Yme New Development

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1 Introduction

1.1 Purpose

The purpose of this document is to summarize the evaluations done for the Yme field regarding power from shore. A grand total of three studies have been undertaken at different times during the development project:

- First in 2006/2007 at the Re-Development project executed by Talisman.
- Secondly during the assessment of the Yme Future project in 2013/2014 in an attempt to find a development scenario for Yme following the decision to remove the then installed production facility at the field.
- And finally in 2017 as a part of developing a revised plan for development and operation for Yme.

Information from the studies done in 2007 and 2013 provide the basis for the study done in 2017, however a revised technical solution has also been provided as the concept for the Yme New Development has been the re-use of an existing drilling and production installation (Mærsk Inspirer).

The technical basis for the solution is based on the Unitec report, ref./1 /, however, the cost estimate has been updated and verified as part of this work.

1.2 Definitions and Abbreviations

BAT	Best Available Technology
CAPEX	Capital Expenditure
OPEX	Operating cost
ABEX	Abandonment cost
D/S	Downstream
MD	Maersk Drilling
MI	Mærsk Inspirer
MOPU	Mobile Offshore Production Unit
MOPUstor	Mobile Offshore Production Unit with Storage
PDO	Plan for Development and Operation
PfS	Power from shore

1.3 References

/1/ YME New Development. Power from Shore Evaluation, Doc. No. YME04-25429-Z-RA-0001, Unitech Power Systems, April 2017.

/2/ YME01-23058-E-RA-0003, Electrical Power from shore select study, Aibel, December 2013

/3/ 104174-Z-RA-00001, YME new development, high level evaluation of electrification alternative, Aker Solutions, December 2017

2 Yme Field Description

2.1 Yme Field and License Information

The Yme Field is located approximately 100 km from the Norwegian coastline, in the Egersund basin in the central part of the North Sea. The water depth is 93m. The field consists of two main structures: Yme Beta and Yme Gamma, which are located approximately 12 km apart.

The Gamma structure was discovered in 1987 and in 1990 oil was proven in the Beta structure.

Current License owners are:

- Repsol Norge AS (operator) : 55 %
- Lotos Exploration and Production Norge AS : 20 %
- OKEA : 15%
- Kufpec Norway AS : 10 %

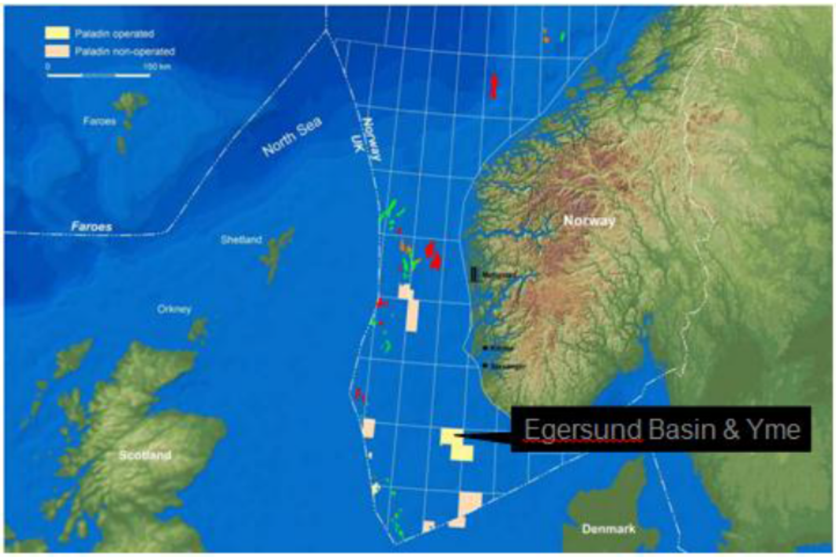

Figure 2-1 North Sea Area Map

2.2 Project Background

Statoil developed the field using Mærsk Giant Jack-Up Drilling rig with processing facilities and a separate storage vessel for production in the period 1996-2001. The field was abandoned in 2001 following low oil prices and significant requirements for investments in the field.

Paladin Resources was awarded the license as operator from Norwegian Authorities in 2004 and initiated work for a new Plan for Development and Operation (PDO) for the Yme field. Paladin was acquired by Talisman in 2005 which was granted permission to re-develop the field in 2007.

