Subsea processing and transportation of hydrocarbons

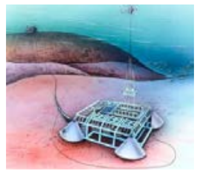
Pål Hedne, Statoil

Subsea Technology Steps

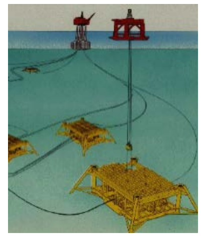
Multiphase Flow

1980
Start OLGA development

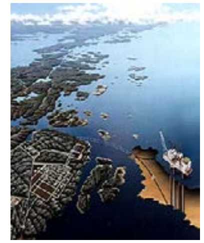
1987
Gullfaks
First subsea short oil wellstream transfer



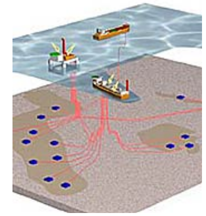
1991
TOGI
Medium range gas condensate wellstream transfer



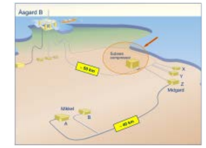
1995
Statfjord sat
Medium range oil wellstream transfer



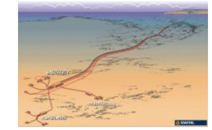
1996
Troll
Long range subsea to shore gas condensate transfer



1999
Åsgard
Complex subsea development; advanced flowline concepts



2003
Mikkel
Long range subsea to subsea



2007
Ormen Lange / Snøhvit
Long range subsea to shore in deep / in "arctic"

1986
Start Poseidon multiphase pump development

1996
Gullfaks
First multiphase pumps (topsides, part of Framo commercialisation)

1997
Lufeng
Subsea pumps

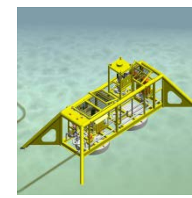
2000
Troll
Subsea water removal and injection

2003
Norne
Technology program Subsea separation concept developments

2005
Troll
Pipe separator Qualifications Subsea water removal

2007
Tordis
Subsea water removal & injection, oil & gas boosting

2009
Tyrihans
Subsea raw seawater injection (operation 2011)

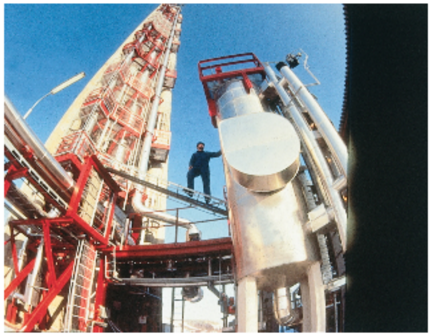


Subsea Processing

Multiphase Flow and Subsea Processing

Publisert 19. juni 2013

Flerfaseteknologien har gjort det mulig å bygge ut flere og mindre felt enn det ellers ville vært mulig.



Fagjuryen valgte flerfaseteknologien som den beste norske oppfinnelsen siden 1980. Teknologien ble utviklet av IFE og SINTEF i Trondheim og har hatt en enorm betydning for den norske oljebransjen og dermed for Norges økonomiske utvikling. Jon Harald Kaspersen er i dag forskningssjef på SINTEF Petroleumsforskning AS og svært fornøyd med juryens beslutning.

Åsgard subsea gas compression receives ONS innovation award

Gas compression is one of the most important measures Statoil employs to deliver volumes from existing fields on the Norwegian shelf. ONS is awarding the prize to Statoil and Aker Solutions, who together nominated Åsgard subsea gas compression.

Norwegian petroleum and energy minister Ola Borten Moe (left) presented the award to Statoil Åsgard subsea gas compression project manager Torstein Vinterstø and Aker Solutions subsea processing head Knut Nyborg (right).

Laboratoriet på Tiller utenfor Trondheim skal utvides fra et tofaseanlegg, til et trefaset testanlegg som kan transportere olje, gass og vann. Foto: SINTEF

FLERFASETEKNOLOGI

«Norges viktigste oppfinnelse» kan bli viktigere

Forskningsrådet deler ut penger til flerfaseteknologi, elbiler og smartnett.

Av Lars Taraldsen (@LarsTaraldsen)

Publisert 30. oktober 2013 kl. 10:40

Forskningsrådet deler i dag ut en halv milliard kroner til moderne forskningsinfrastruktur i form av laboratorier, databaser og utstyr.

Dette melder Forskningsrådet i dag.

Både oljeindustrien, marine næringer og teknologibransjen vil dermed få tilgang på topp moderne forskningsutstyr, heter det.

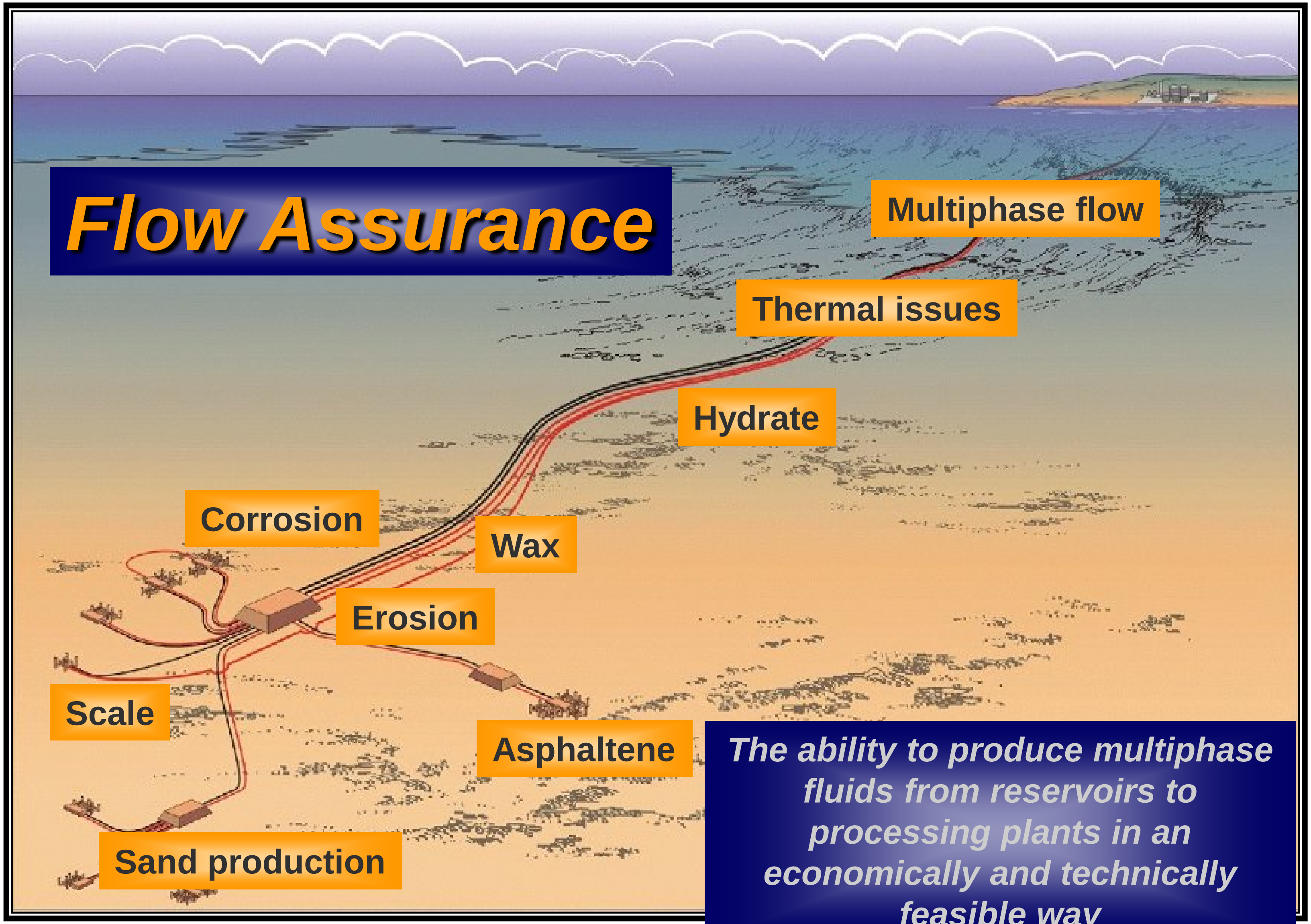
Klar: Åsgard subsea gasskompressor er nå klar til avseiling. Foto: Øyvind Hagen/Statoil

ÅSGÅRD HAVBUNNSKOMPRESJON

Årets ingeniørbragd er klar for havbunnen

Kompressorstasjonen til Åsgard skal seiles ut fra Aker Solutions' verft i Egersun neste uke.

