

# OIL AND GAS FIELDS IN NORWAY

## INDUSTRIAL HERITAGE PLAN



NORSK OLJEMUSEUM



# THE EKOFISK AREA

The Ekofisk area lies in 70-75 metres of water at the southern end of Norway's North Sea sector, about 280 kilometres south-west of Stavanger. In addition to Ekofisk, it embraces Eldfisk, Embla and Tor. All four fields are operated by ConocoPhillips on behalf of the Ekofisk licensees. The area also includes the Cod, Mime, Edda, West Ekofisk, Albuskjell and Tommeliten Gamma fields, which have ceased production. It has comprised a total of 32 platforms, including the first production installation, Gulftide. Developed in a number of stages, the area has the highest concentration of offshore installations and flowlines/pipelines in the whole North Sea. Nine platforms are due to be disassembled and removed up to 2013.

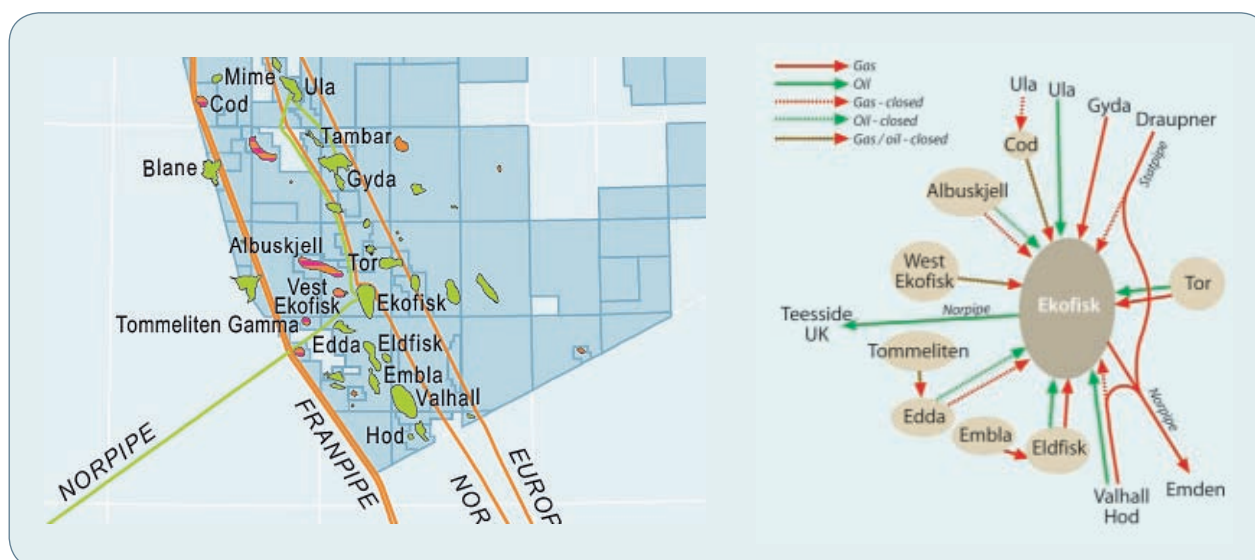


## Ekofisk

The discovery of Balder in 1967 and Cod in 1968 demonstrated that hydrocarbons were also present on the Norwegian side of the North Sea, although these initial finds were not commercial at the time. After a number of dry wells, the Phillips group discovered Ekofisk in the autumn of 1969. This proved to be a huge oil field, currently estimated to have

originally contained more than three billion barrels of recoverable oil. Production began officially in the summer of 1971 from the Gulftide jack-up rig.

Approval in principle was given to the technical plans for developing Ekofisk in 1972. The plan for waterflooding in Ekofisk received a green light on 20 December 1983, the PDO for Ekofisk II was approved on 9 November 1994, and the PDO for Ekofisk Area Growth gained official sanction on 6 June 2003.



### Bravo and Kielland

Accidents in the Ekofisk area have helped to focus attention on safety issues and the risks associated with offshore petroleum operations. The uncontrolled blowout on Ekofisk 2/4 B (Bravo) in April 1977 put pollution on the agenda, and speeded up the creation of an oil spill clean-up organisation. With 123 fatalities, the capsizing of the Alexander L Kieland accommodation rig in March 1980 was the worst industrial accident in Norway's history. The Norwegian Maritime Directorate commanded in the autumn of 1980 that all offshore workers should be issued with a survival suit.

### Subsidence and jacking up

Unlike many other fields in the North Sea, Ekofisk is a chalk structure. Declining reservoir pressure has led over the years to seabed subsidence. Work to safeguard the platforms against this phenomenon began as early as 1985. The steel jackets in the Ekofisk centre were jacked up by six metres in 1987, and a protective breakwater was installed around the Ekofisk tank two years later. The rate of seabed subsidence has slowed in recent years.

### Reservoir and recovery strategy

Ekofisk produces from naturally fractured chalk belonging to the Ekofisk and Tor formations of early Palaeocene and late Cretaceous age. These reservoir rocks have high porosity but low permeability, and are fine-grained and tight. However, the fracturing allows oil and water to flow more easily. Located at a depth of 2 900-3 250 metres below sea level, the reservoir has an oil column of more than 300 metres and is 10 kilometres long by eight wide.

The field was originally developed with pressure reduction as the drive mechanism and an expected recovery factor of 17 per cent. Limited gas injection and extensive waterflooding have subsequently helped to improve oil recovery substantially. Large-scale waterflooding began in 1987, and has since been expanded in several stages. Experience shows that the water effectively displaces the oil, and the expected recovery factor for Ekofisk is now about 50 per cent. In addition, compaction of the soft chalk provides additional drive for draining the field.

Immediately after the plans to merge Conoco and Phillips became known in December 2002, the company announced the Ekofisk Area Growth project. This aims to improve oil and gas recovery

### Ekofisk

Block	2/4
Production licence	018
Awarded	1965
Total recoverable reserves	3 324.2 mill bbl oil 156.1 bn scm gas 14.5 mill tonnes NGL
Remaining at 31 Dec 2008	790.6 mill bbl oil 20.4 bn scm gas 2.2 mill tonnes NGL
Discovery year	1969
Approved for development	1 Mar 1972
On stream	15 Jun 1971
Operator	ConocoPhillips
Development operator	Phillips Petroleum Co
Operations organisation	Stavanger
Main supply base	Tananger
Licensees	
Total E&P Norge	39.90%
ConocoPhillips	35.11%
Eni Norge	12.39%
Statoil	7.60%
Petoro	5.00%

while enhancing Ekofisk's processing capacity and reliability. The field is currently expected to continue producing until 2050.

### Transport

Oil and gas are piped today from Ekofisk 2/4 J to Teesside in the UK and Emden in Germany respectively.