The basis for the re-development was the use of a Mobile Offshore Production Unit with Storage (MOPUstor) at the Gamma location, and tie-back of subsea templates at the Beta location. All wells were drilled and subsea equipment, including subsea storage tank and caisson, were installed on the field prior to arrival of the MOPU. Due to safety reasons the MOPU was evacuated in 2012 and finally removed in 2016.

In 2015 the Joint Venture decided to initiate work to abandon the field.

Changing market conditions have since generated a potential for an alternative development of the Yme field, this time based upon the lease of an existing jack-up drilling rig with processing facilities. Together with a general cost reduction in the industry, this represents a new opportunity for the Yme field. The PL 316/316B licensees have thus decided to submit a revised PDO for the Yme field.

2.3 Project Description

The Yme New Development Concept is based on lease of an existing Jack-Up with Drilling and Production Facilities installed on the Gamma location, and a new wellhead module to be installed on top of the existing caisson.

The existing wells, storage tank, caisson, pipelines, subsea templates and offloading system shall be reused. Some repair work is required on existing facilities, most notably a Caisson Permanent Support and SLS.

A new subsea development on the Beta North structure will be tied in to the existing subsea infrastructure.

Six (6) new wells will be drilled, including one (1) producer at Beta North, one (1) producer at Beta East, one (1) water injector at Beta North and two (2) producers and one (1) water injector at Gamma.

The layout of the Yme New Development Facilities is shown in Figure 2-2 Yme New Development Field Layout

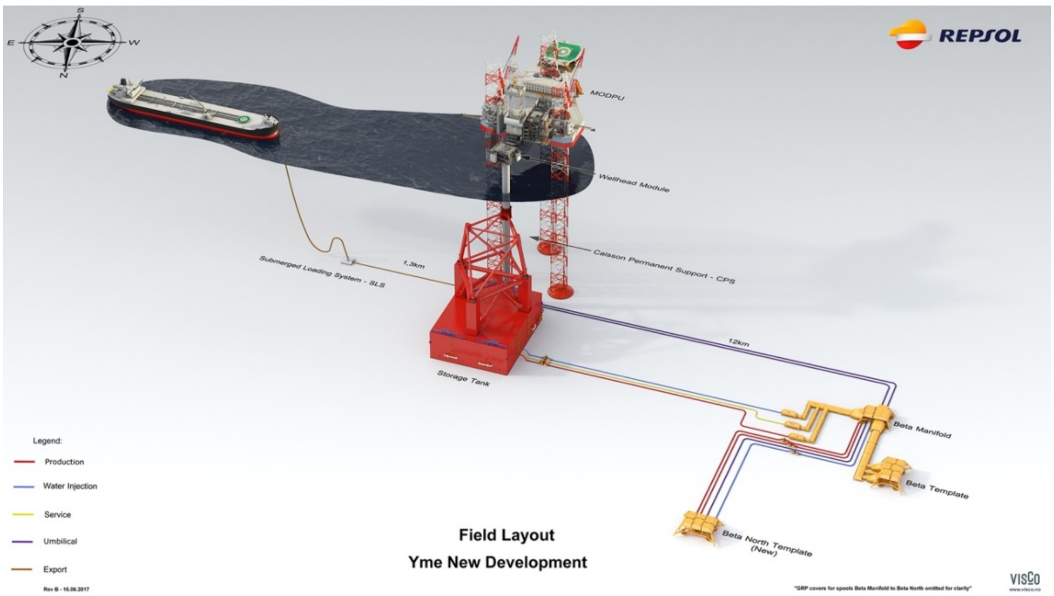

Figure 2-2 Yme New Development Field Layout

3 Power from Shore

The PDO from 2007 contained a development solution without power from shore. At the time, there were no firm requirements for power from shore evaluations in a PDO, however, power from shore was at the time very interesting for the licensees for two reasons: to avoid emissions; and to reduce costly diesel consumption as reservoir simulations showed gas deficiency after 3-5 years. However, the conclusion from 2007 was not to implement power from shore.

The power from shore evaluation was repeated in 2013/14 as a part of a project preparing a revised PDO for the Yme field following a decision to remove and scrap the then current production facility from the field due to structural deficiencies. This project stopped at BOV / DG2 based on poor economics. The power from shore study concluded again that the cost for implementing would be so high that it was not recommended to be a part of the project presented.

When considering the power from shore in the Yme New Development project, a new attempt to find a solution for development of the Yme field, the starting point has been the conclusions from the previous projects to not include power from shore. This basis has first been qualitatively viewed with respect to the current development scenario to see if there is a potential to support a development with power from shore Ref /1). Further the technical basis from Unitech has been cost estimated to provide sufficient basis for an evaluation of abatement cost.

