and turning it back into energy when renewables are unavailable.

But Blindheim says that this approach would not supply enough hydrogen. Britain, Germany and the Netherlands have specific projects under way to identify how the gas could be produced in combination with renewables and thereby reduce GHG emissions.

The fertiliser industry already uses natural gas to produce hydrogen, but has so far been unable to store the resulting CO_2 instead of emitting it.

"That's where the companies on the NCS come in, with trials of storing captured CO_2 beneath the seabed," explains Blindheim. "Both Norway and other countries have mapped possible sites."

She notes that the EU mentions hydrogen in its long-term *Clean Planet* vision published last November, where particular attention has been given to CCS from industrial processes.

This is because emissions from these operations cannot be overcome through greater use of electricity. Processing limestone to produce cement, for example, releases CO_2 regardless.

The EU also sees that hydrogen will be important for reaching climate targets, but has yet to produce any specific plans for a commitment here.

Quick cuts

"We're fully aware that quick cuts in GHG emissions are needed if we're going to reach the climate goals," says Wærness, but believes economic growth and development must also be secured.

Hydrocarbons have to be delivered as energy-efficiently as possible, he emphasises, with the lowest possible emissions during actual production. Oil and gas must be used with maximum efficiency and minimum waste.

He therefore points to the need for more effective internal combustion engines and extremely rapid electrification in parts of the transport sector – much faster than today's pace.

Electric cars and buses must be adopted and electric lorries used for local deliveries. Some increase is likely in replacing petrol with biofuels, and diesel with natural or bio gas.

"Demand for oil must be reduced, while gas consumption is likely to remain at today's level rather longer but will eventually also decline," Wærness believes.

When that happens, he thinks Norway will also get more CCS. That would create greater space for natural gas – particularly in the energy sector.

"We often forget that, even if oil consumption declines, investment is needed to meet residual demand. Supply would otherwise fall much faster as reservoir pressure drops.

"As a result, our view is that Norway and Equinor will continue to be involved with oil and gas for many decades to come even if we move towards the climate goals."

At the same time, Wærness hopes the company can play its part in achieving the low-carbon share of the energy mix – in other words, CCS, hydrogen and eventually new renewable power.

But it needs time to do this slowly. "Many people forget that the costs are high, and that it's demanding to make new renewable energy profitable."

Planned

A planned and controlled transition from a society dependent on fossil fuels to a more sustainable existence is very important, says Johan Einar Hustad.

He is director of NTNU Energy, one of the four thematic research priorities at the Norwegian University of Science and Technology in Trondheim.

In his view, progress must be made through international deals similar to those pursued for about 30 years under UN auspices, from the Kyoto protocol to the Paris agreement.

Collaboration is needed between nations, within countries and in industry, Hustad says, and notes that consumption patterns must change if renewables are to develop into real alternatives.

"These options can only be secured by using the time available to come up with the necessary incentives and investments, even though everyone agrees that this is an urgent matter."

He points out that consumers must be given choices like those they now possess when buying cars or making daily food purchases. "It's important that they become more aware.

"On the other hand, we're dependent on what the government does to promote alternatives through incentives. That's the only way to ensure profitability for the first people to initiate renewable activity, as we've seen in electricity generation."

Hustad notes that it is only 10 years since solar and wind power really got going. The price of such supplies has only recently reached a competitive level.

He is also a supporter of CCS, and agrees with Blindheim that Norway has a good basis for becoming well qualified in this area, thanks to its oil-industry experience.

Hurry up

"We must do a lot more than today, and need to hurry up," Hustad emphasises. "We've got to reorient investment toward renewables. Shutting down the oil sector would worsen the whole position.

"That would destroy everything. Without a gradual and controlled approach, we'll find ourselves returning to the pre-oil age or perhaps heading even further back."

Nevertheless, he believes it is important to listen to the young people who are calling for oil production to be terminated at once.

"These voices are needed in order to shift policy in a more sustainable direction," he argues. "If nobody speaks out, nothing happens.

"We must stop finding excuses for not finding alternatives. But if we move too fast, we also destroy the opportunities which exist for creating sustainable replacements."

ROCKSHOT

Crushed rock

Alexey Deryabin, geologist, NPD

The photograph shows brecciated granitic rocks (Precambrian basement). Breccia consists of large angular fragments cemented together by a fine-grained matrix. In this case, the matrix comprises finely crushed stone which could be mixed with shale.

This site is interpreted as crushed rock immediately beneath the base of nappes formed during the Caledonian mountain-building episod in the Silurian-Devonian periods, when the Baltic and North American plates were colliding. The nappes have grated over the bedrock, crushing the interface between them.