Initially, oil produced from the field was loaded into tankers via two loading buoys tied back to the Gulftide jack-up. Gas was burnt off from a flare stack on the rig. The problem with this approach arose when the tankers were forced to disconnect from the loading buoys because of strong winds or high waves, and production had to cease. Ekofisk was shut down by bad weather for 20 per cent of the time during the first year.

After Gulftide had been removed in 1974 and production was under way from Ekofisk 2/4 A, B and C, the loading buoys were moved further from the platforms and Ekofisk 2/4 T (the Ekofisk tank) became operational. The latter was highly useful for oil storage, making it possible to remain on stream when bad weather prevented the tankers from connecting



Ekofisk 2/4 T. Photo: ConocoPhillips

to the buoys. Production could thereby continue in virtually all weather conditions. The tank was used for storage for a year from the autumn of 1974.

Submarine pipelines provided the permanent solution for transporting oil and gas to land.

Running for 354 kilometres, the Norpipe oil pipeline to the receiving terminal in Teesside became operational in October 1975. The oil and natural gas liquids (NGL) were pressurised by pumps on Ekofisk 2/4 P. Two pumping stations – Ekofisk 36/22 A and 37/4 A – were originally installed along the pipeline to maintain pressure, but were disconnected in 1983 and 1987 respectively. Both stood on the UK continental shelf (UKCS).

The Norpipe gas pipeline became operational in September 1976, with the gas initially pressurised by compressors at the Ekofisk centre. Two compressor platforms – B-11 and H-7 – are located along the 443-kilometre pipeline to Emden. Both

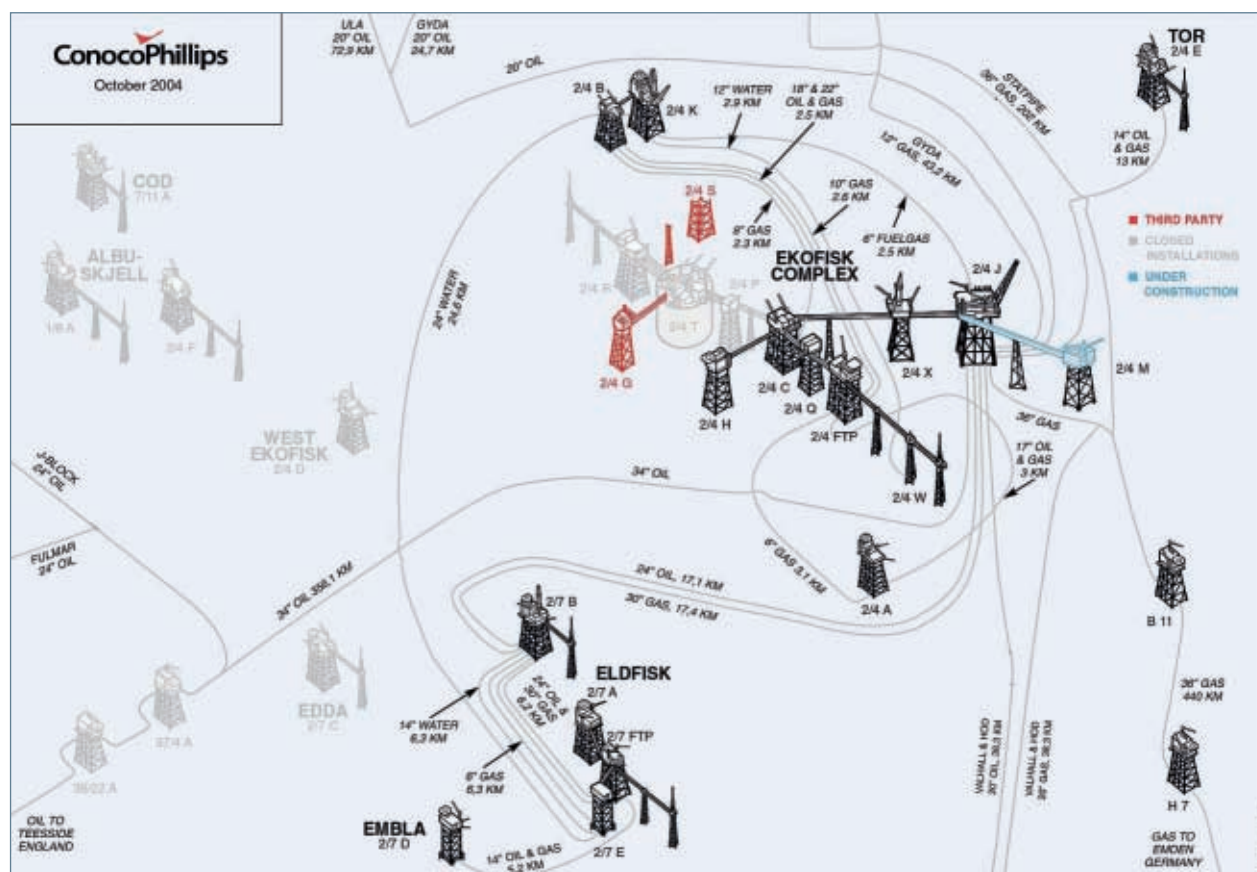


Illustration: ConocoPhillips





*The Ekofisk centre. Photo: Kjetil Alsvik/ConocoPhillips*

stand on the German continental shelf, while the pipeline also crosses the Danish sector. H-7 was shut down in 2007.

Since the Ekofisk centre was strategically located in the centre of the North Sea basin, using the existing platforms and pipelines to transport other oil and gas to land was a natural solution. Transport of the field's own production was supplemented with output from Cod, Albuskjell, West Ekofisk, Tommeliten, Edda, Tor, Embla, Eldfisk, Valhall, Hod, Ula and Statpipe. The first five of these fields have now ceased production.

### **Development solution**

Phase one of development and production in the Ekofisk area began with the first oil produced by the Gulftide jack-up in 1971, and ended with the shut-down of Ekofisk I in 1998. A new PDO for the field – Ekofisk II – was approved in 1994, at the same time

as the production licence was extended until 2028. This led to large parts of the Ekofisk area being converted in 1998.

The installations located centrally on the field and linked by bridges are termed the Ekofisk centre, and this consisted until 1998 of eight platforms and two flare stacks. In addition came the 2/4 G and 2/4 S platforms owned by Amoco (later BP) and Statoil respectively.

A reconstructed Ekofisk centre is now in place on the field, including the 2/4 X wellhead platform positioned in the autumn of 1996. The 2/4 J structure for processing and transport followed in 1997, and Ekofisk 2/4 M – a steel wellhead and processing platform – was installed in the summer of 2005. Ekofisk, Eldfisk, Embla and Tor are now tied back to the new centre.

Platforms outside the Ekofisk centre are 2/4 A to the south as well as 2/4 B and 2/4 K to the north.



