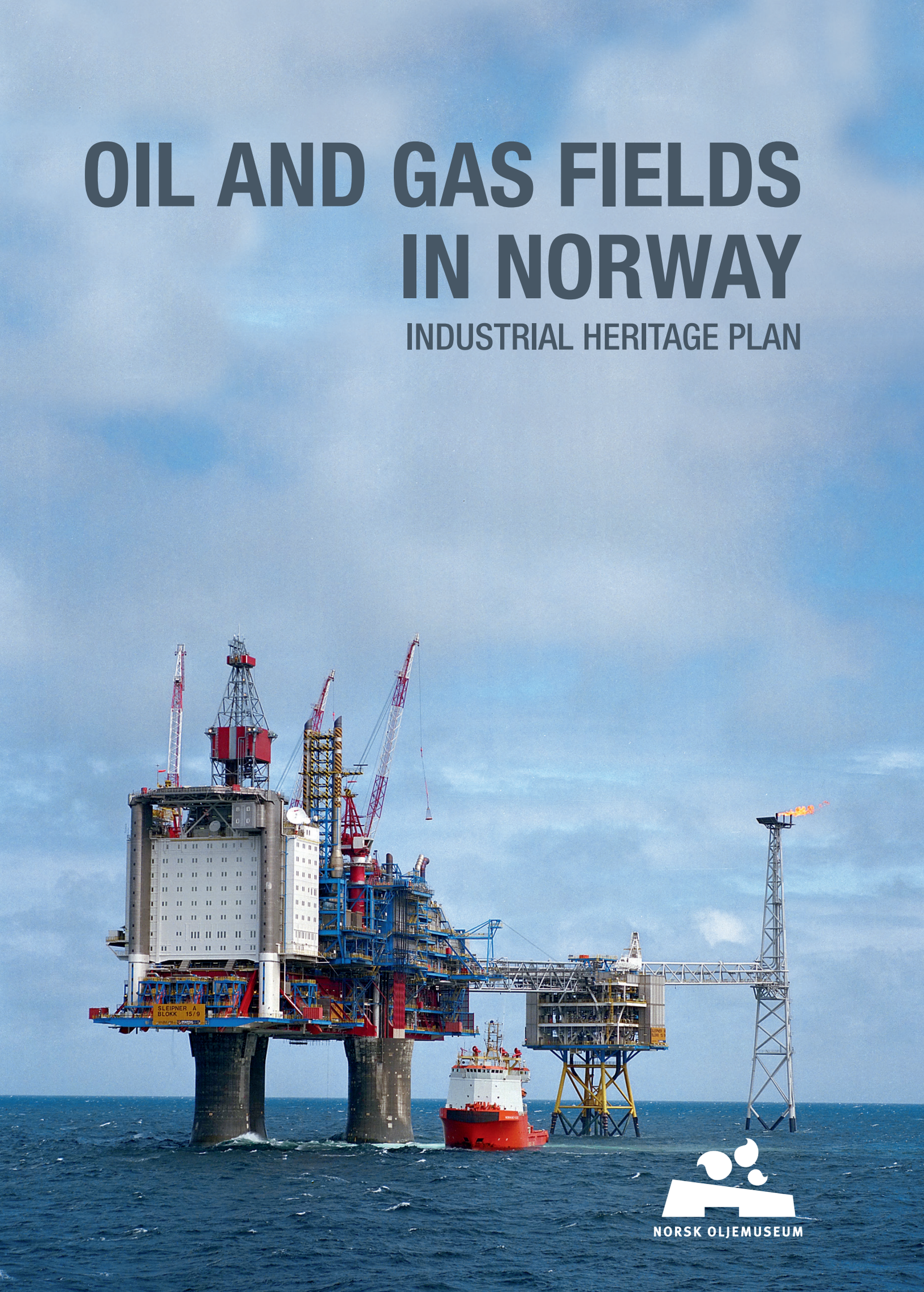
OIL AND GAS FIELDS IN NORWAY

INDUSTRIAL HERITAGE PLAN



NORSK OLJEMUSEUM

THE TROLL AREA

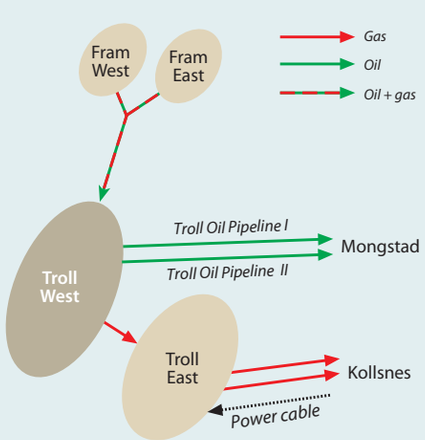
The Troll area of the northern North Sea lies in more than 300 metres of water, 65 kilometres west of Kollsnes near Bergen. It embraces Troll East (gas), Troll West (oil) and the Fram oil field.

Troll

This field embraces the main Troll East and Troll West structures in blocks 31/2, 3, 5 and 6. While Troll East primarily contains gas, Troll West has mostly oil. Recoverable reserves estimated at 1 330 billion scm of gas and 1 500 million barrels of oil make Troll Norway's largest field. It is also the biggest gas field in Europe by remaining reserves. Although Troll contains less oil than gas, its size can be illustrated by the fact that it has been the biggest oil producer on the NCS for a number of years. The reservoirs are expected to remain on stream for at least 50 years.

Block 31/2 was awarded in the fourth licensing round during 1979, with Norske Shell as operator. Drilled in the summer of that year by the Borgny Dolphin rig, the first exploration well confirmed that the field contained huge volumes of gas with an underlying oil zone. The block was declared commercial in 1983.

Norske Shell acquired responsibility for the first gas development phase on Troll, but the licence terms for 31/2 specified that Statoil could take over



Infrastruktur i Trollområdet.

as operator eight to 10 years after a declaration of commerciality. This option was exercised in the summer of 1996 after production had begun.