The Flow Assurance Challenge



The ability to produce multiphase fluids from reservoirs to processing plants in an economically and technically feasible way

Long Distance Well Stream Transfer

State of the art Gas-Condensate Systems

1991
TOGI
48 km
platform to
subsea
injection

1996
Troll
67 km
platform to
shore

1999
Midgard
54 km
subsea to
platform

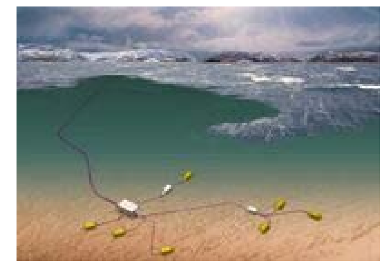
2002
Huldra
150 km
platform to
platform

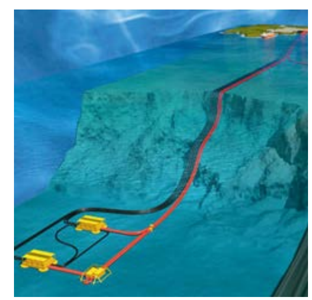
2003
Mikkel
75 km
subsea to
platform

2004
Kvitebjørn
140 km
platform to
shore

2007
Ormen Lange
120 km subsea
to shore

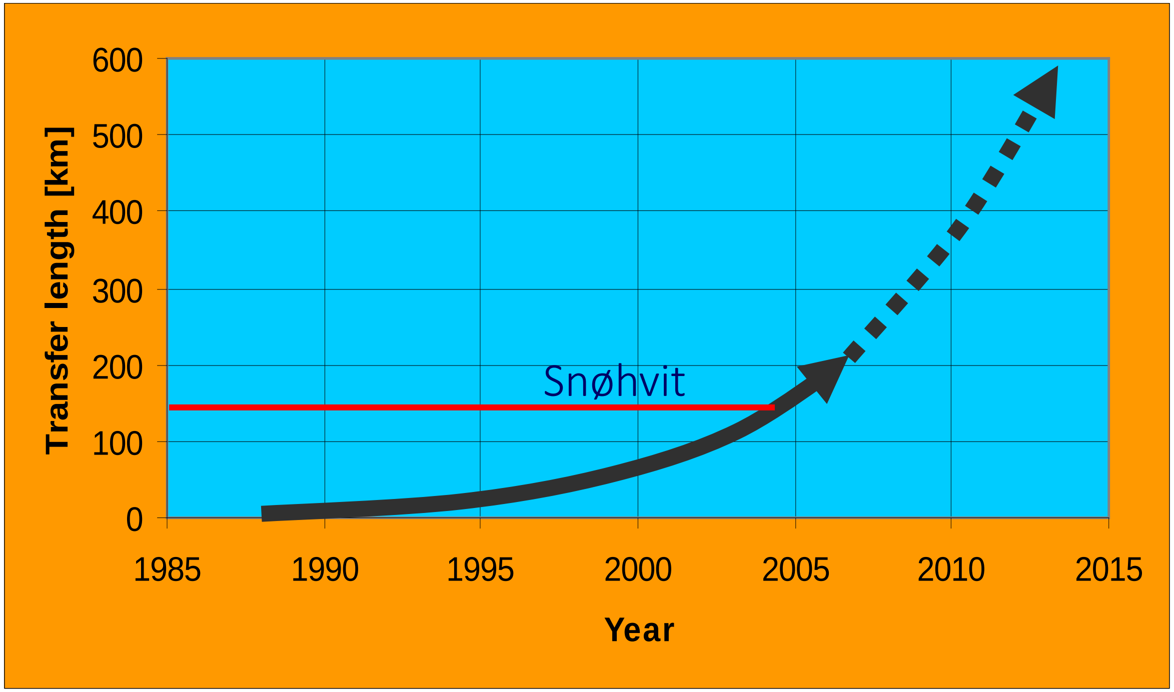
2007
Snøhvit
140 km subsea
to shore





Multiphase Gas-Condensate Systems

Well Stream Transfer Length



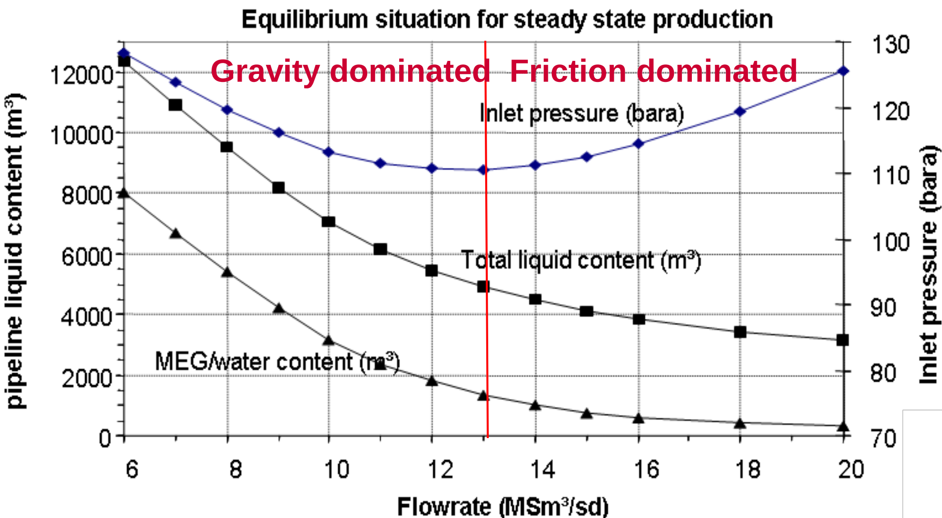
Issues

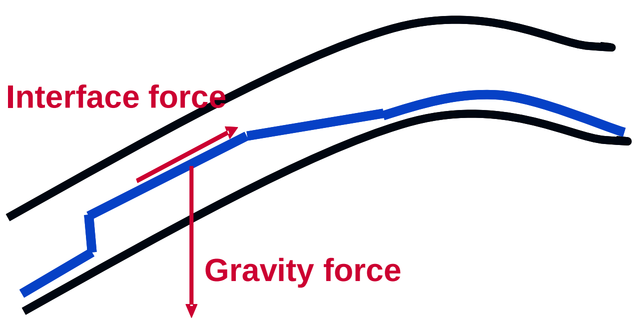
- Gas compression
- Power supply
- Hydrate remediation
- Remote control

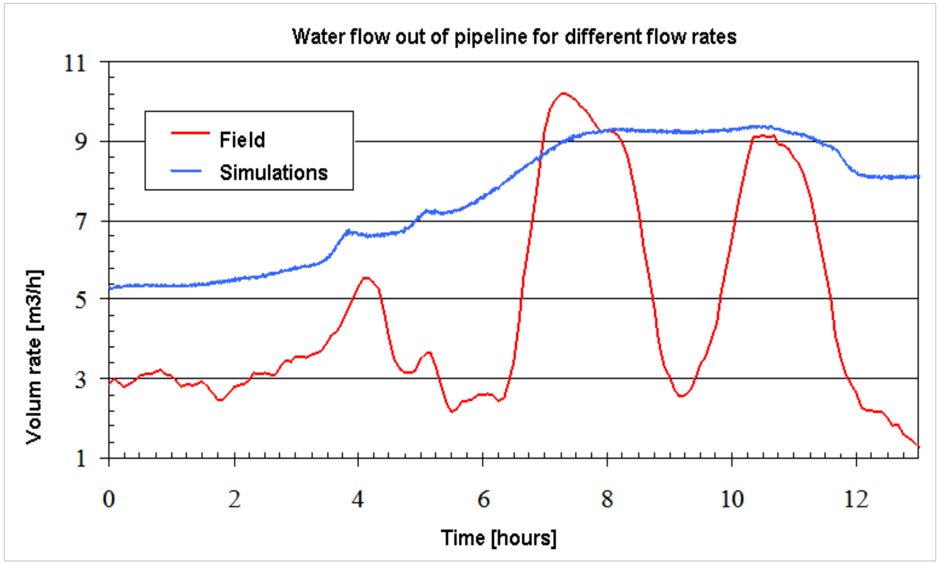
Can in principle be stretched very long

Multiphase Gas-Condensate Systems

Modelling Challenges







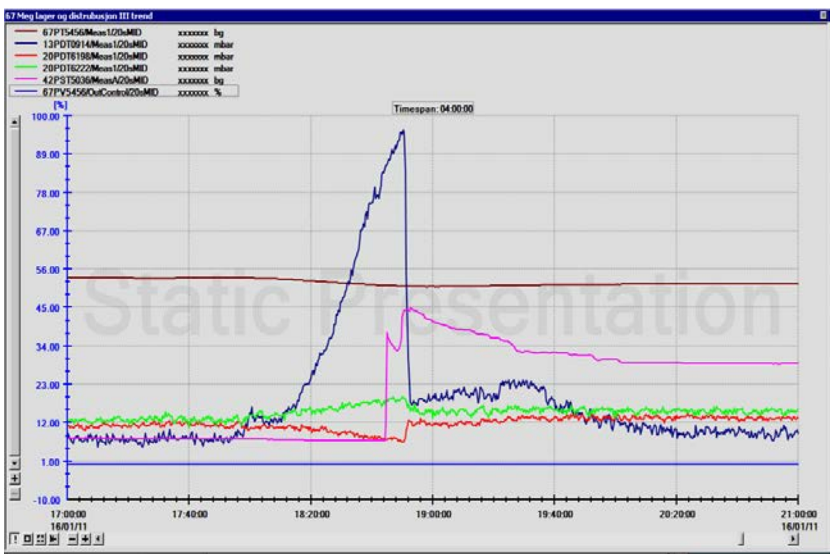
GIFF=Gravity-Interface Friction Force factor