<b>Year</b>	<b>Overview of developments in the Ekofisk area</b>
1971	Gulftide begins production from Ekofisk, with the oil loaded into tankers.
1973	Ekofisk 2/4 Q comes into use as a quarters platform.
1974	Ekofisk 2/4 A, B and C come on stream. Ekofisk 2/4 FTP and the southern flare stack become operational. Gulftide ceases production and is removed.
1975	The Ekofisk 2/4 P pumping platform and the Norpipe pipeline to the UK, with the 36/22 A and 36/4 A pumping platforms, become operational. Offshore loading ceases.
1977	The processing facilities on the Ekofisk tank and the northern flare stack start operation. The tank is no longer used as an oil store. Tor, West Ekofisk and Cod are tied back to the new Ekofisk 2/4 R platform. Gas is piped through a new Norpipe line via the B-11 and H-7 compressor platforms to Emden in Germany.
1978	The Ekofisk 2/4 H hotel platform becomes operational.
1979	Albuskjell, Edda and Eldfisk are tied back to the Ekofisk centre.
1981	Valhall produces to a new platform, Ekofisk 2/4 G, which is linked by a bridge to the Ekofisk tank.
1983	The Ekofisk 36/22 A pumping platform is shut down.
1985	The Statpipe line is tied to the Ekofisk centre via the 2/4 S platform.
1987	The Ekofisk 2/4 K waterflood platform comes on stream. It is linked by a bridge to Ekofisk 2/4 B. Tommeliten starts production through a tie-in to Ekofisk via Edda. The Ekofisk 37/4 A pumping platform is shut down.
1990	Albuskjell 2/4 F ceases production.
1991	The Ekofisk 2/4 W water injection platform is placed on the bridge support to the southern flare stack.
1993	Embla starts production through a tie-in to the Ekofisk centre via Eldfisk.
1995	Norpipe is re-routed to bypass the 36/22 and 37/4 A pumping platforms.
1996	The new Ekofisk 2/4 X drilling and wellhead platform comes on stream.
1997	Cod ceased production.
1998	The Ekofisk 2/4 J processing platform comes on stream. Ekofisk 2/4 G, 2/4 P, 2/4 R and 2/4 S, Albuskjell 1/6 A, West Ekofisk 2/4 D, the process plant on the Ekofisk tank, and production from Edda 2/7 C and Tommeliten ceases. Large parts of the pipelines around the Ekofisk centre are relaid.
2000	Eldfisk 2/7 E comes on stream.
2005	Ekofisk 2/4 M is installed.



### Gulftide

This four-leg jack-up rig was built in Glasgow in 1967 for Ocean Drilling & Exploration Co, and converted in 1971 to serve as a production platform. It produced on Ekofisk from 1971 to 1974, when the first well on the fixed 2/4 A platform came on stream. To win time, it was resolved that the three



*Gulftide. Photo: Terje Tveit/Norwegian Petroleum Museum*

wells drilled by Ocean Viking to delineate Ekofisk as well as the discovery well would be converted for production. The statistics show that each of these wells flowed 10 000 barrels of oil per day. Oil and gas were dewatered on the platform, with the gas burnt off from a flare boom on the drilling derrick. The oil was piped through flowlines to two loading buoys which linked the platform with tankers.

### Ekofisk 2/4 A

Originally a combined production, drilling and quarters platform, Ekofisk 2/4 A serves today as a pure wellhead structure. It stands in 74 metres of water, 2.9 kilometres south of the Ekofisk centre. It was installed in 1972 and came on stream in April 1974.

Production was processed in the platform's separators and piped to Ekofisk 2/4 FTP for further separation. Ekofisk 2/4 A has 11 producing wells with gas lift from 2/4 C.

The quarters module originally provided 42 berths, but new accommodation was installed in 1984



*Ekofisk 2/4 A. Photo: Husmo Foto/Norwegian Petroleum Museum*



with two-berth, en-suite cabins. Drilling equipment was upgraded to the top drive system in 1991.

Personnel moved from the platform in 1993, and it was remotely operated from Ekofisk 2/4 K (and could also be controlled from 2/4 FTP) and from 2/4 J after 1997. The derrick and drilling equipment were removed in the latter year.

A breach in the riser on the pipeline to Ekofisk 2/4 FTP led to ignition of the gas on 1 November 1975 and a big fire. Crew had to be evacuated, with the loss of three lives. The downhole safety valve functioned as intended and production was automatically halted, but the gas pack in the 2.9-kilometre pipeline fed the flames until this fuel has been exhausted and the fire died of its own accord. The cause of the fire was corrosion of the riser in the wave zone beneath the platform.

#### **Ekofisk 2/4 B**

This is a combined production, drilling and quarters platform standing in 70 metres of water, 2.3 kilometres north of the Ekofisk centre. Installed in 1972, it came on stream two years later.

The processing equipment comprises two identical parallel separators and a test separator. Of the 24 platform well slots allocated to production, 22 were completed as producers and two held in reserve. The production wells delivered a mix of oil and gas, which was piped to Ekofisk 2/4 FTP.

Ekofisk 2/4 B carried two derricks for a time, but both are now removed. The 68-berth quarters model



*Ekofisk 2/4 B. Photo: Husmo Foto/Norwegian Petroleum Museum*

was removed after the installation of the neighbouring 2/4 K platform, which is connected to 2/4 B by a bridge.

An uncontrolled blowout of oil and gas occurred from this platform in April 1977. Well B-14 needed a workover, which required the 3 000 metres of production tubing to be pulled. The blowout preventer failed during this operation, and it took a week to bring the well back under control.

#### **Ekofisk 2/4 C**

This PDQ platform is linked by bridges to Ekofisk 2/4 P, 2/4 Q and 2/4 H. Installed in 1972, it stands in 70 metres of water and has 12 wells. Nine of these are used for gas injection and the other three produce oil, gas and condensate, which are piped via the bridges to 2/4 FTP for separation and processing.

The platform came on stream in 1974.

#### **Ekofisk 2/4 FTP**

This riser (formerly production) platform was installed in 1972 and became operational in 1974. Until



*Ekofisk 2/4 C. Photo: Husmo Foto/Norwegian Petroleum Museum*

the Norpipe oil pipeline to Teesside was installed, oil was shipped from two loading buoys tied back to 2/4 FTP by 30-inch flowlines. The platform is linked by bridges to Ekofisk 2/4 Q on the northern side and Ekofisk 2/4 W to the south.

Its original function was to process oil and gas from the 2/4 A and 2/4 B platforms, and later also 2/4 C. The processing equipment comprised separators for oil, water and gas as well as two compressors for pressurising the gas and sending it on – first to Ekofisk 2/4 C for injection into the reservoir and later to 2/4 T when that unit became operational. Peak flow via 2/4 FTP was 420 000 barrels per day.



*Ekofisk 2/4 FTP. Photo: Husmo Foto/Norwegian Petroleum Museum*

For many years, the platform had its own management and staffing on a par with other installations in the Ekofisk centre. It also has a helideck, which was in use for many years. After 28 years of operation, control room staff were withdrawn from 2/4 FTP in September 2001. All shutdown signals and safety systems were transferred to the Ekofisk 2/4 J control room.