The three neighbouring blocks, 31/3, 5 and 6, were awarded to Statoil, Norsk Hydro and Saga Petroleum with Hydro as operator.

Troll A was originally due to be installed in block 31/2, where Norske Shell and later Statoil were the operator. But it turned out that Troll East held the biggest gas reserves in block 31/6, and the A platform was duly relocated there.

The production licences were unitised in 1985, with a joint management committee, so that decisions on gas and oil production could be taken in the same forum. Statoil became operator for gas production in Troll East and Hydro for oil output from the western structure. Statoil is today operator for the whole field.

This company is also production operator for the pipelines to land. Gassco became operator, on behalf of the Gassled joint venture, for the gas processing plant at Kollsnes in 2002, with Statoil as technical service provider. Supply services for Troll are provided from Coast Centre Base (CCB) at Ågotnes near Bergen and Fjord Base in Florø further north.

Sales contracts for Troll gas were entered into in 1986 and came into force on 1 October 1993. However, the field did not begin gas production until February 1996. Sales commitments during the early years were therefore met from Sleipner East.

Reservoir and recovery strategy

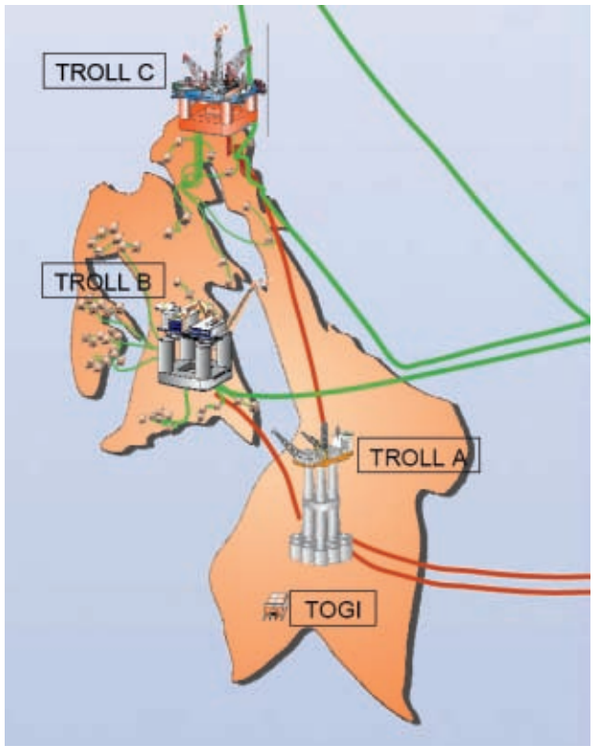
Troll covers about 700 square kilometres, and has a relatively shallow reservoir located 1 300-1 600 metres beneath sea level.