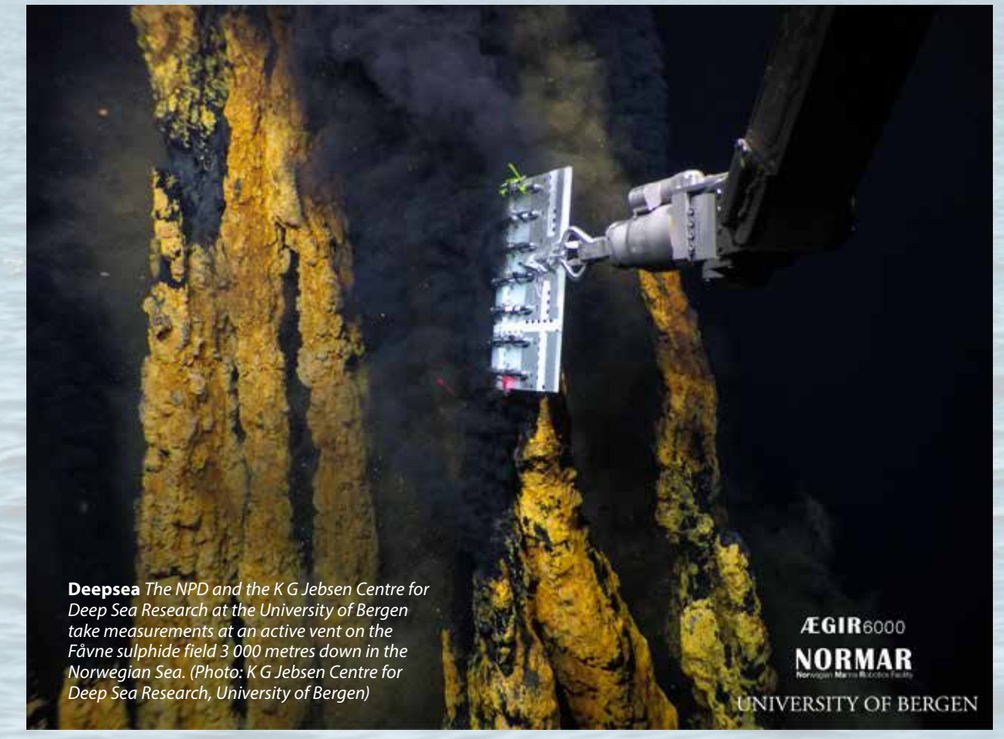
The photograph was taken from a kayak in the Gands Fjord near Stavanger. Crushed rock can also be observed on a smaller scale at the top and western slope of the Lifjell ridge outside Sandnes.

Breccia at Lihalsen on the Gands Fjord near Stavanger. This outcrop is three metres high. (Photo: Fridtjof Riis)

Success in seeking seabed assets

A big area of previously unknown sulphide mineral deposits in the Norwegian Sea has been identified by the NPD in the first survey of its own to map such resources. This took place last summer on the Mohn Ridge.

Astri Sivertsen



Deepsea *The NPD and the K G Jebsen Centre for Deep Sea Research at the University of Bergen take measurements at an active vent on the Fåvne sulphide field 3 000 metres down in the Norwegian Sea. (Photo: K G Jebsen Centre for Deep Sea Research, University of Bergen)*

All Norway's copper sulphide mines began life at ancient seabed vents, explains NPD geologist Dag Bering – including Løkken and Røros in Trøndelag and Visnes on Karmøy north of Stavanger.

The Mohn Ridge is a modern zone of seabed spreading, where the continental plates are diverging and lava wells up to create new oceanic crust.

Sulphides form through chemical processes around active hydrothermal vents – also known as black smokers. The magma chambers located beneath these chimneys have temperatures of around 1 100-1 200°C.

Water flowing from the smokers reaches 300-400°C and carries a number of minerals from the Earth's interior. Despite the high temperature, the huge pressure prevents it from boiling.

Data acquisition on the Mohn Ridge took place in 1 200-3 500 metres of water. This area was chosen because the University of Bergen (UiB) found active smokers there two decades ago.

The NPD has collaborated closely with the UiB for many years and, among other measures, is financing two doctoral students researching manganese crusts and methods for sulphide mapping.

Inactive

NPD geologist Jan Stenløkk accompanied last year's expedition, and explains that it looked for areas with inactive smokers – where water is no longer emerging and the chimneys have collapsed.

He says there are many more inactive areas than active ones on the NCS. The trick is to find them.

Various tools were tested during the NPD expedition, including an instrument for measuring self potential (SP) which the NPD believes could be useful in the time to come.

When metal sulphides come into contact with salt water, a weak electric current is generated which can be picked up by SP sensors.

The three-week trip found an extensive new area of sulphide minerals which could contain important industrial metals such as copper, zinc, cobalt, nickel, vanadium, wolfram and silver.

Preliminary calculations indicate that they could hold as much as eight per cent copper, compared with a normal concentration of one per cent for mines on land. See the article below.

Value

Just over five years ago, the Norwegian University of Science and Technology (NTNU) produced a best-case estimate of NOK 1 000 billion for the value of minerals and metals on the NCS.

This calculation utilised the same methodology applied by the NPD to predict Norway's undiscovered petroleum resources, reports Steinar Løve Ellefmo.