Ekofisk 2/4 FTP is to be regarded today as a riser platform for a production flowline from 2/4 A, and also supplies the latter with power.

#### **Ekofisk 2/4 G**

Owned by the Valhall licence, this was a riser platform which tied Valhall to Ekofisk. The fields were connected by two 20-inch pipelines, for oil and gas respectively. Oil was piped on to Teesside and gas to Emden.

A bridge with piping systems linked Ekofisk 2/4 G to the 2/4 T tank. Installed and operational in 1981, the platform was shut down in 1998 when a new 24-kilometre gas pipeline from Valhall was tied directly into the Norpipe line to Emden. The oil pipeline was re-routed to Ekofisk 2/4 J for continued transmission to Teesside.

#### **Ekofisk 2/4 H**

This is a specialised service platform for accommodation and administrative functions. Providing 212 berths in double cabins, it is linked to Ekofisk 2/4 C by a bridge.



*Ekofisk 2/4 G.  
Photo: Husmo Foto/Norwegian Petroleum Museum*





*Ekofisk 2/4 H. Photo: Jan A Tjemsland/Norwegian Petroleum Museum*

The platform is equipped with all the facilities required by the personnel quartered on it, including its own generator and water production as well as full catering provision. In addition come a cinema, gym, games and reading rooms, chapel, coffee lounge, sick bay, equipment for technical education and storage capacity for a number of technical functions, a helideck, a hangar and a control centre for sea and air traffic. The top management for the whole Ekofisk field and offices for a number of shared services are also located there.

Installed in 1977, Ekofisk 2/4 H became operational in 1979 and functions as the main accommodation installation for the Ekofisk centre until a new quarters platform is built.

#### **Ekofisk 2/4 J**

All production from the Ekofisk centre and the field's satellite platforms goes to this processing and transport platform before gas is piped to Emden and oil to Teesside.

Large parts of the Ekofisk centre were reorganised in 1998, with 2/4 J as the key installation in these changes. In addition to production from the main Ekofisk field, it receives oil and gas from Eldfisk, Embla, Tor and Valhall. Gas and oil also arrive from Gyda and Ula respectively for onward transmission to Emden and Teesside.

Oil, gas and water are separated on Ekofisk 2/4 J, with the hydrocarbons pressurised at the start of their journey to Emden and Teesside. On stream since 1998, the platform also has equipment for gas injection into the reservoir.

#### **Ekofisk 2/4 K**

This combined water injection, drilling and quarters platform stands three kilometres north of the Ekofisk centre and is linked by a bridge to the adjacent Ekofisk 2/4 B installation. With the quarters module providing 182 berths over six stories, Ekofisk 2/4 K became operational in 1987.

To boost pressure and improve production, water-flooding of the reservoir was initiated from the plat-



*Ekofisk 2/4 K and 2/4 B. Photo: ConocoPhillips*





*Ekofisk 2/4 J. Photo: Jan A Tjemsland/Norwegian Petroleum Museum*



*Ekofisk 2/4 M (left). Photo: Kjetil Alsvik/ConocoPhillips*

form in 1987 in order to replace the oil and gas as they are produced. Injection water is filtered and has chemicals added. Ekofisk 2/4 K has also supplied the 2/4 W platform with water since 1990 for pressure maintenance in the southern part of the reservoir. Ekofisk 2/4 K was later supplied with additional injection water from Eldfisk 2/7 E.

Operations on 2/4 B were run by the 2/4 K control room from 1995. The latter also took over remote monitoring of Edda 2/7 C and Albuskjell 1/6 A in May 1999. These installations then shut down and, rather than leaving them staffed until the wells were permanently plugged, a solution was introduced based on remote operation of such functions as emergency shutdown, fire and gas systems, ventilation, power supply and well status.

#### **Ekofisk 2/4 M**

This steel wellhead and processing platform was installed in the summer of 2005 south-east of Ekofisk 2/4 J and tied to the latter by a bridge. The installation was constructed as part of the Ekofisk Area Growth project, which aims to improve oil and gas recovery as well as increasing processing capacity and reliability at the Ekofisk centre.

In addition to 30 well slots, the platform has a high-pressure separator, equipment for handling produced water, and risers for use in future projects. It does not have its own drilling rig, and wells are drilled by a chartered jack-up. However, arrangements are made for coiled tubing operations.





*Ekofisk 2/4 P. Photo: Husmo Foto/Norwegian Petroleum Museum*

#### **Ekofisk 2/4 P**

Ekofisk 2/4 P pumped oil from the field through a 34-inch pipeline running for 350 kilometres to Teesside. Three turbine-driven centrifugal pumps provided a total capacity of one million barrels per day.

Oil from the Ekofisk area is very clean in terms of sediment and water content. Its wax content can nevertheless create problems for efficient flow through the pipeline. Ekofisk 2/4 P was accordingly equipped with a pig launcher as well as equipment for injecting chemical corrosion inhibitor. Warehousing was another important function of this platform, which held more than 5 500 spare parts in its central stockroom.

Installed in 1974, 2/4 P became operational in 1975. It was shut down in 1998, and the topside was removed in 2009.

#### **Ekofisk 2/4 Q**

This is a pure quarters platform with 68 berths in double cabins as well as a canteen, lounge and offices. Linked by bridges to 2/4 C and 2/4 FTP, it

was installed in March 1972 and the first residents moved in during 1973. The quarters module was replaced in 1981.



*Ekofisk 2/4 Q.  
Photo: Husmo Foto/Norwegian Petroleum Museum*



*Ekofisk 2/4 R. Photo: Husmo Foto/Norwegian Petroleum Museum*

### Ekofisk 2/4 R

This riser platform tied Cod, Albuskjell, West Ekofisk, Edda, Eldfisk, Ula, Gyda and Tor to the Ekofisk centre. It was also tied to the Statpipe system via a pipeline bridge to Ekofisk 2/4 S.

The processing facilities comprised a one-stage, two-phase gas/condensate separator for output from Tommeliten, Albuskjell, Gyda and Eldfisk. Oil was transferred directly to Ekofisk 2/4 T. Processed gas was returned from 2/4 T to 2/4 R, where it entered the pipeline to Emden. Ekofisk 2/4 R had pig traps for the incoming pipelines, and a pig launcher for the Emden line.

Installed in 1975, the platform became operations in 1977. It was shut down and the pipelines disconnected in 1998, and removed in 2009.

#### Pipelines tied into Ekofisk 2/4 R

- From Tor 2/4 E 12-inch oil
- From Tor 2/4 E 14-inch gas
- From Cod 7/11 A 16-inch oil/gas
- From Edda 2/7 C 10-inch oil
- From Edda 2/7 C 12-inch gas
- From Albuskjell 2/4 F 18-inch oil
- From Albuskjell 2/4 F 24-inch gas
- From Eldfisk 2/7 B 24-inch oil
- From Eldfisk 2/7 B 30-inch gas
- From West Ekofisk 2/4 D 24-inch oil/gas
- From Ula 20-inch oil
- From Gyda 12-inch gas
- From Ekofisk 2/4 S via bridge, gas
- To Norpipe B-11 36-inch gas



### Ekofisk 2/4 S

Ekofisk 2/4 S was a riser platform which tied the Statpipe line into the Ekofisk system.