3.1 Gas Deficiency

The drainage strategy for the Yme field has been evaluated in detail and has now been changed for at least two reasons.

Improved oil recovery and gas reproduction. This allows the proposed development solution to be based on gas as fuel for the lifetime of the field both for 10 and 15 years production scenarios.

The current reservoir simulations show a gas deficiency after 13,5 years, however should 15 years production time be an alternative, new sidetracks or tie-ins will most probably materialise and more gas be available.

The change in drainage strategy offers a solution where the gas is injected and back produced with the result that the emissions compared to the 2007 PDO has been considerably reduced.

3.2 Power from Shore Solution

A review of providing power from shore was conducted in preparation for execution.

Providing power to the Yme - field was the basis of a study performed by Aibel in 2013, Ref. /2/. The proposed manner of providing power was via subsea cable connected to the 300 kV grid at Kjelland substation in Egersund kommune.

Yme New Development project contracted Unitech Power Systems to perform a review of the study and evaluate the possibility of applying this solution to the project.

Among the factors considered when reviewing the study was that the project is based on modifications to a leased facility with an existing power supply and the requirement to reinstate the Mærsk Inspirer at the end of production.

The conclusion of the study was that it is feasible to provide power from shore, but it would require frequency converter to convert the supply from 50Hz to 60 Hz, it would require 30 MVA transformers offshore connected to a 6.6kV switchboard, and 2 reactors adjustable by OLTC to manage surplus reactive power.

An onshore bulk conversion was viewed as the only realistic solution, as the converters are quite large and heavy. This space could be rented from the owner of Kjelland station, with a protective housing unit of approximately 200 m^2 built to house the equipment. Power would be transferred to the offshore facility by a 12 km trenched onshore cable which will be connected to a 114 km trenched subsea cable connecting to the Mærsk Inspirer via a flexible cable from the seabed.

The Equipment and space at the Kjelland station is under change, there is also plans for updating the national grid. In this review it is assumed that that will not affect the power from shore solution.

The existing gas turbines on Mærsk Inspirer provide possibility for heat generated with waste heat recovery units. Hence a power from shore solution would have to provide also the power needed to heating medium system in addition to the direct electricity needed. Process heating is in this solution proposed as one 100 % 13 MW heater.

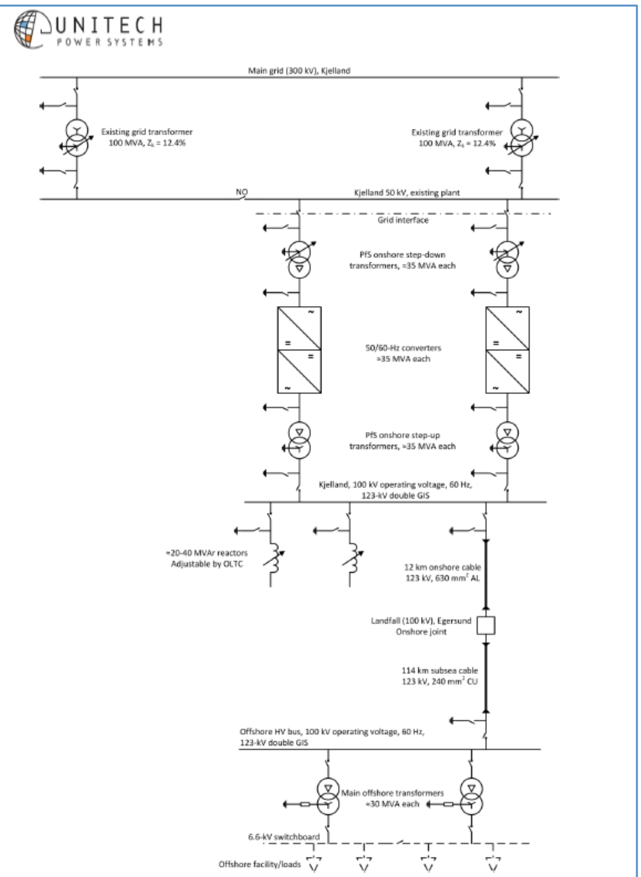

Figure 8-1 Proposed PfS system topology for YND

Although feasible, this solution was not viewed the best solution as it would increase significantly the amount of weight on the Mærsk Inspirer, it would require removal of equipment that will have to be stored and then re-installed at the end of production, and would increase operating costs.