It is built up from three relatively large rotated fault blocks:

Troll East contains mainly gas, with an underlying oil zone up to four metres thick

Troll West oil province comprises an oil zone 22-26 metres thick under a small gas cap

Troll West gas province has an oil zone 12-14 metres thick under a gas cap roughly 200 metres thick.



The Troll field with its platforms. Illustration: Norsk Hydro

About two-thirds of the recoverable gas reserves are estimated to be in Troll East.

The gas lies in reservoir sandstones deposited 190-136 million years ago in the middle and upper Jurassic, with a high permeability which provides good production properties. Gas and oil are found mainly in the Sognefjord formation, which is built up from shallow marine sandstones. Part of the reservoir also extends into the underlying Fensfjord formation. Troll East and West are in pressure communication. Only in Troll West is the oil zone thick enough to justify commercial production at present.

Gas in Troll East is produced through pressure reduction. Oil production in the Troll West oil province is optimised with the aid of gas injection. An important part of the production strategy has been to drain the oil quickly, because its recovery could be reduced as pressure declines in Troll East. Gas production from the latter has accordingly been held back.

Block 31/2 - production licence 054. Awarded 1979
Block 31/3 - production licence 085. Awarded 1983
Block 31/3 - production licence 085 C. Awarded 2002
Block 31/3 - production licence 085 D. Awarded 2006
Block 31/5 - production licence 085. Awarded 1983
Block 31/6 - production licence 085. Awarded 1983
Block 31/6 - production licence 085 C. Awarded 2002
Block 31/6 - production licence 085 D. Awarded 2006

Development solution

Troll is being developed in several phases.

Phase 1

Troll Gas, production of Troll East gas from the Troll A platform.

Phase 2

Troll Oil, production of Troll West oil from the Troll B and C platforms.

Phase 3

Gas reserves in Troll West will be produced in a future phase.

Oil from Fram West and East is piped to Troll C for processing and onward transport to Mongstad. Plans also call for the Vega and Gjøa discoveries to be tied back to the C platform.

It was decided in 1986 to inject Troll gas in Oseberg to enhance production pressure in the latter and thereby recover more of its oil. The gas was produced from the subsea Troll-Oseberg gas injection (Togi) module, which stood on Troll East. This later ceased production and will be removed.

Troll East

The development concept for Troll East comprises three integrated components – the Troll A combined production, drilling and quarters platform, two multiphase flow pipelines for wet gas, and a processing and compression plant at Kollsnes in Øygarden local authority north-west of Bergen. The last of these facilities processes the gas before compressing and exporting it by pipeline to Emden in Germany and Zeebrugge in Belgium. This tripartite solution simplified the Troll A topside, reduced its staffing and thereby significantly enhanced safety.

Troll A

The GBS for this platform was built in concrete by Norwegian Contractors. It is the last and tallest of the Condeep structures to be built, and marked a high point for this concept. Constructing the huge GBS, which stands 360 metres high, took four years and employed more than 2 000 people at peak. The work began during 1991 in the dry dock at Hinna outside Stavanger, with the GBS towed in 1993 to Vats north of the city for mating with the steel topside. Measuring 472 metres from its base to the top of the flare stack, Troll A ranked as the tallest structure ever moved by humans when it was towed out to the field in 1995. More than 245 000 cubic metres of concrete and 100 000 tonnes of reinforcement steel were consumed in its construction. The GBS has 19 cells and four shafts. To achieve sufficient stability in 300 metres of water, concrete skirts beneath the structure penetrate 36 metres into the seabed. A characteristic feature of the GBS is the "chord shortener", a reinforced concrete box connecting the four shafts roughly halfway up. This stif-

Troll A. Illustration: Norwegian Contractors

fened the structure and helped to give it sufficient buoyancy for towout to the field.

Production

Forty wells have been drilled from Troll A, each capable of producing 3.4 million cubic metres of gas per day. In normal operation, however, their daily flow is limited to 2.8 billion cubic metres. The platform also receives gas from Troll West through separate pipelines. Troll A and the processing plant on land are dimensioned for a production capacity of roughly 80 million cubic metres per day, corresponding to an annual output of more than 20 billion cubic metres.