The Statpipe transport system comprises 880 kilometres of pipelines, with two riser platforms and a terminal at Kårstø. Rich gas from fields in the northern North Sea (the Gullfaks, Statfjord and Oseberg areas) is piped to Kårstø, where the NGLs are removed and fractionated to commercial products for onward transport as liquefied ship cargoes. The dry gas was carried in a 28-inch pipeline via the Draupner S riser platform in block 16/11 and Ekofisk 2/4 S to tie into the Norpipe line to Emden. Statpipe now bypasses the Ekofisk platforms to tie directly into Norpipe.

Installed in 1984, Ekofisk 2/4 S became operational the following year. It was shut down in 1998 and its whole topside removed in 2001. The jacket and bridge foundation remain, and will be taken away later. Statoil was the owner of the platform.



*Ekofisk 2/4 S.*

*Photo: Husmo Foto/Norwegian Petroleum Museum*

### Ekofisk 2/4 T – the Ekofisk tank

Built in Stavanger in 1971-73 as a storage tank for oil when bad weather prevented offshore loading,



*Ekofisk 2/4 T. Photo: ConocoPhillips/Norwegian Petroleum Museum*



this was the first concrete structure on the NCS. It was installed on the field in the summer of 1973, and became operational the following year. Ekofisk 2/4 T was eventually linked by bridges with 2/4 R to the north, 2/4 G to the west and 2/4 P to the south.

After oil began to be exported by pipeline to Teesside in 1975, the tank lost its original storage role. It nevertheless continued to be used for intermediate storage of oil waiting to be piped to the UK, thereby allowing residual water to be removed.

A new deck was installed on the tank in 1977 to carry a large processing plant, making this structure the most important hub for oil/gas production and processing in the North Sea. The facility included systems for separating water, oil and gas, as well as equipment to dewater and compress the separated gas.

Completion of the processing plant on the tank was complicated by delays to finalising the NGL

terminal at Teesside. This meant that the system had to be modified so that NGLs produced with the dry gas and oil could be injected back into the reservoir with the aid of dedicated pumps on Ekofisk 2/4 C. That solution persisted until the spring of 1979, when the NGL could be received together with the oil at the UK terminal.

The plant on the tank almost doubled processing capacity for oil and gas at the Ekofisk centre. That also created a need for a second flare stack as a safety precaution, and this was positioned north of the tank.

Seabed subsidence on the field prompted the installation of an additional concrete breakwater around the tank in 1989.

Ekofisk 2/4 T was shut down in 1998 and the systems cleaned. The topside has now been removed, while the tank will be left in place.



*Ekofisk 2/4 T with breakwater. Photo: Husmo Foto/Norwegian Petroleum Museum*



### Ekofisk 2/4 W

Originally a bridge support, Ekofisk 2/4 W was converted to a water injection platform in 1989 and stands between the southern flare stack and Ekofisk 2/4 FTP. It was shut down in 2009.

The topside equipment comprised a riser and six water injection wells with wellheads.

Waterflooding was used to improve the recovery of oil and gas. Its function is to maintain pressure by replacing hydrocarbons in the reservoir as these are produced. The water used was carried in a dedicated flowline from Ekofisk 2/4 K, which maintains pressure in the northern part of the reservoir while 2/4 W does the same for the southern area. With the platform unstaffed, waterflooding was initially con-

trolled from 2/4 FTP and later by 2/4 K.

A leak was discovered in the flowline from the latter platform in 1993. It had been damaged by an anchor chain from Safe Lancia while this flotel was moored alongside Ekofisk 2/4 S. The damage was located and repaired.

The Big Orange VIII well stimulation vessel collided with 2/4 W in June 2009. This powerful impact caused extensive damage to both platform and wells, and operator ConocoPhillips is now removing the whole installation and permanently plugging the wells.

This means that the original removal plans for 2/4 W have been brought forward by the collision.



*Ekofisk 2/4 W. Photo: Husmo Foto/Norwegian Petroleum Museum*

**Ekofisk 2/4 X**

Ekofisk 2/4 X is a compact drilling and wellhead platform with 50 well slots. Oil and gas are piped to the other new platform in the Ekofisk II development – 2/4 J. Over time, the wells on 2/4 X are inten-

ded to replace those on the 2/4 A, 2/4 B and 2/4 C platforms. The installation has been built to cope with up to 20 metres of seabed subsidence.

Operational since 1996, Ekofisk 2/4 X is linked with the 2/4 C and 2/4 J platforms.



*Ekofisk 2/4 X. Photo: Jan A Tjemsland/Norwegian Petroleum Museum*



## Tor

Tor is an Ekofisk-area oil field located in about 70 metres of water 13 kilometres north-east of the Ekofisk centre. Its development was approved as part of the overall Ekofisk programme. The field was discovered as early as 1970 by Amoco, drilling in block 2/5. It was later found to extend into Ekofisk block 2/4, and licence interests were unitised on the basis of the estimated volume of hydrocarbons in each block (Phillips about 75 per cent and Amoco roughly 25 per cent).

### Reservoir and recovery strategy

The main Tor reservoir lies about 3 200 metres down and is built up from fractured chalk layers in the Tor formation of late Cretaceous age. Oil is also found in the early Palaeocene Ekofisk formation, but its production properties are poor.

Tor produced originally through pressure reduction, but limited waterflooding began in 1992. The injection facility was later upgraded and the waterflooding scope extended. All five production wells produce with gas lift.

### Transport

Production was carried in the early years to Ekofisk 2/4 R through two pipelines, but these were switched to Ekofisk 2/4 J in 1998. Gas from the Ekofisk area is piped to Emden, while the oil – which also contains the NGL fractions – goes to Teesside.



Tor 2/4 E. Photo: Kjetil Alsvik/ConocoPhillips

### Tor

Blocks	2/4 and 2/5
Production licences	006 and 018
Awarded	1965
Total recoverable reserves	154 mill bbl oil 11 bn scm gas 1.2 mill tonnes NGL
Remaining at 31 Dec 2008	10 mill bbl oil 0.2 bn scm gas
Discovery year	1970
Approved for development	4 May 1973
On stream	28 Jun 1978
Operator	ConocoPhillips
Licensees	
Total E&P Norge	48.20%
ConocoPhillips	30.66%
Statoil	6.64%
Petoro	3.69%
Eni Norge	0.82%

### Development solution

#### Tor 2/4 E

This platform, which came on stream in 1977, is a production, drilling and quarters structure which stands in 70 metres of water about 13 kilometres north-east of the Ekofisk centre. A separate flare stack is tied back to the platform by a bridge.