An associate professor in resource modelling at the NTNU's department of geoscience and petroleum, he adds the proviso that the base data are not as good as those available for oil and gas.

The scientists studied seabed topography using a coarse-meshed data set in an effort to identify structures which might contain minerals and metals.

They then tried to assess how many of these deposits existed, their size, and what they might contain. Attention was confined to sulphides, Ellefmo adds.

"We excluded metallic nodules of the kind found in the Pacific as well as the crusts mapped to some extent by the NPD."

Nor did they seek rare earth elements (REEs or lanthanides), where Ellefmo says the potential is completely unknown. Should the analysis be repeated, it will undoubtedly yield very different results – not least because of last year's NPD findings.

"It was interesting to see that the NPD found fairly large deposits we were unaware of in one of the areas we'd identified as more promising than others," says Ellefmo. "At least that confirms we're on the right track, and that the potential is huge."

ROV *A remotely operated vehicle (ROV) is one of the tools used for subsea mapping and sampling. (Photo: K G Jebsen Centre for Deep Sea Research, University of Bergen)*

More mineral finds

Last year's NPD expedition along the Mohns Ridge in the north-western Norwegian Sea led to the discovery of several previously unknown sulphide deposits.

These seabed accumulations contain metals and minerals which are important in battery technology, wind turbines and mobile phones.

The Mohns Ridge is an oceanic spreading ridge separating two tectonic plates, and the expedition aimed to map the deep seabed in order to identify mineral resources in the area.

Lasting four weeks, the expedition made use of the *Seabed Constructor* vessel. Its assignment came from the Ministry of Petroleum and Energy.

An Act relating to mineral activity on the Norwegian continental shelf (the Seabed Minerals Act) came into force on 1 July 2019.

Read more here: https://www.npd.no/en/facts/news/general-news/2019/successful-exploration-for-seabed-minerals/

Legislating for new resources

Responsibility for administering mineral resources on the NCS was assigned to the Ministry of Petroleum and Energy in 2017, with a new Act on seabed minerals adopted this spring.

That legislation replaced the 1963 Continental Shelf Act, which covered all mineral resources other than oil and gas but was confined to those extending out into the sea from land.

The new Act builds on the administrative regime for oil and gas, with the same procedures – from mapping and impact assessments, via offering blocks or areas, to the award of exploration and production licences.

The job of mapping these resources has been given to the NPD, which administers all NCS data acquired over more than 50 years of Norwegian petroleum activity.

This gives the directorate's geologists a starting point in deciding the best places to explore for minerals. A good array of samples is already held at its Geobank in Stavanger.

These include manganese crusts taken from the Norwegian Sea, some as much as 20 centimetres thick and including the rare metal scandium – an element used in LED lights and various alloys.

The samples also show that REEs exist in higher concentrations in the Norwegian Sea than in other oceanic regions, such as the Pacific.

Three types of seabed mineral deposits are known: manganese nodules, manganese crusts and sulphides. All contain a variety of metals and lie in waters 1 500-6 000 metres deep beyond the continental shelves where oil and gas are found.

Manganese nodules are found on soft seabeds in deep waters and contain much manganese and iron as well as smaller amounts of copper, nickel, cobalt, titanium and platinum.

Manganese crusts also contain mostly manganese and iron, plus smaller quantities of titanium, cobalt, nickel, cerium, zirconium and REEs.

They grow as laminated deposits on bedrock where this is exposed on the seabed, typically at depths between 1 500-3 000 metres.

Sulphides mainly comprise lead, zinc, copper, cobalt, gold and silver. They are associated with hot springs on midocean volcanic spreading ridges and island arcs where black smokers form.

Such vents are active for periods from a few decades to a millennium before dying out and leaving sulphide mounds. The latter account for the bulk of these seabed resources.

Manganese crusts and sulphides have been found on the NCS, but not manganese nodules.

(Sources: GEO, NPD)

Black smoker *The NPD retrieved an old extinguished vent in 2018 from 3 000 metres of water on the Fåvne field in the Norwegian Sea. (Photo: K G Jebsen Centre for Deep Sea Research, University of Bergen)*

Analyses reveal rich seabed minerals

| Bjørn Rasen

The NPD's chemical analyses of sulphides and manganese crusts from the NCS show high concentrations of copper, zinc and cobalt.

While the sulphides mostly contain iron, they also have a relatively high content of copper (up to 14 per cent in some samples), zinc (three per cent) and cobalt (below one per cent).

These are important metals at a time when society is making increasing use of electricity, while also being in demand by industry.

Concentrations of metals in sulphides and manganese crusts from the NCS are higher than for samples collected in other parts of the world.

Seabed minerals are known to be present in the deeper parts of the Norwegian Sea. The NPD has been charged with mapping their extent and systematising data from collected samples.

A number of sulphide and manganese crust deposits have been identified, most recently during the NPD's expedition in the summer of 2018.

The sulphides are found along the volcanic Mohns Ridge between Jan Mayen and Bear Island. Manganese crusts have been proven in several places along the Vøring Spur and around Jan Mayen.