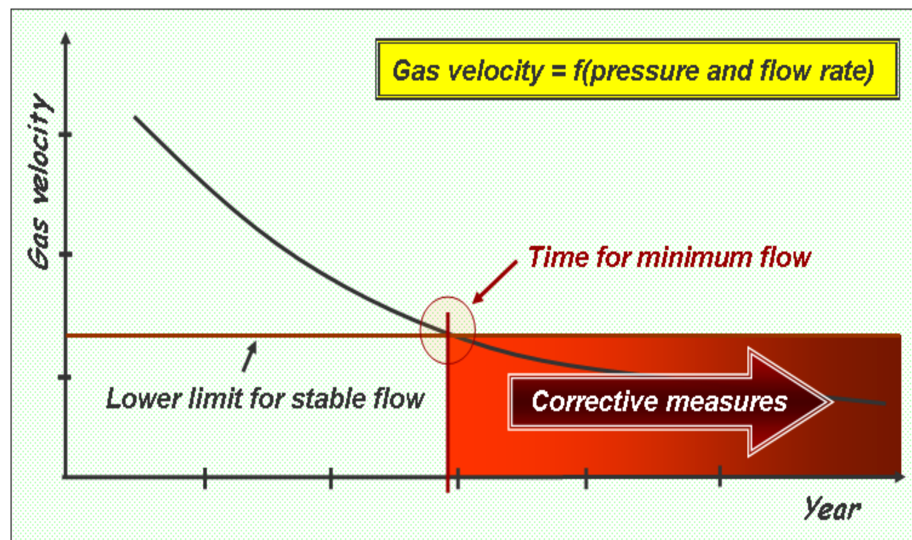
Minimum Flow Challenge

Surge Wave Instabilities

A minimum gas rate is required to:

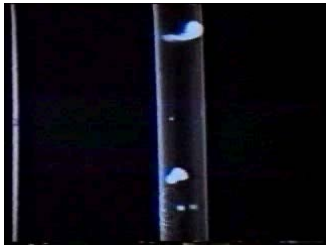
- Avoid dynamical instabilities in flow lines
- Ensure surge waves not exceed liquid handling capacity
- Maintain continuous MEG production
- Avoid hydrate incidents





Multiphase Gas-Condensate Systems

Fluid Challenges



Hydrates

- Low water production
- Fully inhibited system
- Depressurisation

Corrosion

- Chemical inhibition
- pH stabilized MEG

Scale

- Chemical inhibition

Concept:

- Bare carbon steel pipe lines
- Fluid temperature at ambient sea temperature
- Inspection pigging, only

Broad operational experience

Long Distance Well Stream Transfer

State of the art multiphase oil systems

1986
Gullfaks
First subsea short oil wellstream transfer

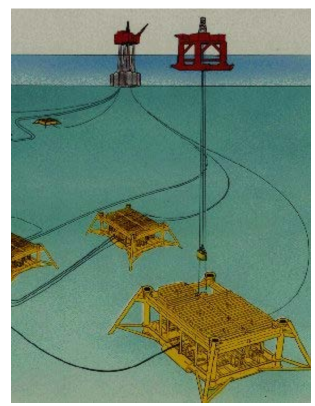
1995
Troll
Subsea to platform

1998
Gullfaks sat.
Subsea to platform maks 15 km

1994-2000
Statfjord sat.
Subsea to platform maks 21 km

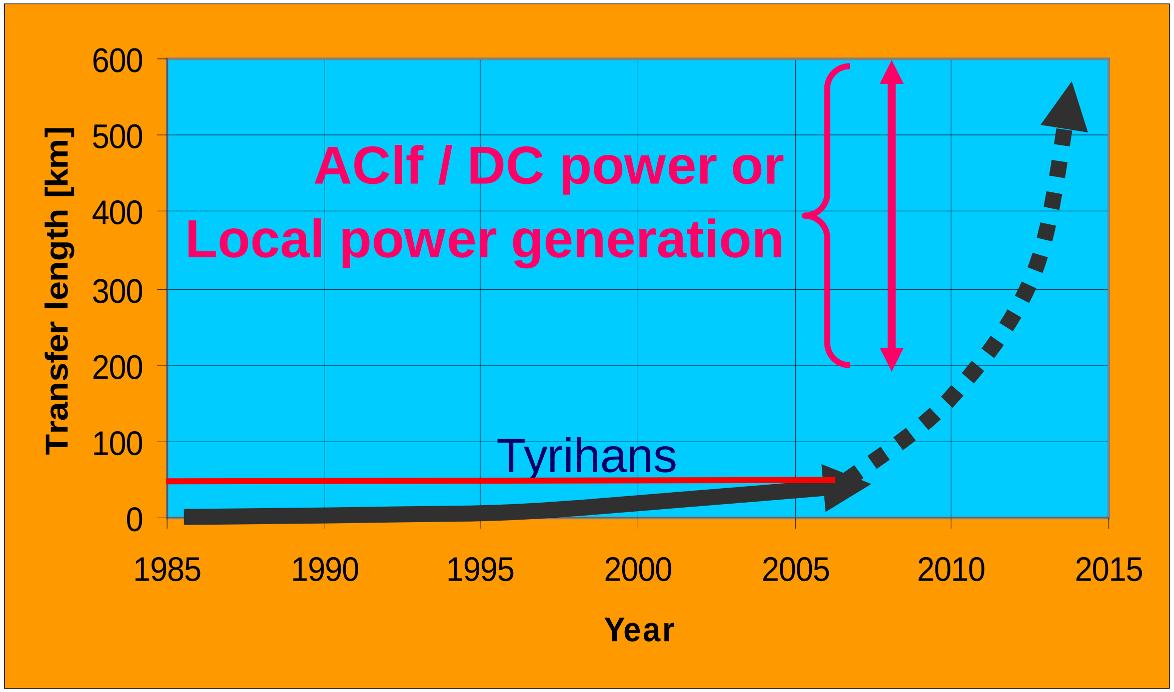
1999
Åsgard
Subsea to platform, maks 12 km

2009
Tyrihans
Subsea to platform 43 km



Multiphase Oil Systems

Well Stream Transfer Length



Issues

- Fluid conditioning
- Complex fluid flow
- Pumping
- Power supply
- Remote control

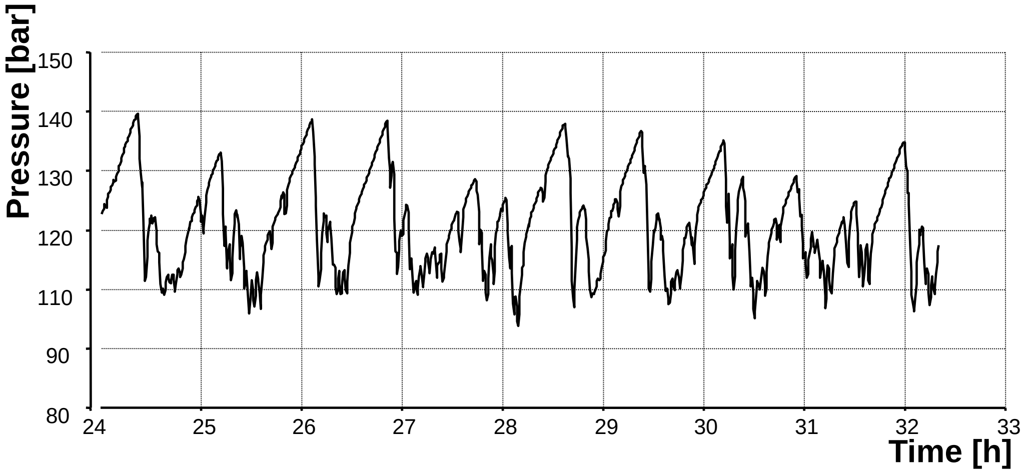
Existing technology can be stretched to ~ 200 km

Comprehensive step out to extend >> 200 km

Multiphase Oil Systems

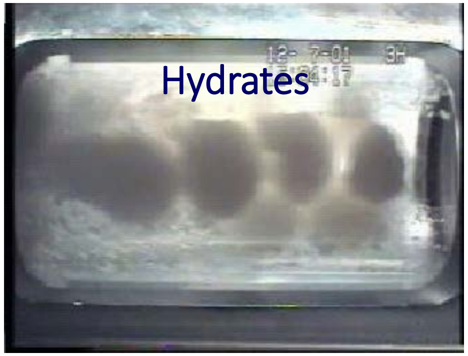
Modelling Challenges

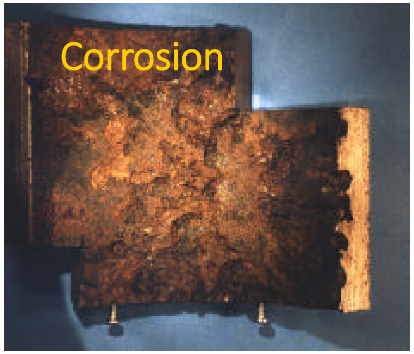
Dynamic Behaviour

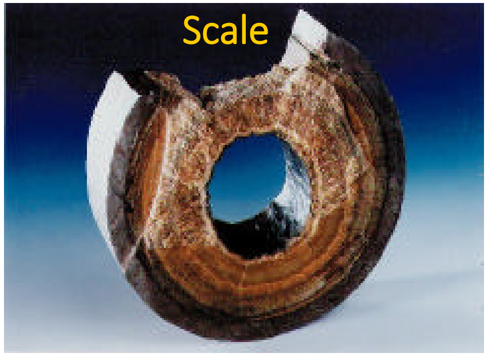


Multiphase Oil Systems

Fluid challenges







Temperature!