The wellstream contains both gas and condensate as well as water. Before it is piped ashore, some of the water and condensate are removed in an inlet separator. While the condensate gets returned to the gas in the export pipelines, the water is thoroughly treated and discharged to the sea. Glycol added to inhibit corrosion and hydrate (hydrocarbon ice) formation in the pipelines is removed in the processing plant and returned to the platform in a small flowline. During the early years, pressure in the reservoir was high enough to drive the gas over the 60 kilometres to land. Compressors were installed on Troll A in 2005 to maintain pressure in the pipelines.

A control centre on land monitors operation of the platform, the pipelines and the Kollsnes plant. This system comprises two control loops, one on land and one on Troll A, connected by a fibreoptic cable integrated with a transmission cable carrying power from Kollsnes to the platform.

Troll A was the first installation on the NCS to receive all its electricity requirements from land, supplied through three submarine cables.

Troll A. Photo: Marit Hommedal/Statoil

The pipelines

One of the biggest challenges when developing Troll Gas was to come up with a new multiphase flow technology which made it possible to pipe wet gas over long distances. During the journey from the platform to the receiving terminal, the gas is coo-

Troll East

Total recoverable reserves	1 330.7 bn scm gas 25.7 mill tonnes NGL 1.6 mill scm condensate
Remaining at 31 Dec 2008	995 bn scm gas 22.1 mill tonnes NGL
Discovery year	1983
Approved for development	15 Dec 1986
On stream	9 Feb 1996
Operator	Statoil
Operations organisation	Bergen
Main supply base	Ågotnes

Licensees

Petoro	56.00%
Statoil	30.58%
Norske Shell	8.10%
Total E&P Norge	3.69%
ConocoPhillips	1.62%

Kollsnes gas processing plant

Owner	Gassled
Operator	Gassco
Technical service provider	Statoil

The Kollsnes processing plant. Photo: Dag Myrestrand/Statoil

led down by the surrounding seawater. That in turn causes water vapour and condensate to liquefy. If production halts, these liquids could accumulate and form slugs which have to be trapped in special "slug catcher" tanks on land when operation resumes. Detailed research and development have made it possible to predict the number, location and size of these slugs, and provide a better basis for dimensioning pipelines and slug catchers. "Intelligent" pigs were also developed for pumping through the pipelines with the gas to inspect and measure corrosion. The multiphase flow pipelines from Troll A to Kollsnes are 63 kilometres long. Since the seabed off Øygarden is very uneven and difficult to traverse, the two 36-inch pipelines have been laid through a tunnel for the final three kilometres into land.

The land-based processing plant

Gas from Troll is dewatered in the Kollsnes plant to leave only minor quantities of water vapour. Pressure reduction and cooling are used to separate out the heavier hydrocarbon fractions in liquid form. The gas is then compressed before being piped 1 100 kilometres to continental Europe. Condensate and NGL removed from the gas is piped either to the Sture terminal or to Mongstad further north.

It was resolved in 1999 that Kvitebjørn gas would be landed at Kollsnes. The composition of the gas from this field makes it very suitable for further processing into upgraded products. A new facility has been built at Kollsnes to extract NGLs from rich gas supplied by Kvitebjørn. This includes deliveries from Visund via a pipeline link to Kvitebjørn. The Vestprosess pipeline links Kollsnes to the Mongstad refinery complex further north, where NGL gets fractionated into propane, butane and naphtha. Dry gas is exported from Kollsnes through the Zeepipe IIA and IIB lines to Sleipner East and Draupner for onward transport to continental Europe or the UK. After upgrading, the plant's daily capacity is 143 million scm of dry gas and 9 780 scm of condensate. A new export compressor became operational in October 2006 to ensure that the plant could deliver this gas volume.

Troll West

The oil in Troll West is produced via subsea templates tied back by flowlines to the two platforms.

Production began on 19 September 1995.

While Troll B produces from the Troll West oil province, the C platform handles oil from the Troll West gas province and also processes production from Fram.