Tor 2/4 E has 15 producing wells. Output is separated in a three-phase production separator, the gas dewatered and the oil stabilised.

The quarters module originally provided 58 berths but was replaced in 1982 with a new unit with 96 berths in double cabins. In addition, a module containing a laundry and workshop was lifted on board. A new gas lift module was installed in 1989, making it possible to extend gas lift capacity from three to eight wells.

## Eldfisk

Eldfisk is an oil and gas field located in 70-75 metres of water in block 2/7, 16 kilometres south of Ekofisk. A waterflood programme for the field was approved in December 1997. Upgrading Eldfisk capacity received a green light in June 2003 as part of plans for Ekofisk Area Growth.

### Reservoir and recovery strategy

The Eldfisk field produces from chalk layers belonging to the Ekofisk, Tor and Hod formations of early Palaeocene and late Cretaceous age. Although fine-grained and tight, the reservoir rocks have high porosity. Natural fracturing allows their fluid content to flow more easily. Located at a depth of 2 700-2 900 metres, the field comprises three structures: Alpha, Bravo and East Eldfisk.

Eldfisk was originally developed with pressure reduction as the drive mechanism. Waterflooding began in 1999, based on horizontal injection wells. Gas was also injected at times when it could not be exported. Pressure reduction has caused the reservoir to compact and the seabed on Eldfisk to subside by several metres.

### Eldfisk

Block	2/7
Production licence	018
Awarded	1965
Total recoverable reserves	850 mill bbl oil 43.5 bn scm gas 4 mill tonnes NGL
Remaining at 31 Dec 2008	288.7 mill bbl oil 5.9 bn scm gas 0.4 mill tonnes NGL
Discovery year	1972
Approved for development	25 Apr 1975
On stream	8 Aug 1979
Operator	ConocoPhillips
Operations organisation	Stavanger
Main supply base	Tananger
<b>Licensees</b>	
Total E&P Norge	39.90%
ConocoPhillips	35.11%
Eni Norge	12.39%
Statoil	7.60%
Petoro	5.00%



The Eldfisk field centre. From left: the flare stack, Eldfisk 2/7 E, Eldfisk 2/7 FTP and Eldfisk 2/7 A. Photo: Kjetil Alsvik/ConocoPhillips





*Eldfisk 2/7 B. Photo: Kjetil Alsvik/ConocoPhillips*

### Transport

Oil and gas from Eldfisk and Embla were piped originally to Ekofisk 2/4 R, and have been sent to Ekofisk 2/4 J since 1998 for onward transmission in the export pipelines to Teesside and Emden.

### Development solution

Eldfisk comprises four platforms. Eldfisk 2/7 A, 2/7 FTP and 2/7E are linked by bridges, while Eldfisk 2/7 B stands a few kilometres from the others.

### Eldfisk 2/7 A

This combined production, drilling and quarters facility is linked by a bridge to Eldfisk 2/7 FTP. It operates as a wellhead platform with 30 producing wells. Two drilling rigs were installed for a time. Wellstreams are gathered in three flowlines and piped to 2/7 FTP for processing. Installed in 1975, the platform came on stream in 1979 at the same time as Eldfisk 2/7 B and 2/7 FTP.

Eldfisk 2/7 A was the first installation in the North Sea to be fitted with a Safedek helideck, built by Oil Industry Services in Kristiansand and placed on the new quarters module at Stord Verft.

When the quarters module was replaced in 1982, the Safe Concordia flotel provided accommodation.

The new quarters module provides 112 berths in double cabins and comprises six stories compared with four in the earlier structure.

### Eldfisk 2/7 B

A combined production, drilling and quarters platform, Eldfisk 2/7 B has its own flare stack and came on stream in 1979. It produces oil and gas from 19 wells. While oil is separated and stabilised, with the gas dewatered and compressed.



*Eldfisk 2/7 A. Photo: Husmo Foto/Norwegian Petroleum Museum*



*Eldfisk 2/7 E (foreground). Photo: Kjetil Alsvik/ConocoPhillips*

This platform receives oil and gas from Eldfisk 2/7 FTP and exports all production to Ekofisk. The pipelines initially went to Ekofisk 2/4 R, but were re-routed to Ekofisk 2/4 J in 1998.

A new quarters module with Safedek was installed in 1983.

#### **Eldfisk 2/7 E**

This treatment platform for injection water has a daily capacity of 670 000 barrels of treated water



*Eldfisk 2/7 FTP.*

*Photo: Husmo Foto/Norwegian Petroleum Museum*

as well as equipment for gas lift and injection. On stream since 2000, it is connected by a bridge to Eldfisk 2/7 FTP and operated from there.

About half the water is piped 25 kilometres to Ekofisk 2/4 K for injection in that reservoir at a pressure of almost 5 000 pounds per square inch (psi). This helps to boost oil production and retard subsidence. The water is thoroughly treated to eliminate bacteria which can form hydrogen sulphide and thereby acidify the oil and gas in the reservoir.

Eldfisk 2/7 E was the world's first offshore platform to use exhaust heat from gas turbines to generate electricity via a 10-megawatt facility. Together with conventional diesel generators on 27/A, electricity is supplied to Eldfisk 2/7 A, 2/7 FTP and 2/7 E as well as the unstaffed Embla platform.

#### **Eldfisk 2/7 FTP**

Processing production from Eldfisk 2/7 A and Embla 2/7 D, this platform is linked by bridges to Eldfisk 2/7 A and 2/7 E. Oil is piped via Eldfisk 2/7 B to Ekofisk, while the gas must first pass through compressors to increase its pressure and then be dewatered in a glycol plant before also being piped to Ekofisk. The platform became operational in 1979.



## Embla

Embla is an oil field located close to Eldfisk at the southern end of the NCS. It has been developed with the Embla 2/7 D wellhead platform, remotely operated from Eldfisk. The water depth in the area is 70-75 metres.

The field lies in the south of block 2/7, which was awarded to the Phillips group as early as 1965. Drilling began there in 1974 to depths of 4 500-5 000 metres, but pressure and temperature in the wells were too high to permit testing with the available equipment. The first production well was not drilled and tested until 1988, followed by a second in 1990. Both yielded very promising results, and the decision to develop Embla was taken in 1990. The field came on stream in 1993, with an amended PDO approved in April 1995.

### Reservoir and recovery strategy

Embla produces from a segmented sandstone reservoir of Devonian and Permian age – in other words, at least 250 million years old. The other fields in the Ekofisk area comprise fine-grained limestone or chalk deposited about 70 million years ago. Located more than 4 000 metres down, the reservoir has a temperature of 160°C compared with the 125°C normally found in the chalk formations 1 000 metres higher up, and the pressure differential is almost 100 per cent. Embla is the first high pressure/temperature field developed in the area.

The field is produced through pressure reduction.