Emulsion

Multiphase Oil Systems
Traditional Pipeline Transportation Mode

Concept include:

- Insulated/heated pipelines
- Fluid temperature above hydrate appearance temperature
- Injection of hydrate inhibitor during shut-down
- Wax control by regular loop pigging
- Current design < 50 km

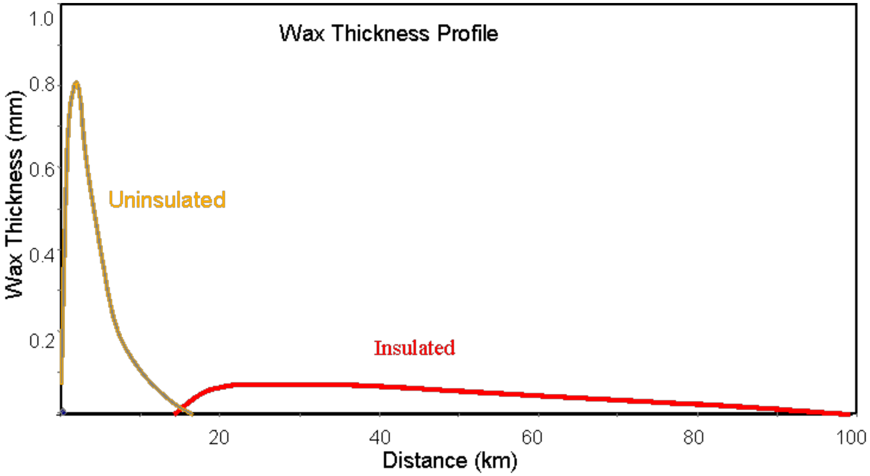
Future applications:

- Possible extension to 150-200 km
- Direct electrical heating (DEH)
- Subsea separation and boosting

Multiphase Oil Systems
Cold Flow Pipeline Transportation Mode

Concept:

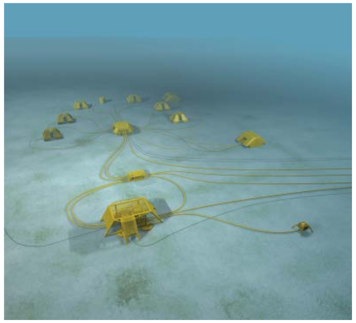
- Bare carbon steel pipe lines
- Fluid temperature at ambient sea temperature
- Hydrate control
- Wax control
- Subsea pig launching
- No operational experience

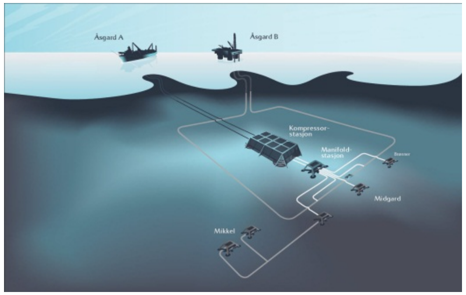


Future applications:

- Can in principle be stretched very long
- Includes comprehensive subsea processing

Subsea Processing

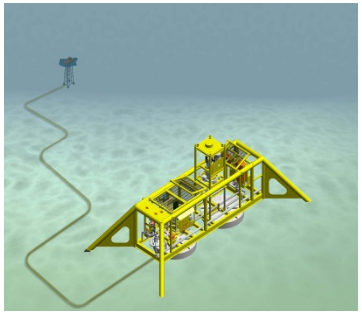




Lufeng: 1997
Subsea pump
5 x 0,4 MW
1 km

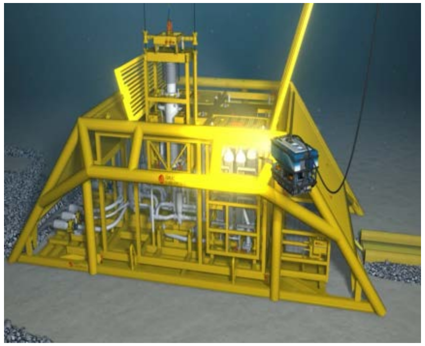
Troll: 2001
Subsea sep.
1 x 1,6 MW
4 km

Tordis: 2007
Subsea sep.
Sand handling
2 x 2,5 MW
12 km



Tyrihans: 2009
Subsea raw seawater injection
2 x 2,5 MW
43 km

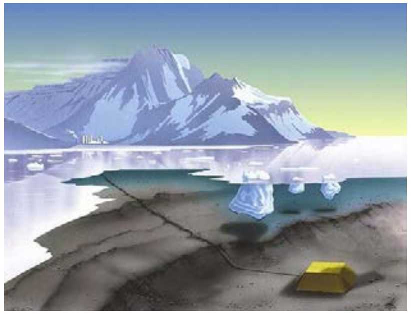
Åsgard: 2015
Subsea compression
2x11,5 MW
50 km



Gullfaks: 2015
Subsea compression
2x5 MW
17 km

Snøhvit: 2017-2020 ?
Subsea compression
140 km

Arctic: 2020+ ?
Subsea processing
Large step-out, large duty



Subsea Processing

Status World Wide

Boosting and injection

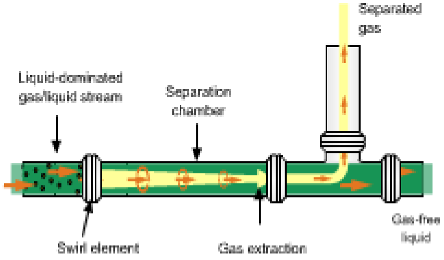
- ~70 pumps worldwide installed
- Typically 0.4-1.8 MW (SPP and MPP)
- 2.5 MW at Tordis 2007 and Tyrihans 2009
- MPP ΔP=30-40 bar, Q ~ 1500 m3/h

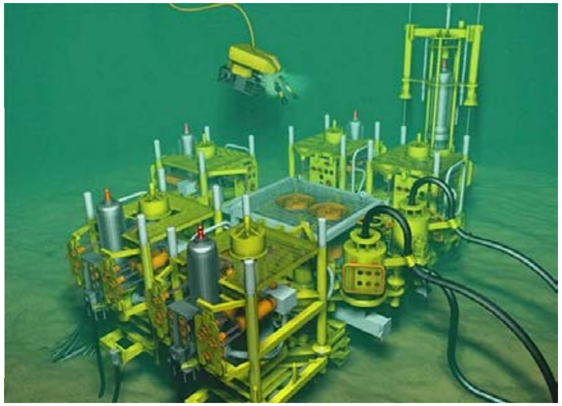
Compression

- World's two first being installed now
- Åsgard 2015, 2 x 11.5 MW
- Gullfaks 2015, 2 x 5 MW

Separation

- Water/oil, Troll Pilot 2001
- Water/oil/sand, Tordis 2007
- Pazflor 2010
- No compact equipment installed subsea





Lufeng

Statoil's First Subsea Processing Application

- Lufeng 22-1 in operation 1997-2009
- 5 horizontal production wells
- 5 subsea booster pumps
- A small field development with cost effective development solution

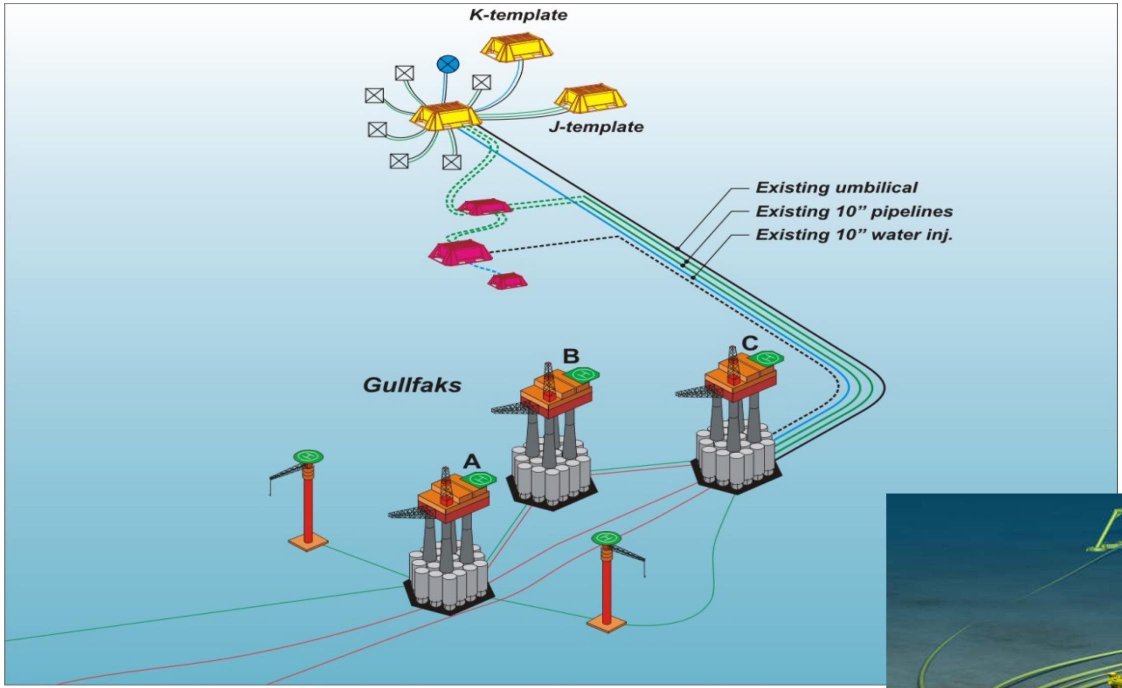
Key data:

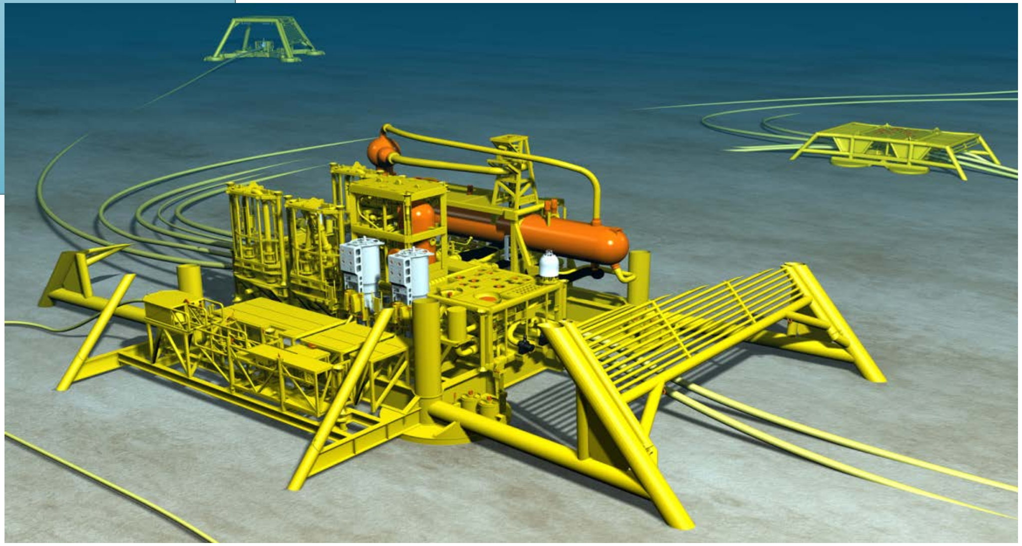
- Multipurpose shuttle tanker
- 333 m water depth
- 9000 bbl per day
- 75% Statoil / 25% NOOC

7 years operation of subsea pumps without intervention

Tordis SSBI

Subsea Separation, Boosting, and Injection





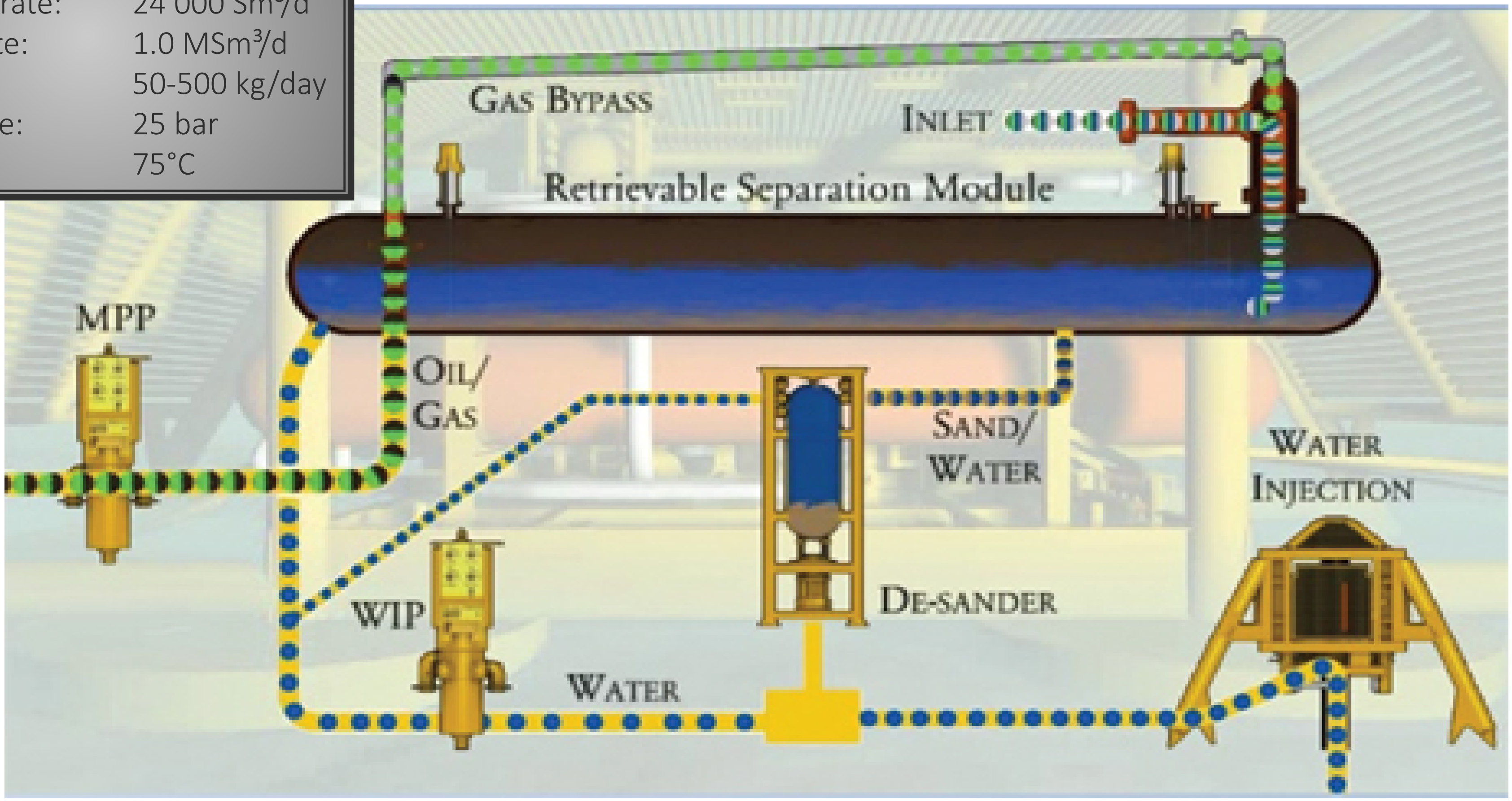
Features:

- Bulk water separation
- Multiphase boosting
- Water and sand injection

Tordis SSBI
Process Flow Diagram

Key data:

Oil flow rate:	10000 Sm^3/d
Water flow rate:	24 000 Sm^3/d
Gas flow rate:	1.0 MSm^3/d
Sand rate:	50-500 kg/day
Op. pressure:	25 bar
Op. temp.:	75°C