Additionally, costs for performing the required modifications in order to bring power from shore did not provide substantial benefits compared to the overall emissions, including the CO_2 cost per tonnes. In addition power from shore is not an energy effective solution as 13 MW for heating is generated utilizing waste heat recovery from gas turbines. Furthermore the power transfer from shore will incur line losses. Hence the energy delivered from the national grid will have to be higher than the locally produced power/ heat.

In a global perspective the YND concept is based on recycle. Re-utilization of Mærsk inspirer for what the rig is produced to do, represent a huge energy saving compared to producing a new rig. This is also valid for the PfS scenario. All cables, transformers and other equipment will have to be produced to replace equipment that already exists.

3.3 Cost Estimate

Overall CAPEX has been estimated to be in excess of 2,3 BNOK with approximately half of those costs attributable to modifications required on the Mærsk Inspirer in order to accommodate the provision of power from shore.

Table 3.1 High level cost estimate

CASE: Power Solutions	**Scenario 1 Power From Shore**	**Scenario 2 Power From Shore**	**Scenario 3 Local generated power**
Yme New Developement Base Assumptions: **• Average electrical power consumption YND is 16.7 MW** **• Average Heat load is 8MW** **• Average electrical power and heat load 25.7 MW.** **• Peak load 54 MW** **• Electrical system on Maersk Inspirer is 60Hz** **• Electrical system onshore is 50Hz** **• Expected operations is 10 years commencing in 2020** **• Onshore tie-in for power at Kjelland** **• Transmission voltage = 100Kv (Optimal)** **• 50kv breakers are already installed in substation**	***Electrical power provided via subsea cable via transformers located at Kjelland. Required electrical & utility equipment installed on MI. Expected completion date 2021. Offshore modification and installation campaign. Fuel gas used until PfS ready, and injected afterwards.*** ***Production start-up as planned.***	***Electrical power provided via subsea cable via transformers located at Kjelland. Required electrical & utility equipment installed on MI during onshore yard stay to avoid offshore work. Expected completion date 2021. All fuel gas is injected.*** ***Production start-up 2 year delayed.***	***Power generation on MI via 2 off. Solar Titan (GTG's) incl. WHRU's in the process module, and 4 off. diesel motor driven generators for supply to the rig hull and drilling systems. Fuel gas used to provide power. Unused fuel gas is injected.*** ***Production start-up as planned.***
Sum Total Cost (CAPEX + OPEX + ABEX)	**2 943 537 064**	**5 256 155 074**	**670 976 120**
Development CAPEX Cost Total	**2 361 870 983**	**2 167 480 984**	**25 776 120**
Onshore & Subsea	**1 240 020 287**	**1 240 020 287**	**0**
Maersk Inspirer modifications	**629 902 732**	**473 213 866**	**25 776 120**
Secondary Capex costs	**491 947 964**	**454 246 831**	**0**
OPEX Cost	**534 454 304**	**3 016 117 880**	**640 400 000**
ABEX Costs	**47 211 777**	**72 556 210**	**4 800 000**

Development CAPEX cost Total in table 3.1 is the sum of the onshore and subsea infrastructure equipment+ Mærsk Inspirer equipment modification + the engineering and project management cost (Secondary Capex)

OPEX cost include the following ; Diesel, electricity for PfS, Maintenance of PfS Equipment, Maintenance of GTG & utilities, Diesel Taxes, Fuel gas taxes, and increase in rates for extension of production contract for 2 years. Not all elements are relevant for all cases. For instance the significant difference in opex in alternative 2 is explained with increased rates after 10 years. The Maersk contract has lease rates valid from 1/1-2020.

ABEX cost include removal of onshore facilities and reinstate leased facility to agreed status. In this case it is especially relevant with respect to reinstating the gas turbines and removal of PfS equipment onboard Mærsk Inspirer.

A review of the Unitech proposed solution as well as a validation of the CAPEX estimate was performed in a workshop with Aker Solutions in order to ensure a thorough and quality consideration of the possibilities was performed by the project. The findings of this workshop can be found in Attachment 1, Ref. /3/.

The reviewed case for PfS assumes that the proposed project schedule will be maintained and that required equipment will be installed during a shut-down period. This is due to the expected lead time of the equipment and subsea cable of approximately 2 years, during which time power will be provided locally via the selected solution.

Case 2 versus case 1. If the project was to wait until power could be provided from shore prior to starting production, this would potentially increase the overall costs (delta cost CAPEX, OPEX and ABEX) an additional 2.3 BNOK.