Transport

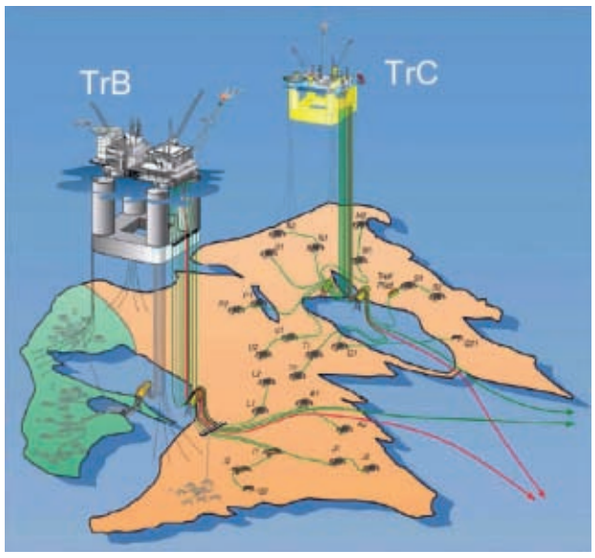
Two oil pipelines have been laid from Troll West to the receiving terminal at Mongstad north of Bergen. Troll Oil Pipelines I and II carry production from Troll B and C respectively. Troll West gas is exported to Troll A through pipelines from both Troll B and C.

The technological challenges faced in producing Troll oil related particularly to three issues:

1. the oil is contained in thin zones
2. the oil-bearing zones are very extensive
3. the water depth is roughly 340 metres, which was considered technologically demanding at the time development plans for Troll were being laid.

When planning work began on Troll in the early 1980s, no technology was available for profitable production of the oil. To make drilling economic, it was clear that wells had to be driven horizontally with great precision over long distances. Hydro drilled the first horizontal well on the NCS in 1989. With the aid of advanced horizontal drilling and new technological solutions, what was originally only a gas discovery became one of the biggest oil-producing fields on the NCS. Average daily output exceeded 400 000 barrels.

A number of multilateral wells have since been drilled, making it possible to reach larger parts of the reservoir. Roughly half of all the advanced multilaterals in the world have been drilled on Troll.



Troll B and C on Troll West, with seabed installations. Illustration: Norsk Hydro

Troll West

Discovery year	1979
Total recoverable reserves	1 538 mill bbl oil
Remaining at 31 Dec 2008	288 mill bbl oil
Approved for development	18 May 1992
On stream	19 Sep 1995
Operator	Statoil
Operations organisation	Bergen
Main supply base	Ågotnes
Licensees	
Petoro	56.00%
Statoil	30.58%
Norske Shell	8.10%
Total E&P Norge	3.69%
ConocoPhillips	1.62%

Troll B

Kværner Concrete Construction was the key supplier of the concrete hull for Troll B, the first semi-submersible platform built in this material.

Located in 325 metres of water, the floater is tied to seven subsea templates with a total of 56 oil production wells and one gas injector. The wells have been drilled in both the oil and gas provinces. Oil is separated and stabilised in Troll B's processing facilities and exported through Troll Oil Pipeline I to Mongstad. Associated gas travels by pipeline via Troll A. Produced water is treated and discharged to the sea. Apart from the processing plant, the platform has living quarters but no drilling equipment.

Troll B was installed in September 1995 and began producing from the oil province on 19 September 1995 and from the gas province in November of the same year.

Troll C

The steel-hulled Troll C production floater began production on 1 November 1999 from the northern

Troll B. Photo: Terje S Knudsen/Statoil

Troll C. Photo: Terje S Knudsen/Statoil

part of the Troll West gas province. Oil is separated and stabilised by its processing facilities for export through Troll Oil Pipeline II to Mongstad. The gas is piped to Troll A. Eight subsea templates with 49 oil production wells are tied back to Troll C, which includes living quarters as well as the processing plant but not drilling equipment.