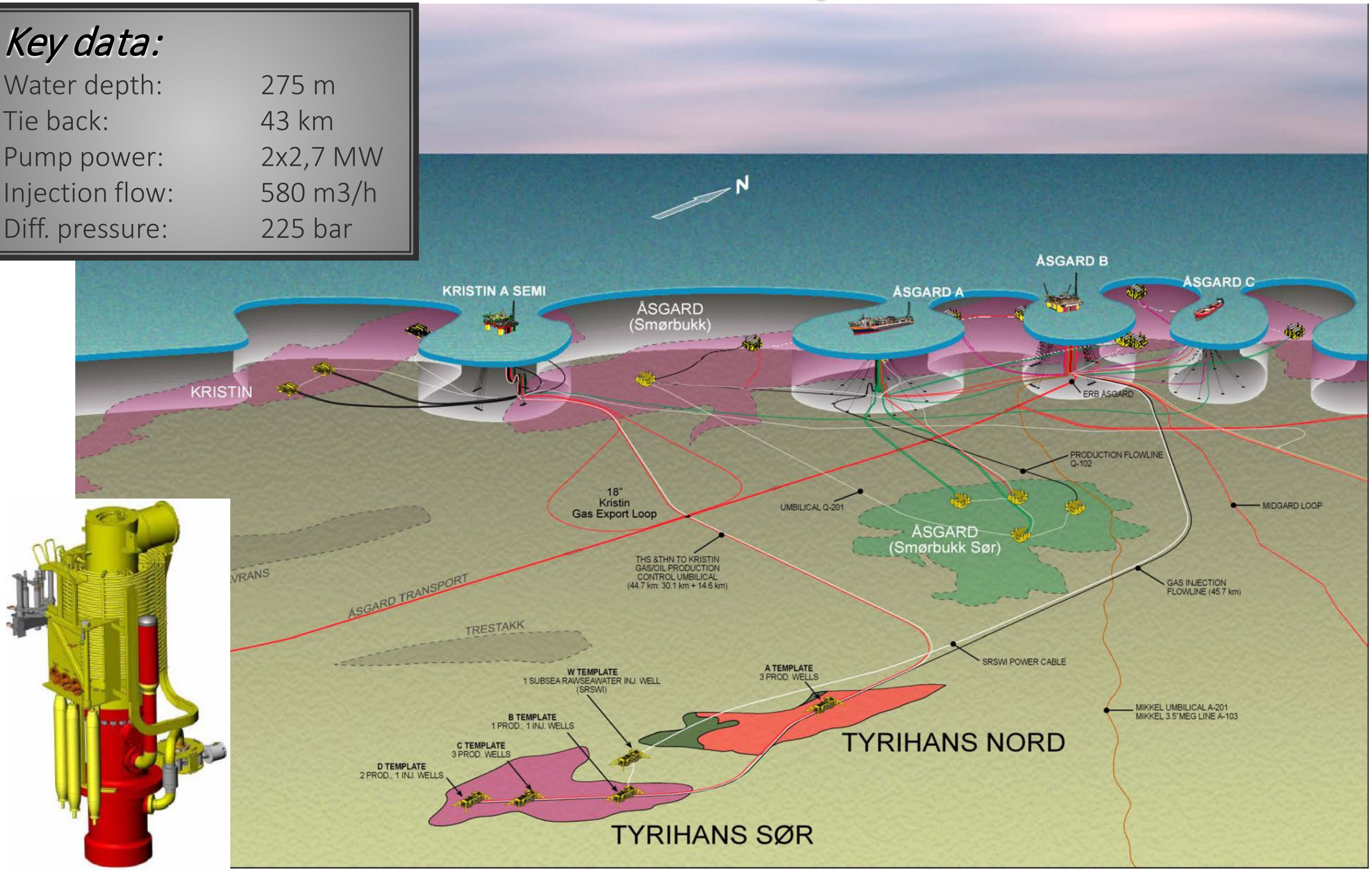


Tyrihans

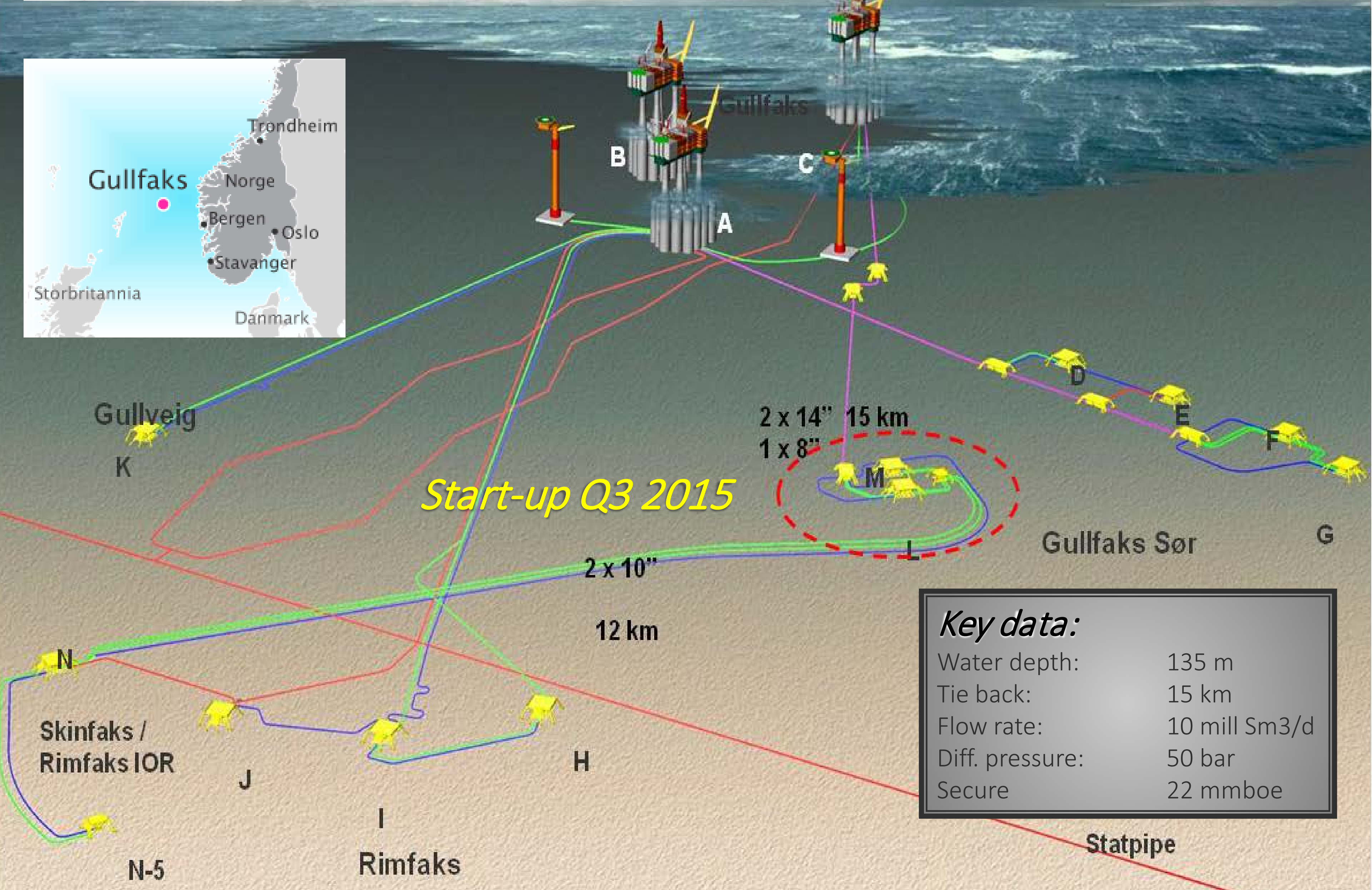
Raw Seawater Injection

Key data:

Water depth:	275 m
Tie back:	43 km
Pump power:	2x2,7 MW
Injection flow:	580 m3/h
Diff. pressure:	225 bar



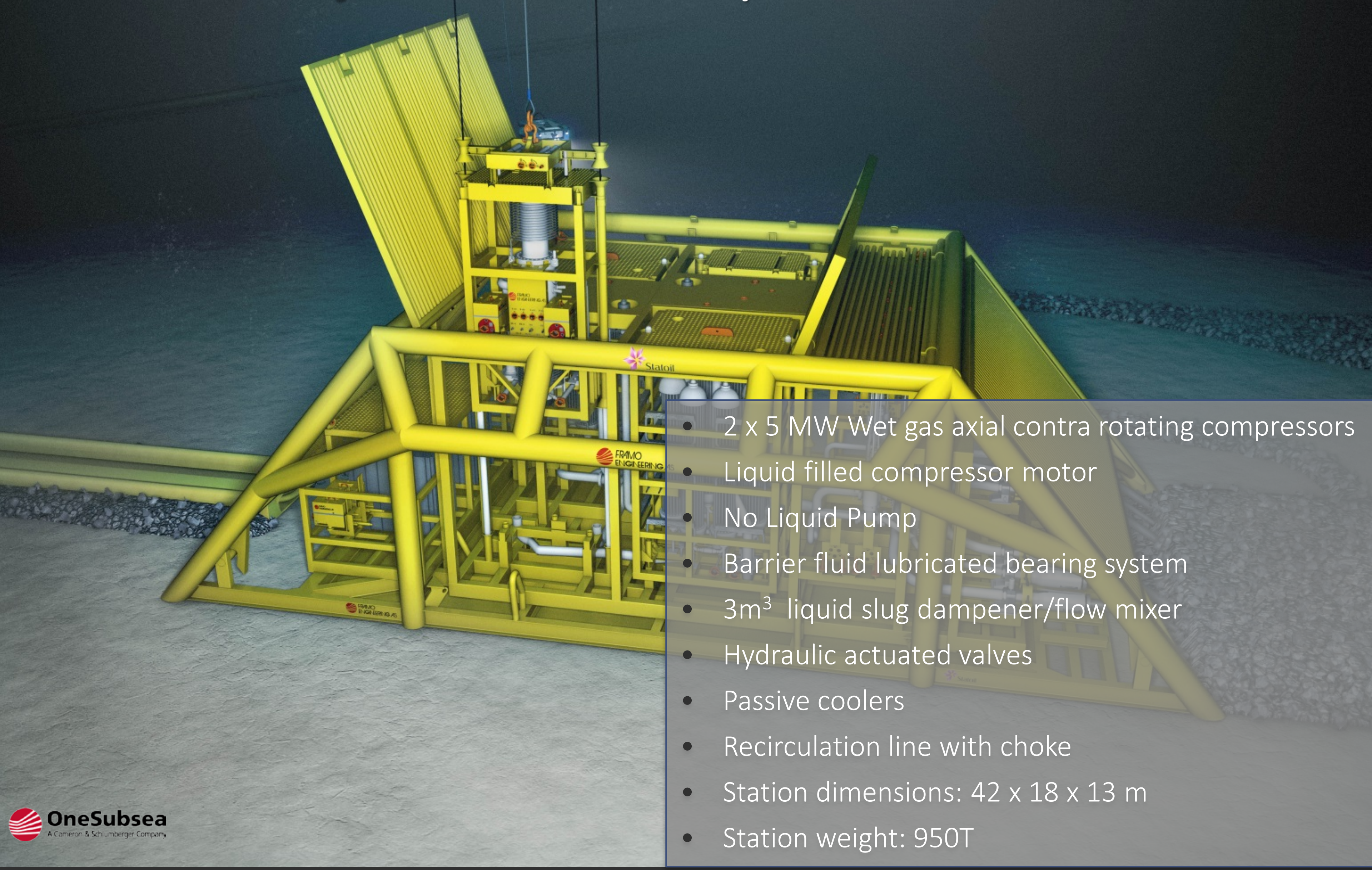
Gullfaks Subsea Compression



Key data:

Water depth:	135 m
Tie back:	15 km
Flow rate:	10 mill Sm3/d
Diff. pressure:	50 bar
Secure	22 mmboe