3.4 Alternative solutions

Alternative solutions in addition to local generated power or power provided from shore were examined, but no realistically feasible option was identified. A subsea cable could potentially be provided from Valhall, however with a peak load of 54MW for Yme the Valhall does not have the capacity available and the Mærsk Inspirer requires AC whilst Valhall uses DC.

Johan Sverdrup will also be developed with power from shore, and provide a potential power source to Yme. However the distance between the fields are longer than the distance from shore, and furthermore the transmission would have to be DC and it is not possible to install equipment for DC/AC conversion onboard Mærsk Inspirer.

All together this requires a solution with a much higher CAPEX than the evaluated alternative.

4 Power from Shore - Economics and Abatement cost

An Yme New Development will yield a net present value before tax of 8.1 billion 2017-kr at 7% discount rate. The break-even price before tax, i.e. the oil price that gives a net present value equal to zero, is $45.2/boe at 7% discounting.

With regards to power from shore, two economic cases have been evaluated versus the PDO base case:

- The first case assumes production start-up of Yme in accordance with the PDO base case in April 2020, with power from shore introduced in 2022. This case give a net present value before tax of 6.0 billion 2017-kr at 7% discount rate; approximately 2.1 billion 2017-kr less than the PDO base case. The break-even price at 7% discount rate in this case increases by $6.2/boe versus the PDO case to $51.4/boe.

  Abatement cost is here calculated to 3,446 2017-kr per tonne of saved CO_2 emission.

- The second analysis assumes that the production start-up of Yme is delayed to 2022 and thus a case with power from shore throughout the production period. This case give a net present value before tax of 3.1 billion 2017-kr at 7% discount rate; approximately 5.0 billion 2017-kr less than the PDO base case. The break-even price at 7% discount rate in this case increases by $13.9/boe versus the PDO case to $59.1/boe.

  Abatement cost is here calculated to 4,530 2017-kr per tonne of saved CO_2 emission.

Table 4.1 Economics calculation

			Sanction Case	Case 1	Case 1 Delta	Case 2	Case 2 Delta
Emissions CO2		**Tonnes**	825 071	139 635	-685 436	-	-825 071
Development CAPEX		MNOK 17	8 231	10 593	2 362	11 969	3 738
Abandonment CAPEX		MNOK 17	2 983	3 030	47	3 056	73
CAPEX total		MNOK 17	11 214	13 623	2 409	15 024	3 811
OPEX total		MNOK 17	10 135	10 051	-84	9 943	-192
Net Present Value before tax	NPV 0%	MNOK 17	12 517	10 192	-2 325	8 890	-3 628
	NPV 7%	MNOK 17	**8 058**	**6 041**	-2 016	**3 101**	-4 957
Break-Even price NPV 7% pre-tax real = 0		US$/boe	45,2	51,4	6,2	59,1	13,9
Abatement cost (Dev CAPEX/Tonnes)		kr/Tonnes			3 446		4 530
Abatement cost (OPEX+CAPEX/Tonnes)		kr/Tonnes			3 392		4 386

The evaluation of the economics is based on the sanction case (as presented in the PDO) and adjusted with CAPEX and OPEX as relevant in case 1 and case 2.

Case 1 is modeled as described above in section 3.3. In addition the two first years has usage of diesel and fuel gas before power from shore starts.

Case 2 is modeled as described above in section 3.3. In addition it assumes a two years delay of production start-up where all relevant field development activities being delayed accordingly. This includes two years added general management costs of 500 MNOK 2017-kr per year. A significant difference is the increased lease rate for the rig the last two years after 10 years of pre-agreed rates.

5 Recommendation

Power from shore has an abatement cost at minimum 3300 NOK per tonnes CO_2 saved. A value of 500 NOK / tonnes CO2 saved has been viewed as acceptable figure for positive socioeconomic project.

Implementing power from shore will increase breakeven price in the project with at least 6,2 $/boe.

All remaining weight capacity on Mærsk Inspirer will be spent to accommodate a module for the transformers reducing the possibility for future tie-ins.

It is not recommended to implement power from shore solution as a part of the Yme New Development project. The abatement cost is high and a positive effect in the socioeconomic calculation cannot be demonstrated.

Appendix 1 YND High level evaluation of electrification alternative


AkerSolutions

Yme new development, High level evaluation of electrification alternative

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YME, High level evaluation of electrification alternative		08.12.2017

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