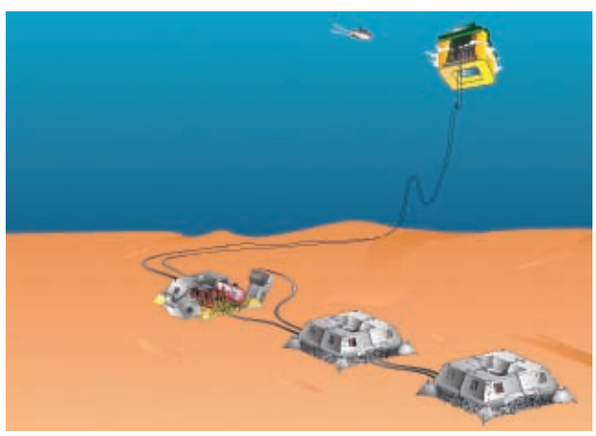
Oil from Fram West and East is piped to Troll C for processing and onward transport to Mongstad. Plans also call for Vega and Gjøa to be produced via Troll C.

Troll Pilot

Hydro became the world's first oil company to install an advanced subsea processing facility in 2000. Created in collaboration with ABB Offshore Systems, the Troll Pilot represented a big advance in transferring functions from a surface platform to the seabed.

This installation stands in 340 metres of water to separate produced water from the wellstream and inject it back below ground without passing first to the production platform. Its processing equipment comprises a subsea separator, a water injection pump and an Xmas tree for water injection. Oil is piped to Troll C. The new solution makes the development more environment-friendly and reduces production costs by cutting energy consumption.

The Troll Pilot technology was Hydro's response to the challenge presented by handling produced water from the thin oil zones in Troll. Wellstreams can contain as much as 60-80 per cent water. Eliminating the need for water separation on the platform freed up capacity to produce and process more oil. Troll Pilot has the capacity to process 50 000 barrels of liquid per day, and can inject up to 37 500 daily barrels of water.



Troll Pilot. Illustration: Norsk Hydro

Fram

This oil field lies in roughly 350 metres of water in the northern North Sea, 20 kilometres north of Troll. It is divided into Fram West and East.

Reservoir and recovery strategy

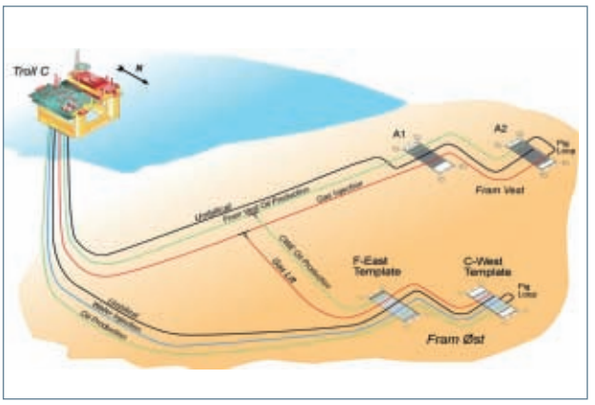
The Fram West and East reservoirs comprise turbidite sandstones and shallow marine sandstones in the Draupner and Sognefjord formations respectively, both of late Jurassic age, and middle Jurassic sandstones in the Etive formation.

Fram West is produced through the injection of gas for pressure support.

Where Fram East is concerned, the Sognefjord reservoir is produced through water injection from Troll C as pressure support and with gas lift, while the Etive will be produced with expansion from the gas cap. How long Fram produces depends on the production life of Troll C.

Transport

The Fram wellstream is piped to Troll C for processing, with the oil sent on to Mongstad through Troll Oil Pipeline II and gas which is not injected exported via Troll A to Kollsnes.



Fram East. Illustration: Norsk Hydro

Development solution

The Fram West development embraces two subsea templates with a total of five oil production wells and a gas injector, which are tied back to Troll C. Gas is separated from the liquids on the latter and injected back into the Fram West reservoir.

Development of Fram East comprises two subsea templates tied back to Troll C. Plans call for five production wells and two water injectors.

Fram

Block	35/11
Production licence	090
Awarded	1984
Total recoverable reserves	150 mill bbl oil
	8.4 bn scm gas
	0.1 mill tonnes NGL
Remaining at 31 Dec 2008	67.9 mill bbl oil
	8 bn scm gas
	0.1 mill tonnes NGL
Operator	Statoil
Discovery year	1992

Fram West development approved	23 Mar 2001
Fram West on stream	2 Oct 2003
Fram East development approved	22 Apr 2005
Fram East on stream	30 Oct 2006
Operations organisation	Bergen
Main supply base	Mongstad

Licensees

Statoil	45%
ExxonMobil	25%
Gaz de France Norge	15%
Idemitsu Petroleum Norge	15%