Gullfaks Subsea Compression Station

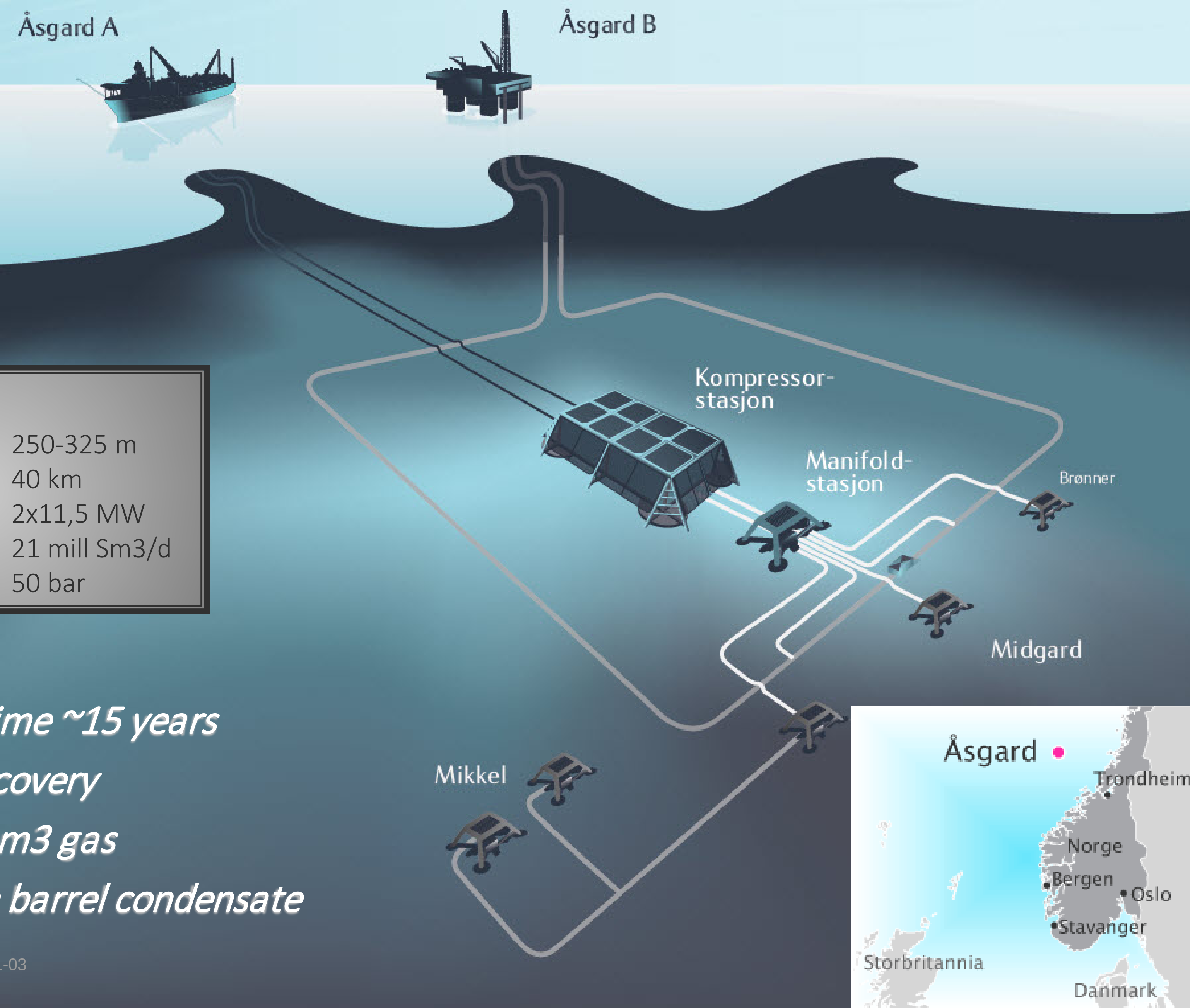


- 2 x 5 MW Wet gas axial contra rotating compressors
- Liquid filled compressor motor
- No Liquid Pump
- Barrier fluid lubricated bearing system
- $3m^3$ liquid slug dampener/flow mixer
- Hydraulic actuated valves
- Passive coolers
- Recirculation line with choke
- Station dimensions: 42 x 18 x 13 m
- Station weight: 950T

OneSubsea
A Cameron & Schlumberger Company

Statoil

Åsgard Subsea Compression



Key data:

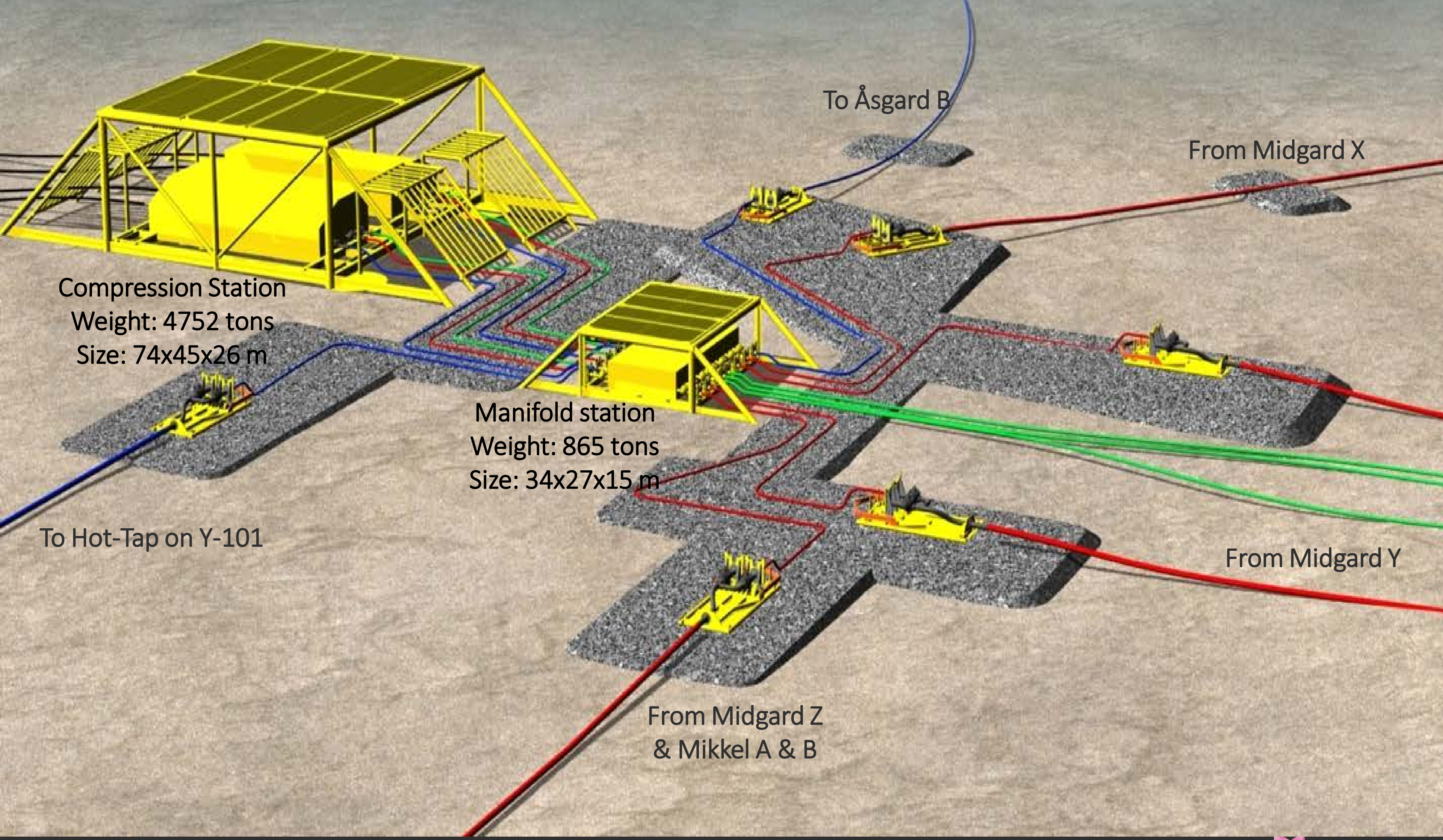
Water depth:	250-325 m
Tie back:	40 km
Power:	2x11,5 MW
Flow rate:	21 mill Sm3/d
Diff. pressure:	50 bar

Prolonged life time ~15 years

Increased oil recovery

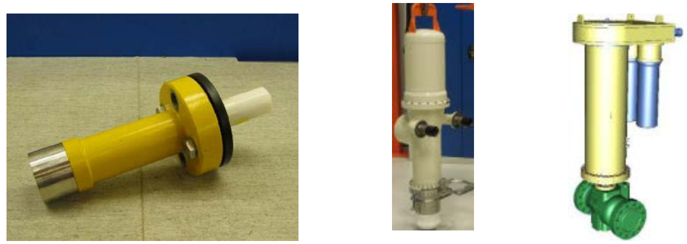
- *~29 billion m3 gas*
- *~22 million barrel condensate*

Åsgard Subsea Compression
Subsea Modules



Technology Qualification Program

Cooler



All Electric Subsea Control System

Active Magnetic Bearing Control

Scrubber

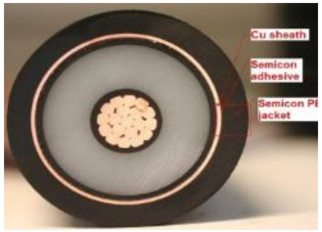
Initiated 2007

Comprehensive Scope

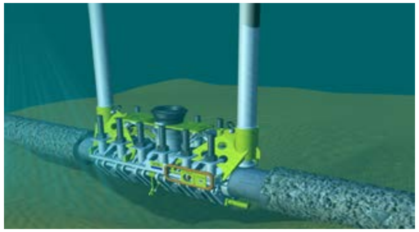
Maturing Competitive Vendors

Subsea Transformer

HV Connectors and Penetrators



Power Cable



Hot-Tap

Pump

K-lab Test Facility

- World's first large scale test loop for subsea compressors built 2007-2008
- Large upgrade 2011-2013
- Shallow water test pit
- 11,5 MW compressor shaft power
- 17 million Sm^3/d flow rate hydrocarbon gas
- Condensate and water/MEG injection
- Long- step-out, high voltage, high frequency power supply
- Experienced Statoil operating personnel