Manganese crusts in the Norwegian Sea fall into two groups. One contains roughly twice the amount of REEs as samples from the Pacific and other Atlantic sources, the other has less.

Both groups hold considerably more lithium (20-80 times as much) and scandium (four-seven times). All these elements are metals with important roles to play in the green shift.

Circle closed

Dag Bering's father urged him to study manganese nodules in the Pacific when he first heard of them at the age of 10. Fifty years later, seabed minerals have finally been recovered from the NCS. Sadly, however, this key specialist is now retiring.

| Bjørn Rasen and Monica Larsen (photos)

From the depths *It was a big moment for Dag Bering when the samples from some 3 000 metres beneath the Norwegian Sea were brought ashore in 2018.*

Expertise *Dag Bering notes that the NPD's 200 employees cannot match the oil companies for staff numbers, "but our expertise must be on a comparable level".*

> *"The nation needs geologists, in several sectors. I also think that youngsters who start out with this discipline in the oil industry will be able to stay in it until they retire."*

The first thing Bering does when we meet is to emphasise that it will take a long time before any of these resources are recovered from the depths of NCS.

"A lot more mapping will be needed before then," he says. "And we must study the impact of such production."

He reports that a global hunt is under way on land for such metals – which are essential for the "green shift" – and that they are extracted under tough environmental conditions.

"Metals from new deposits on the seabed could be a better solution," Bering says. "But we don't know what such production would cost yet.

"What we do know is that certain metals in the seabed deposits are present in percentages of seven-eight per cent, compared with one per cent for mines in several African countries."

The hunt today is for minerals containing valuable metals which the world needs, including rate earth elements (REEs). And some players have got off to an early start.

Bering reports that China currently controls about 90 per cent of the world's REEs because the country has pursued a clear strategy here.

"If the Chinese wanted, they could reduce availability. That happened in 2010, when prices shot up. This led in turn to a big rise internationally in applications for prospecting licences."

Bank

Our meeting is in the NPD's most international space – the rock store in what is now known as the Geobank. Bering has put in a substantial effort here ever since his arrival in 1990.

He has worked on resource data from the NCS, which play a key role in the NPD's much-used fact pages on the web – which he helped to develop.

The rock store has cores from every one of the almost 6 500 wells drilled off Norway, for both exploration and production. Its cold room also holds oil samples from all the discoveries made.

In addition, the Geobank contains thousands of microfossils from the various wells. These holdings collective give the NPD a unique overview which benefits all the companies in their hunt for more oil and gas.

"We originally published geodata from the exploration wells – on paper," Bering reports. "But that ceased in the early 1990s. The Norwegian Oil Industry Association complained a bit."

Eventually, a work group got to grips with creating an internet version, and the rest is history. The fact pages are visited daily by hundreds of specialists.

The extent to which the companies have their own databases for such information is limited, and they rely wholly on the NPD to maintain an updated version.

Field

In his search to learn more, Bering has also been responsible for a number of field trips with the NPD's geologists. These have often been fairly local, north and south of Stavanger, but occasionally range further afield.

Countries such as Denmark, Spain and Iceland offer rock formations on land which correspond with those found several thousand metres beneath the NCS.

"We've also taken non-geologists on such trips," Bering says. "All our employees are involved in one way or another with the industry which produces petroleum from different formations. Understanding how this hangs together is important for doing a good job."

The NPD must also be in step with the wider world, he notes. "We have to ensure that we do at least as good a job as the industry itself.

"We can't challenge it to come up with better solutions for exploration, development and production if we're not on the same level and don't possess the same expertise.

"Since there are 200 of us compared with several thousand in the companies, we can't claim the same capacity – but our expertise must be on a comparable level."

The alternative is failing to achieve efficient exploration of the NCS and optimal development solutions. But fortune favours the prepared mind, and he feels the NPD has been good at recruiting able personnel.

Thread

And expertise runs like a red thread through Bering's life and career – ever since he learnt about the discovery of manganese nodules in the Pacific as a 10-year-old.

He joined the NPD after seven years as a researcher at the University of Bergen, and was given assignments as a geologist – starting with modelling the Gullfaks South field.

But his path took him more and more into research and development, and he has spent nine years as discipline coordinator for geology.

"Progress is what concerns me," Bering says. "And to achieve that, we must establish various forms of collaboration with the outside world."

He has been closely involved in that activity, with the forum for reservoir characterisation and reservoir engineering (Force) as the most outstanding example.

This body brings together government and industry, with the NPD as the secretariat, to share experience and develop methods for more efficient exploration and enhanced oil and gas recovery – and thereby to boost value creation from the NCS.

When its Profit predecessor terminated in 1993, Bering was among those charged with creating a new forum for scientists, government and industry to resolve common issues. Today, 23 years later, the Force seminar programme is fully booked – all the time.

Facilitates

Everyone must be involved, internally as well, says Bering, and has plenty of praise here for his long-standing employer.