### Transport

Oil and gas are piped to Eldfisk and on to the Ekofisk centre for export. Gas from the Ekofisk area travels to Emden while the oil, which also contains NGL fractions, goes to Teesside.

### Development solution

#### Embla 2/7 D

This unstaffed wellhead platform is remotely controlled. Installed in 1992, it came on stream in May 1993.

The platform has six production wells and an average daily output of roughly 7 000 barrels of oil. All processing and metering takes place on Eldfisk 2/7 FTP, which stands 5.2 kilometres further north. A 14-inch flowline links the two platforms. Produced in Scotland, this line was floated out to the field in

#### Embla

Block	2/7
Production licence	018
Awarded	1965
Total recoverable reserves	75.5 mill bbl oil 5.6 bn scm gas 0.6 mill tonnes NGL
Remaining at 31 Dec 2008	15 mill bbl oil 2.2 bn scm gas 0.2 mill tonnes NGL
Discovery year	1988
Approved for development	14 Dec 1990
On stream	12 May 1993
Operator	ConocoPhillips
Operations organisation	Stavanger
Main supply base	Tananger
Licensees	
Total E&P Norge	39.90%
ConocoPhillips	35.11%
Eni Norge	12.39%
Statoil	7.60%
Petoro	5.00%

one piece. Topside equipment includes the wellhead area, helideck, crane, control room, workshop, test separator and glycol pump.

Electricity supplies for Embla 2/7 D and communication with Eldfisk utilise a submarine umbilical incorporating a power line and fibreoptic cables for data and telecommunications.



Embla 2/7 D. Photo: Kjetil Alsvik/ConocoPhillips

## Cod

Cod is a gas and condensate field located in the south-west corner of block 7/11, 283 kilometres south-west of Stavanger and 75 north-west of Ekofisk. Block 7/11 lies on the boundary between the British and Norwegian North Sea sectors. Cod was found by the Phillips group in April 1968, before the discovery of Ekofisk. It came on stream in 1977 and ceased production during 1998.

### Reservoir and recovery strategy

The field was a combined stratigraphic-structural trap producing from deep marine turbidite sandstones of Tertiary Palaeocene age, at a depth of roughly 3 000 metres. Hydrodynamic studies identified a number of separate formations rather than a continuous reservoir. Production was based on natural pressure reduction.

### Transport

Since Cod ranked as the most distant of the six fields around the main Ekofisk development, the pipeline solution was an important element. While the other

satellite fields were provided with separate oil and gas pipelines – with the exception of West Ekofisk close to the central installations – an early choice was made to lay a single line from Cod. This two-phase-flow facility carried both oil and gas/condensate to Ekofisk 2/4 R. Mime and Ula were linked to Cod by pipelines measuring seven and 10 inches in diameter respectively.

### Development solution

Cod 7/11 A was a combined production, drilling and quarters unit standing in 75 metres of water. Installed in 1975, it came on stream two years later. The drilling rig with its equipment was removed in October 1997 and the platform ceased production and was abandoned in 1998. In addition to cleaning the process plant, the wells were plugged and secured. The platform is due to be removed by 2013.

A separate flare stack is linked to 7/11 A by a bridge. Nine producers were drilled beneath the platform. The quarters module provided 52 berths.



Cod 7/11 A. Photo: Husmo Foto/Norwegian Petroleum Museum



# Mime

This is a small oil field about seven kilometres north-east of Cod in block 7/11, produced through a subsea Xmas tree controlled from the Cod platform. The wellstream was piped to the latter installation for metering and processing before being transported to the Ekofisk centre. During its 10 months on stream, Mime produced 2.46 million barrels of oil and 81 million scm of gas. The field ceased production on 4 November 1993 after asphaltenes blocked the production tubing in the well.

<b>Mime</b>	
Block	7/11
Production licence	070
Awarded	1981
Recoverable reserves	4.2 mill bbl oil 166 mill scm gas
Discovery year	1982
On stream	1 Jan 1993
Ceased production	4 Nov 1993
Operator	Norsk Hydro
<b>Licensees</b>	
SDFI	41.3%
Norsk Hydro Produksjon	25.5%
Statoil	19.6%
Saga Petroleum	9.8%
Amoco Norway	7.35%
Norske Conoco	7.35%



Mime subsea production tree. Illustration: Oceaneering

## Albuskjell

This oil and gas/condensate field lay 21 kilometres north-west of the Ekofisk centre and extended across blocks 1/6 and 2/4, licensed to Shell and the Phillips group respectively. Albuskjell was later unitised on a 50-50 basis with Phillips as the operator, came on stream in 1979 and ceased production during 1998. By the latter year, the field had produced 46.25 million barrels of oil, 15.53 billion scm of gas and almost a million tonnes of NGL.

### Reservoir and recovery strategy

The producing formation in Albuskjell comprised limestone with some thin shale. This structure formed 22-55 million years ago over a salt dome. Production was based on natural pressure reduction.

### Transport

Fra An 18-inch gas pipeline and a 24-inch oil line ran from Albuskjell to Ekofisk 2/4 R.

### Development solution

Albuskjell was developed with twin platforms, 1/6 A and 2/4 F. These were designed a little differently from the other Ekofisk-area installations, with waterfilled module support frames intended to help prevent heat propagation in the event of fire.

### Albuskjell 1/6 A

Installed in 70 metres of water during 1976, Albuskjell 1/6 A came on stream in 1979. It was originally designed as a combined production, drilling



Albuskjell 1/6 A. Photo: Husmo Foto/Norwegian Petroleum Museum





*Albuskjell 2/4 F. Photo: Husmo Foto/Norwegian Petroleum Museum*

and quarters platform, but the derrick and drilling equipment were removed as early as 1979.

Albuskjell 1/6 A produced from 11 wells and was tied back by gas and oil pipelines to Ekofisk 2/4 R via Albuskjell 2/4 F. A separate flare stack was linked to the platform by a bridge. The processing plant comprised an oil/gas separator. Gas was dewatered and compressed before export in a 24-inch pipeline. The separated oil was exported through an 18-inch line. Before being piped away, the oil and gas passed through a fiscal metering station to measure the volumes produced.

This platform was the first in the Ekofisk area with a Norwegian-built jacket, fabricated by Aker under the first order of its kind placed with a domestic yard.

The quarters module with helideck was replaced in 1983 to increase berths from 46 to 96. Production ceased in 1998, and the platform became unstaffed in 1999 with remote monitoring from Ekofisk 2/4 K. The processing plant has been cleaned and the wells plugged and secured, and the platform is due to be removed by 2013.