Subsea Compressor Station Modules

Compressor
289 tons
11x9x10m

Scrubber
210 tons
8x8x12m

Pump
45 tons
5x5x6m

Outlet cooler
107 tons
9x7x5m

Inlet/antisurge cooler
235 tons
15x10x7m

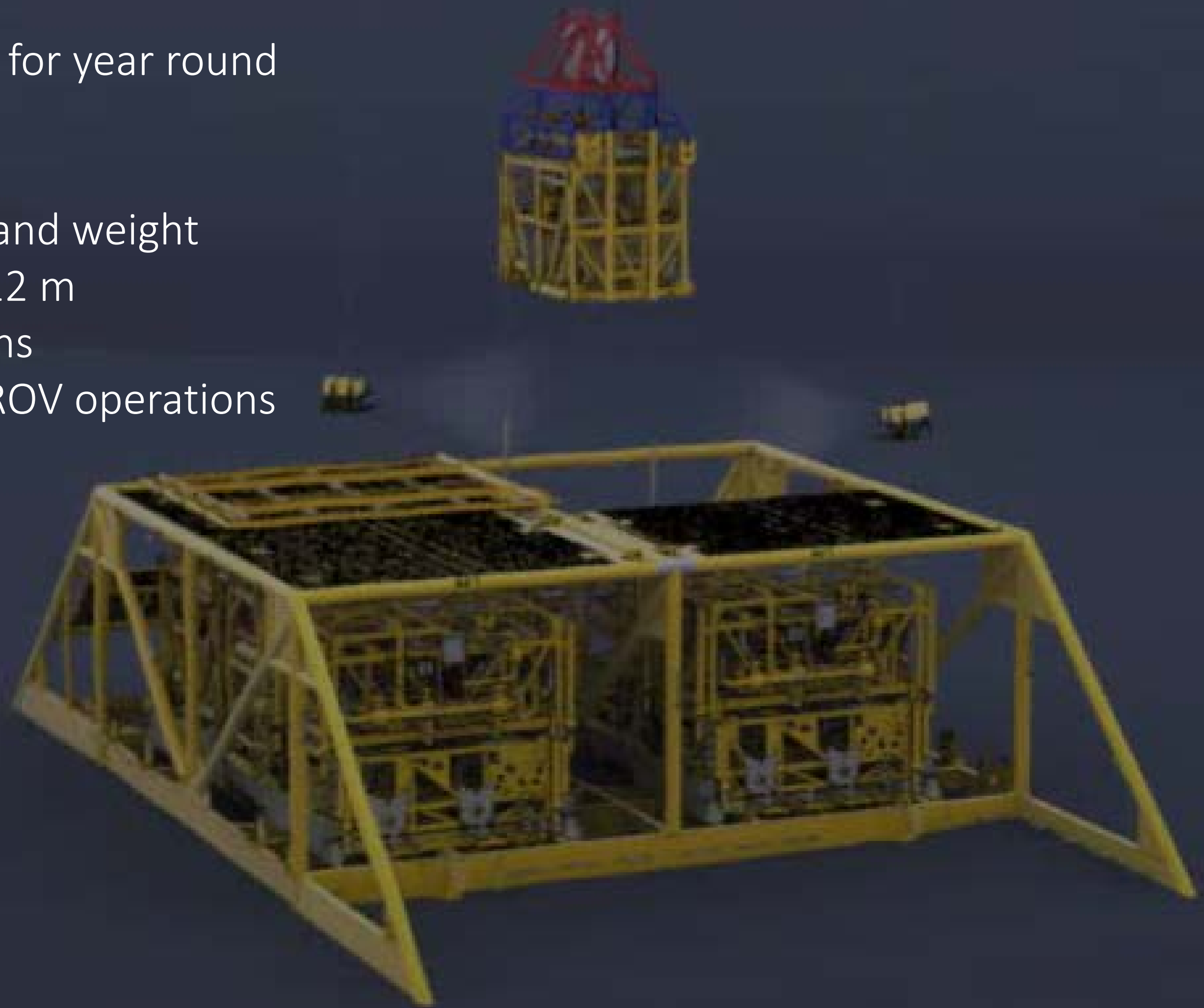
Subsea Compressor Train at Egersund Site

Installation and Intervention

- North Sea Giant
    - DP Class III
    - Size 161x30m
    - Accommodation 120 person
    - Main Deck area 2900m^2
    - WROV x2, Triton XLX and XLR
- SHS for large modules in fabrication
    - Total weight of structure ~1000Te, height 30m
    - Capacity 388 tons, 15x12x12 m, Hs 4.5m
- Moonpool Handling System 70 tons, 7.2x7.2m
- Subsea Process Intervention System
    - Handle residual hydrocarbons in modules
    - MEG displacement of modules
    - Nitrogen flushing

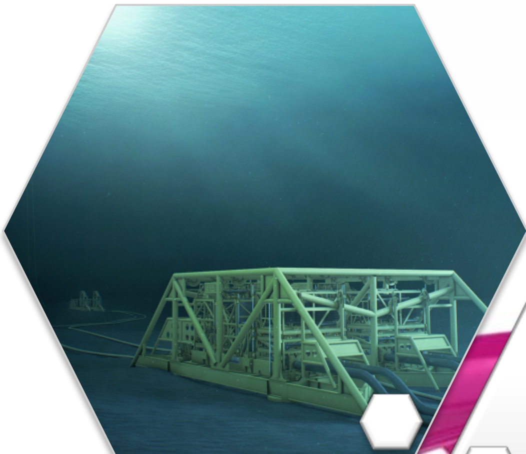
The Intervention Challenge

- Requirement for year round intervention
- Hs=4.5 m
- Module size and weight
  - 15x12x12 m
  - ~350 tons
- Challenging ROV operations



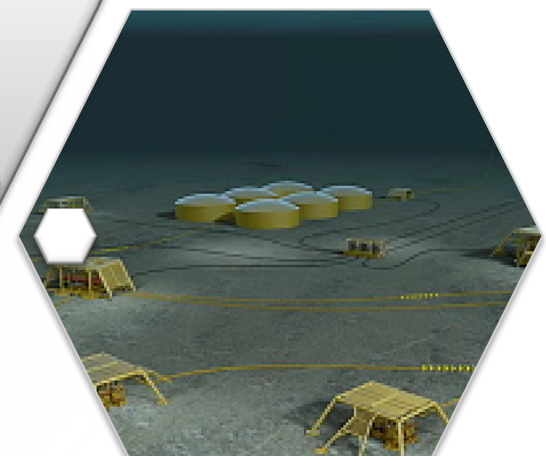
Training on installation and intervention in simulator

Taking Subsea Longer , Deeper, and Colder

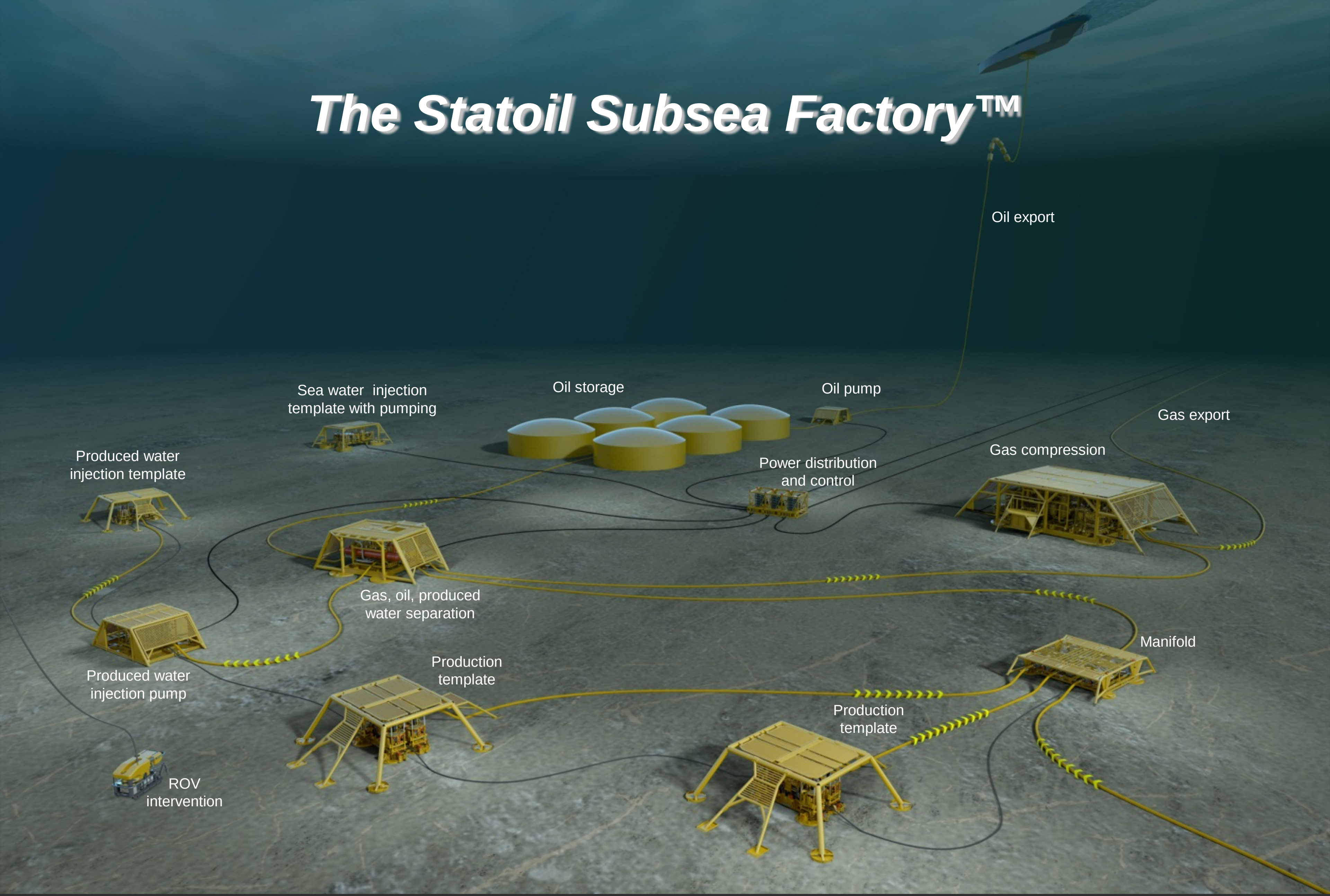


Subsea gas compression by 2015

Subsea factory by 2020



The Statoil Subsea Factory™




Thank you