"The NPD facilitates enhancement of both technical expertise and general understanding. That gives us a fine mix of specialists and all-rounders."

It goes without saying that recruitment to the NPD and the industry in general is something which concerns him. This is a matter of capturing the interest of talented people early.

Bering has had various appointments in Norway's education system to promote interest in the sciences. One of the most enjoyable was the Lego League contest for primary schools.

This got the children to develop various technological solutions with the aid of Lego bricks, in competition with other schools nationwide.

He hopes as many students as possible stay on the right track: "The nation needs geologists, in several sectors. I also think that youngsters who start out with this discipline in the oil industry will be able to stay in it until they retire."

Cutting

He reads the newspaper reports that Norway's Oil Age must end and that people like him will be redundant. Some universities are cutting back on petroleum research, which he thinks is "a pity".

Many geologists are absent from these debates, and not even Bering feels a desire to go too far: "Geologists have a different time frame, and we know that the climate has changed throughout the ages. Nature isn't stable."

His realist side finds easy expression: "I believe we must accept that fossil energy will be required for a long time to come."

Now that retirement beckons, Bering will have to watch the unfolding of the seabed mineral adventure from the sidelines. But one should never say never – although he says his current plans extend no further than maintaining house and holiday cabin.

Mineral hunt *The minerals now being sought include valuable metals, such as rare earth elements (REEs). The world needs these, says Dag Bering.*

Still going strong

Shutting down the Troll A gas platform in the Norwegian North Sea for a year would cost NOK 226 million per day in lost sales revenues. And replacing its output with coal would raise Europe's CO_2 emissions by 150 million tonnes.

Bjørn Vidar Lerøen

After almost 25 years on stream, this field remains the guarantor for major long-term gas deliveries from Norway to continental Europe.

It has yielded assets worth NOK 1 500 billion since production began in 1996. And a lot remains to be recovered, with less than half its gas reserves produced.

Troll alone accounts for 40 per cent of Norway's gas exports, which total well over 100 billion cubic metres per annum, and seven-eight per cent of European consumption of this fuel.

Operator Equinor and its partners are now working on the third development stage, with subsea installations set to ensure that the gas continues to flow.

While this production began from the eastern part of the field, it will be continuing from the western section following the investment of almost NOK 8 billion in phase III

That will give a breakeven price as low as USD 8 per barrel of oil equivalent (boe). Better profitability would be hard to find on the NCS or in other offshore regions around the world.

Troll is set to produce gas for many decades to come. This calls much drilling to continue and for systematic and thorough downhole maintenance. Three rigs are set to be at work for years.

Gunnar Nakken is head of Equinor's operations west core region, in charge of 16 installations in the northern North Sea. He does not talk big, but deals with huge numbers.

Fields he is responsible for include Gullfaks and Oseberg, which are also large. But Troll towers over them all. Its gas reserves are vast, and massive oil volumes have also been produced in a spectacular fashion from thin zones beneath the gas.

Awarded

The first part of Troll to be awarded was block 31/2. This was allocated as production licence 054 in Norway's fourth licensing round in 1979.

Many companies had seen something big in the seismic data acquired from this area as far back as the early 1970s, but water depths and uncertainty were both great.

None of the fourth-round applicants had 31/2 as their first priority. Nor were there many companies capable of taming this Troll.

Shell was one of the players regarded by the NPD and the Ministry of Petroleum and Energy as competent and relevant. After negotiations, it was awarded the 31/2 operatorship on condition that Statoil (now Equinor) could take over when production began.

A wildcat well in the block proved a gas field whose dimensions exceeded all expectations. The reservoir pressure was so great that the *Borgny Dolphin* rig had to use two flare booms.

It was also clear that the massive discovery extended into three neighbouring blocks to the east – 31/3, 31/5 and 31/6 – which had yet to be awarded.

The Labour government under Gro Harlem Brundtland announced in 1981 that this acreage would go to Norway's Statoil, Norsk Hydro and Saga Petroleum companies, with the first in a leading role.

These plans were modified after the Conservatives took office following the general election later that year, although a Norwegian-only solution was still the preferred option.

With the new government seeking to curb Statoil's dominant position on the NCS, the issue unleashed considerable political dissension until the three blocks were awarded in 1983 as PL 085.

All three Norwegian companies were to have independent operator assignments in the exploration phase. Shell and the other foreign companies felt they had been reduced to spectators while domestic solutions were applied to the best fields.

Drilling in PL 085 confirmed the huge reserves and clarified that the bulk of them lay in the eastern area. It also became clear that large oil resources were present beneath the gas.

Plans

When Shell made its discovery in 31/2, it chose with Statoil's support to regard this as a pure gas find – a view which coloured its first development plans. The oil was actually valued at zero.

The question was how such huge amounts of gas could be placed in the market. Before getting that far, however, challenges seen to lie at the frontiers of technology had to be overcome.

The biggest of these was a water depth of 300 metres. "We need a return ticket to the Moon," Norske Shell technical manager Chris E Fay commented.