#### **Albuskjell 2/4 F**

This installation is very similar to Albuskjell 1/6 A, and was a combined production, drilling and quarters structure in block 2/4. It stands in 71 metres of water, 13 kilometres west of the Ekofisk centre and eight from Albuskjell 1/6 A. Installed in 1977, it came on stream in July 1979. A separate flare stack was linked to the platform by a bridge. Producing from 11 wells, the platform's processing facilities comprised a three-phase separator for gas, oil and water, a test separator, a glycol gas dewatering unit with glycol recovery, a filter for produced condensate and a fiscal metering station for oil and gas. Hydrocarbons arriving from Albuskjell 1/6 A were blended with 2/4 F's production and exported to Ekofisk 2/4 R via an 18-inch oil pipeline and a 24-inch gas line.

The quarters module was replaced in 1983 with a new unit built by Offshore Industry Services in Kristiansand to provide 96 berths. The old module was donated to the Trondheim Maritime College at Lade. Production ceased in 1990, with the drilling rig and modules removed in 1997. The processing plant was cleaned, the wells plugged and secured, and the platform is due to be removed by 2013.

## West Ekofisk

This oil and gas field lay 4.5 kilometres west of Ekofisk and was on stream from 1977 to 1998, producing 76.4 million barrels of oil, 25.97 billion scm of gas and 1.43 million tonnes of NGL.

### Reservoir and recovery strategy

West Ekofisk was discovered in 1970 with the 2/4-5X exploration well. Testing of this well, the only explorer drilled on the field, yielded commercial volumes of gas and condensate in two zones. West Ekofisk was a small circular field created by a salt structure which had thrust up the reservoir rocks. Production was through natural pressure reduction.

### Transport

A 24-inch multiphase flow pipeline carried oil and gas from West Ekofisk to Ekofisk 2/4 R.

### Development solution

#### West Ekofisk 2/4 D

West Ekofisk was developed with a combined steel

production, drilling and quarters platform which took almost four years to complete. The jacket was installed in October 1973, but permanent production did not begin until late 1977. A significant cause of this delay was a fire in the Ekofisk 2/4 A riser in 1975, which meant that West Ekofisk had to be used for a long time as an accommodation platform for personnel doing the repairs on 2/4 A.

The platform functioned primarily as a wellhead structure with 15 producing wells, but also carried a test separator and metering equipment for oil, gas and water. It was tied back to Ekofisk 2/4 R by a 24-inch pipeline carrying both oil and gas. A new quarters module installed in 1983 provided 96 berths in double cabins. From 1994, West Ekofisk 2/4 D was remotely operated from the control room on Ekofisk 2/4 T (the tank). The drilling rig and associated equipment was removed in 1997 and production ceased the following year. The processing plant was cleaned, the wells plugged and secured, and the platform is due for removal by 2013.



West Ekofisk 2/4 D. Photo: Husmo Foto/Norwegian Petroleum Museum



## Edda

This oil and gas field lay 12 kilometres south-west of Ekofisk in 71 metres of water. The exploration wells were drilled from Ocean Viking and Zapata Nordic in 1972 and 1973. On stream from 1979 to 1998, Edda produced 30.3 million barrels of oil, 1.97 scm of gas and 21 000 tonnes of NGL.

### Reservoir and recovery strategy

The reservoir, of early Palaeocene and late Cretaceous age, was produced through natural pressure reduction.

### Transport

Oil and gas were piped to Ekofisk 2/4 R in two separate pipelines.

### Development solution

#### Edda 2/7 C

Installed on the field in 1976, this platform came on stream in 1979. Edda 2/7 C was originally designed as a combined production, drilling and quarters plat-

form with a separate flare stack and two submarine pipelines to Ekofisk 2/4 R. However, the drilling rig was transferred in 1987 to Ekofisk 2/4 K and a new process module was installed to handle production from Tommeliten 11.8 kilometres to the west.

Although the platform had 15 well slots, only 10 of these were used. Its processing facilities comprised an oil/gas separator. The gas was compressed to boost its pressure and then dewatered before being piped through a 12-inch line to Ekofisk 2/4 R at the Ekofisk centre. After separation, the oil was pumped through a 10-inch line to 2/4 R. Before entering their respective pipelines, the oil and gas passed through a fiscal metering station which measured the volumes produced.

Production ceased in 1998, with the platform abandoned the following year and remotely monitored from Ekofisk 2/4 K. Such monitoring included emergency shutdown, fire and gas systems, ventilation, power supply and well status. The processing plant has been cleaned, the wells plugged and secured, and Edda 2/7 C is due for removal by 2013.



Edda 2/7 C. Photo: Husmo Foto/Norwegian Petroleum Museum

## Tommeliten

This gas and condensate field lies 11.8 kilometres west of Edda in the Ekofisk area, and comprises the Gamma and Alpha deposits. The first of these lies in block 1/9 and was discovered by Ross Rig when drilling for Statoil. Production licence 044 was awarded in 1976. Statoil's first discovery as an independent exploration operator, Tommeliten Gamma was approved for development on 12 January 1986. The Phillips group took over the licence after Statoil terminated production in 1998.

The 1/9-1 Tommeliten Alpha discovery has not yet been brought on stream, but operator ConocoPhillips is considering a development.

### Reservoir and recovery strategy

The field contains gas and condensate in chalk layers about 3 500 metres deep. Production was based on natural pressure reduction.

#### Tommeliten

Block	1/9
Production licence	044
Awarded	1976
Total recoverable reserves	
Gamma	24.5 mill bbl oil 9.7 bn scm gas 0.5 mill tonnes NGL
Alpha	64.8 mill bbl oil 16.9 bn scm gas 0.3 mill tonnes NGL
Approved for development	12 June 1986
On stream Gamma	3 Oct 1988
Ceased production Gamma	5 Aug 1998
Operator (1976-2003)	Statoil
Operator (2003-)	ConocoPhillips
Licensees (1998)	
Statoil	70.84%
Fina	20.23%
Norsk Agip	9.13%
Licensees (2008)	
ConocoPhillips	41.88%
Statoil	30.00%
Total E&P Norge	15.00%
Eni Norge	13.12%



*The Tommeliten production separator on Edda 2/7 C.  
Photo: Kjetil Alsvik/ConocoPhillips*

### Transport

Gas and condensate were carried 11.7 kilometres in a nine-inch pipeline to the Edda 2/7 C platform.

### Development solution

Tommeliten Gamma was developed with a subsea production system in 83 metres of water. A template producing from a total of six wells represented the very first remotely operated subsea installation brought on stream by Statoil. This structure was large by comparison with later facilities – 42.5 metres long by 27 wide and 11 high, weighing 1 000 tonnes. The wellstream was piped to Edda 2/7 C for processing. Tommeliten was too small to justify a separate platform, and the Edda installation had spare space and capacity. The Tommeliten wells were operated from a dedicated control room on Edda 2/7 C.

Processing facilities for Tommeliten production were similar to the existing plant on Edda 2/7 C, but smaller. Output from both Tommeliten and Edda was carried in the same pipelines – one each for oil and gas – from 2/7 C to Ekofisk 2/4 R.

The seabed template on Gamma was taken to Stavanger in 2001 and scrapped, while the Xmas trees from the six wells were overhauled for further use on Glitne.