When Nakken now looks back, he emphasises that Troll has been a playground for technology development – with multiphase flow as one of the most important areas of progress.

The decision to build a single large production platform was initially based on processing the gas in situ. But it gradually became clear that this would make the structure too heavy.

No towout route would be able to handle its displacement. With Troll A due to sit on the seabed, its height was given by the water depth. But the topside weight could be reduced.

New documented multiphase flow technology allowed the process facilities to be shifted 66 kilometres from the platform to land at Kollsnes in Øygarden local authority, north-west of Bergen.

No unprocessed wellstream had previously been piped over such a long distance. Since then, this technology has been adopted to link Snøhvit in the Barents Sea with a processing plant 142 kilometres away at Melkøya outside Hammerfest.

Troll A still ranked as the world's tallest structure ever moved by humans when it reached the field on 17 May 1995. Images of this offshore skyscraper attracted attention worldwide.

Forward-looking

Big tensions and rivalry between the companies in the two Troll licences eventually resolved themselves as rational and forward-looking decisions prevailed.

Where the NPD was concerned, Troll became its great trial of strength over good resource management. A crucial piece fell into place when it concluded that the aquifer underlying the oil and gas was in pressure communication.

That meant the four blocks formed a single reservoir system. The NPD was very concerned to ensure that the oil resources were saved, and Hydro was the first to grasp and act on this desire.

Disputes over the division of roles in the Troll area were finally resolved by making Shell and Statoil responsible for the gas and giving Hydro the job of developing the oil.

And the latter company was first off the mark, producing crude before the gas started to flow. Nor were the amounts involved insignificant – at peak, Troll yielded 440 000 barrels per day.

Over time, more than two billion barrels of crude have been recovered from Troll. That makes it one of Norway's biggest oil fields.

This output is now in decline. When it was at its highest, however, it equalled Troll's gas production in value terms. The latter had to be restricted over a number of years to maintain reservoir pressure for maximising oil recovery.

Now that this requirement has been met, gas output is rising. The combined approach means that Troll is the first Norwegian field to pass an overall production of five billion boe.

Even before Hydro started producing this oil, it had implemented the Troll-Oseberg gas injection (Togi) project by installing a subsea module with a single well on the field.

Images of this offshore skyscraper attracted attention worldwide.

> *That will give a breakeven price as low as USD 8 per boe. Better profitability would be hard to find in any offshore region around the world.*

Gas from this facility was piped to the Hydro-operated Oseberg field nearby, where it could be used for pressure support to improve oil recovery and create greater value.

Nakken applauds the NPD and the government for their strong commitment to Troll, and sees it as a good example of public-private interaction to manage resources well and add value.

Geopolitical pawn

Thanks to its huge energy resources, Troll even became a pawn in a geopolitical game involving the Cold War and the direct attention of US president Ronald Reagan.

The latter was very keen to weaken the then Soviet Union's capacity to increase its military strength. A key way to do this would be to reduce the cash flow from Soviet gas sales to Europe.

Reagan decided that Troll could provide an important alternative source of European supplies. An offensive was thereby launched to persuade Norway to bring the field's reserves to market faster than new deliveries from the east.

Troll was raised as an issue no less than three times in the US National Security Council. But its development could not be implemented hastily.

Major resources were nevertheless devoted to getting the field on stream as quickly as possible – and not just to satisfy American great-power interests. The huge energy resources involved also had to find a market which could and would buy them.

Norway suffered a major gas-market setback in February 1985, when the UK government under Margaret Thatcher blocked a deal negotiated by Statoil with British Gas for Sleipner supplies.

Until then, the Norwegians had assumed that selling oil and gas would be easy at a time of rising demand and energy security concerns. Norway was, after all, a politically stable supplier.

Troll has made, and continues to make, a crucial contribution to Europe's energy supply and security. It increases competition in the European gas market and provides an alternative to Russia.

But history repeats itself. President Donald Trump is now worried that more Russian gas is set to enter Europe via an expansion to the Nord Stream system through the Baltic to Germany.

Troll gas is sold in a market undergoing fundamental changes, with a shift from long-term contracts to a more short-term and competition-driven approach.

As part of its role as a state oil company, Statoil was responsible for sales negotiations on behalf of the licensees in Troll and other gas fields.

This monopolistic position came under pressure at a time of market liberalisation. New approaches prevailed, with company-based gas sales and third-party access to transport systems.

Where Troll was concerned, however, negotiations were pursued under the old system with a European buyer consortium in which Germany's Ruhrgas played the main role.

The sellers were led by Statoil, with CEO Arve Johnsen in a dominant role. It had secured acceptance for its vision of "oil parity" when Statfjord gas was sold some years earlier.

That meant a unit of gas energy would receive the same price as a unit of oil. But the picture had changed when talks began on Troll gas.

First, the buyers generally took the view that high energy prices would be destructive for the world economy. In the mid-1980s, however, oil prices were under pressure and falling.

Second, Norway found itself in a squeeze because of the British refusal to take Sleipner gas. In these circumstances, the Norwegian gas sellers had to accept a substantial discount.

Troll received a price 40 per cent below the contract level for Statfjord gas – an outcome which sparked disputes between the companies and the politicians.

Despite these difficult circumstances, Johnsen and Statoil succeeded in getting the Sleipner gas included as part of the sales agreements.

While Troll could not begin to produce until 1996, adding Sleipner output made it possible to start deliveries as early as 1993. But that also ended up facing big challenges.

Just before the concrete gravity base structure (GBS) for the Sleipner A platform was due to be mated with its topsides, it sank in the Gands Fjord outside Stavanger.

An asset worth billions of kroner vanished into the depths. However, a quick reaction led to the rapid construction of a new GBS so that the gas could be delivered from the agreed start date.

Troll comes across as a great Norwegian industry adventure, which still has many years to run. For millions of Europeans, it is a story of daily energy supplies. For the companies and the government, the field represents bullions in revenues.

The next chapter

Equinor and its partners in Troll submitted a plan for development and operation (PDO) of the third development phase for this North Sea field in 2018.

Bjørn Rasen

Expected to stay on stream until around 2060, Troll comprises a large gas cap over a relatively thin oil zone and covers 710 square kilometres.

Its petroleum resources are contained in three tilted fault blocks, known as Troll East, the Troll West gas province and the Troll West oil province respectively.

The field has been developed in three phases, starting with gas production from Troll East. This was approved in 1986 and updated in 1990.

Bringing oil on stream from the Troll West province was initially approved in 1992 and has subsequently been through several supplementary and change approval processes.

And the third phase, covered by an amended PDO which is now under government consideration, covers the gas cap in Troll West. Production is due to start in 2021.

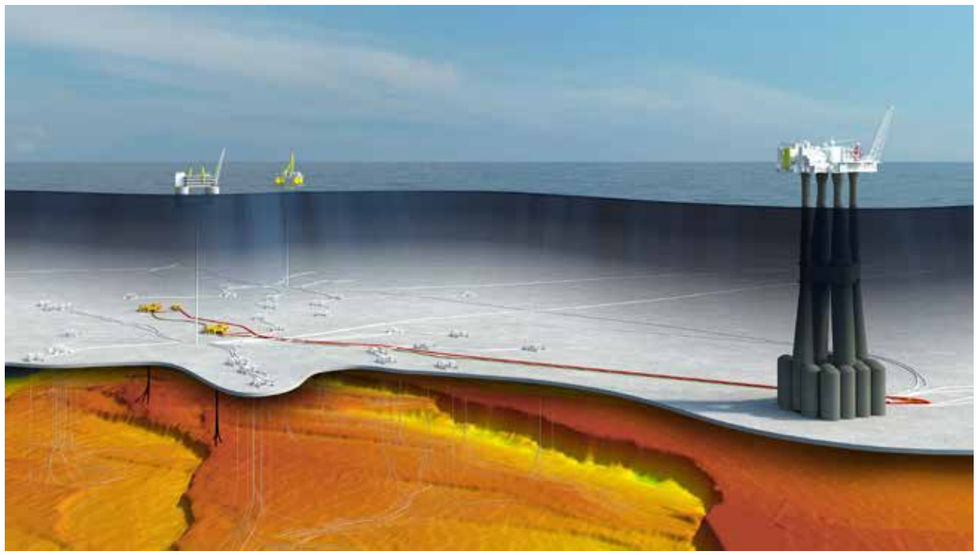
Troll lies about 80 kilometres west of Bergen in 300-340 metres of water and came on stream in 1995. Over some 23 years, it has delivered some 900 million standard cubic metres of oil equivalent (scm oe), or roughly 5.6 billion barrels of oe.

Remaining reserves are estimated at about 870 million cubic metres (5.4 billion barrels). This gas giant delivered 36.7 billion scm in 2017.

At the same time, Troll has been the largest oil producer on the NCS for a number of years. These resources come from a thin oil zone originally considered difficult to produce

But the licensees have been leaders with advanced technology for drilling and completing horizontal wells. They won the NPD's first improved oil recovery (IOR) prize in 1998 for this work.

"Big oil and gas resources remain to be recovered from Troll," observes Arvid Østhus, NPD assistant director for development and operations in the northern North Sea. "So we're still concerned about the balance between oil and gas offtake."



Artist's impression: Equinor

Feelings and facts

On tour *Marius (left), Mariann and Herman at Jåttåvågen upper secondary school in Stavanger last year.*

Young people must be talked *with*, not *at*. That is the lesson three newly-graduated industry representatives learnt after touring Norway last year to talk with schoolchildren. This committed trio also found that the global perspective is under-communicated.

Bjørn Rasen and Monica Larsen (photos)

The goal of the threesome was to involve pupils in a fact-based debate on energy, the climate, technology and prosperity through the New Oil project.

This was launched in 2016 by the Norwegian Oil and Gas Association to help revive interest in the petroleum sector's role in Norway among young people.

Meeting the trio at an upper secondary school in Stavanger, I asked what the problem was from the perspective of many Norwegian pupils. The team listed four findings from its tour.

One is that the oil and gas industry has seen itself as the solution rather than the problem, while young people have taken a different view.

Parts of the petroleum industry have now changed their rhetoric – proclaiming they will accept greater responsibility and contribute to reducing emissions.

Future

Oil and gas do not represent the future many young people want, nor does the industry understand where they are coming from. And, as if that was not enough, it aims its communication widely but makes few hits.

"That's why we opened our meetings with the pupils by saying that 'we're here to talk *with* you'," explains Mariann Forsberg, who is a geologist.

The team then challenged, she says. "When talking about petrochemicals, we generally ask if there are any products they could do without. That usually gets them thinking a bit more."

Fellow proselytiser Herman Bråten Romnes believes that many young Norwegians have not thought enough about the realities. And age and geographical divisions exist.

"There are distinctions between

Young team for New Oil

All three of the members are in their 20s.

Marius hails from Åsgårstrand south-west of Oslo. Having studied economics at the University of Bergen and the London School of Economics, he worked previously for the Ministry of Finance.

"The negative effects of anthropogenic climate change must be curbed," he acknowledges. "Emissions must be reduced, but the world needs energy and people must be lifted out of poverty. How can these concerns best be reconciled?"

Mariann is originally from Oslo but has lived for the past five years in Tromsø, where she has taken an MSc in geology from the Norwegian Arctic University.

"Hardly any other industry possesses as much knowledge and capital as the oil sector," she observes. "I'm looking forward to learning how the industry exploits this know-how to overcome some of the big climate challenges we face, and where it sees itself in a future with a greener energy mix."

Herman comes from Tønsberg, not far from Åsgårstrand. In recent years, he has lived in Trondheim while taking an MSc in electrical engineering and automation. He has also studied in both the USA and Australia, at high school and university respectively.

"When I started at the Norwegian University of Science and Technology (NTNU), my eyes were opened to the climate challenges facing the world today. But I also learned about the growing energy demand created by the growing global population. Fortunately, I'm a technology optimist who believes that many of the solutions lie here – and therefore want to tie existing and future technology closer to ordinary Norwegians."

Demanding *Herman (above) supports pupils during the budget game.*

Eye-opener *Mariann and Marius (left) let the pupils set their own priorities for Norway's national budget – but demand that they balance the books.*

Finance ministers *Christina (left), Silje and Eline conduct an intense discussion on budget items while Mariann monitors their efforts.*

eastern, western and northern Norway," he says. "Moreover, the views of 18-year-olds are clearly more balanced than those who're two years younger."

Global

The travelling trio have also noted that many youngsters lack a global perspective when talking about the climate. Nor is the relationship between climate and prosperity obvious to them.

Young Norwegians show little willingness to accept a reduced standard of living. And "reduced" means something else to them than it does to their parents.

"Nor are the majority aware of Norway's actual weight in an energy context," says Marius Andersen, the third member of the team.

"Many believe that our oil production accounts for 20 per cent of world output, while the reality is two per cent."

"What governs the things we achieve in a country?" the threesome asks pupils. "What can we afford? Now you're going to put on the finance minister's hat."

That introduces a game for them to play about the national budget. If they cut oil revenues, for example, what happens to the balance between government income and spending?

What lessons do the pupils draw from that? How can they increase revenues from other sectors, and by how much? What welfare benefits must be cut? Can we spend less on defence? And so forth.

The game creates engagement and discussion. "We certainly learnt something," is one of the comments afterwards. But change their own daily lives? ... "um, not quite sure".

Emissions

A number of pupils also raised make-up-daubed eyebrows when the New Oil missionaries put Norway's carbon emission figures in a global perspective.

The country release 45 million tonnes of carbon dioxide per annum, with the petroleum industry accounting for 14 million tonnes.

That is relatively little compared with the biggest emitters – China, the USA and India. Worldwide emissions total 36 000 million tonnes – 800 times the Norwegian figure.

While this should not be an excuse for inaction, it nevertheless puts matters in perspective. A majority in the class felt Norway should stick to its goal of halving emissions by 2030.

A minority of the pupils said they read newspapers, under pressure from their parents. The rest preferred to get their information from various social media rather than traditional sources such as TV and the papers.

Fogeys

Asked how they view the oil industry, the youngsters spontaneously characterised it as "old fogeys". Others felt the sector has come across as arrogant and unwilling to present itself.

Few – apart from a couple of exceptions, of course – want to identify with the petroleum business. They regard it as a fossil and on the way out.

The New Oil team thereby passes the ball back to the industry. It has a job to do.

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B-blad

Harmonised *All NPD employees were invited to a party when Bente Nyland (left) bowed out after 12 years as director general and Ingrid Sølvberg (right) was appointed as her successor. (Photo: Arne Bjørøen)*

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