Njord Future

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ENVIRONMENTAL DESIGN REVIEW INCL. BAT

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Rev. 01	Issued for comments
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1 INTRODUCTION

1.1 BACKGROUND

The Njord A installation is a floating steel platform located in the southern part of the Norwegian Sea with facilities for process, drilling and living accommodation. The oil from Njord A is transported by pipeline to the storage vessel Njord Bravo, which is anchored 2,5 km from Njord A, the oil is then transferred from Njord Bravo to oil tanker for transportation to marked. Gas from the Njord A is exported through the Åsgard Transport pipeline to Kårstø gas processing plant

The Njord field is located in Norwegian Continental block 6407/7 and 6407/10 about 130 km north west of Kristiansund and 30 km west of the Draugen Field. The water depth on the field is approximately 280 to 360 meters. Production from Njord field started in 1997.

The Hyme field is located in block 6407/8 about 20 km north east of the Njord field. The water depth on the field is 265m. The Hyme field is connected to existing Njord A infrastructure as a sub-sea tie-back.

The Snilehorn field is located in block 6407/8, approximately 16km from Njord A. The water depth of the on the field is approximately 250-300m. Subsea well and production system will be developed with tie-back to Njord A via a new built production flowline; water injection, gas lift and umbilical is intended via the Hyme facilities.

The Pil is located in block 6406/122 on the Halten Terrace at a water depth of approximately 324 m. The Pil field will be connected to Njord A as a sub-sea tie-back.

As described in the Scope of Work /4/ “Njord Future Project shall upgrade the Platform including Topside, Substructure and permanent mooring to be able to safely and reliably produce the remaining Njord and Hyme reserves within the new design lifetime. Further to the above the Njord Future Project shall facilitate the development of the Snilehorn and other potential tie-in fields by modifications to the Platform.”

The Pil study includes a tie-in of the Pil field to Njord A with minimum topside modification.

As stated in Design Basis /5/, project requirement for environmental care is to use the BAT (Best Available Techniques) methodology as method to optimize the modification with regard to environmental care.

An environment design review was conducted at Aker Solutions office at Sansli, Bergen the 22th of September for Njord Future FEED. This report summarizes identified BAT items from the study and the review. Identified BAT items have been evaluated by using guidelines and checklist from Statoil GL0300 /3/, NORSOK S-003 /2/ and TR1011Environmental requirements for offshore installations /1/.

Separate Environmental Budget reports is made for the project, which summarizes the environmental impact caused by the project and the modifications, e.g. changes in energy consumption, emissions to air, discharge of produced water, oil and chemicals to sea /6,9/.

1.2 OBJECTIVE

The objective of this report is to identify all BAT items in this study and evaluate and compare different alternatives with respect to environmental issues.

This report covers Njord Future the tie-in of Snilehorn field and the tie-in of the Pil field.

2 ABBREVIATIONS AND DEFINITIONS

BAT	-	Best Available Techniques
CO_2	-	Carbon Dioxide
DEH		Direct Electrical Heating
FW	-	Fresh Water
IED	-	Industrial Emissions Directive
NEA	-	Norwegian Environmental Agency
NMVOC		Non-Methane Volatile Organic Compounds
NOx	-	Nitrogen Oxides
OiW	-	Oil in Water
RVP	-	Reid Vapour Pressure
SoW	-	Scope of Work
TEG	-	Trietylenglykol
VOC	-	Volatile Organic Compound
WHRU	-	Waste Heat Recovery
WiO	-	Water in Oil

3 SUMMARY

3.1 ENVIRONMENTAL IMPACT

Tie-in of Snilehorn and Pil will give an increased load on the main generators; this is due to increased production volumes and new equipment. New main consumers are new increased motor for the 3rd stage compressor, new electrical oil heater, and increased motor in the water injection system. This will give a total increase of CO_2 and NOx emission to air. Tie-in of Pil will however reduce the power demand for the new electrical heater. In addition; the replaced fresh water generator is a generator with an internal heat loop, meaning no external electrical heating is required; this will result in a reduction of electrical power demand of approximately 1MW.

Tie-in of Snilehorn and Pil will give an increased load for the turbine driven compressor, this will give a total increase of CO_2 and NOx emission to air.

The amount of produced water discharged to sea and further discharge of oil to sea from produced water will increase due to the increased production. A CFU will be installed as a second technology of water cleaning to meet the requirement for the oil in water content. This will reduced the amount of oil discharged to sea per cubic meter produced water discharged to sea compared to historical data.

Water soluble injected chemicals will follow the produced water to sea. Scale is today mitigated by regular squeeze in the well. After the tie-in of Snilehorn the scale inhibitor will be injected as a continuous operation. Amount of scale discharged to sea will therefore increase.

Following chemicals will be used in accordance to the tie-in of Pil; Asphaltene inhibitor, scale inhibitor, emulsion breaker, pour point depress/WAX inhibitor and H_2S scavenger, last mentioned will only be utilized in the future. The proposed asphaltene inhibitor (EPT-3035), the scale inhibitor (SI-4471), the emulsion breaker (EB-8580) and proposed H_2S scavenger is not classified as environmentally hazardous, but the datasheet does not exclude the possibility that large or frequent spills can have a harmful or damaging effect on the environment. The proposed pour point depressor/wax inhibitor (EPT-3345) is classified as toxic to aquatic life with long lasting effects.

For more detailed information regarding the environmental impact see Environmental Budget reports/6,9/

3.2 CONCLUSION AND RECOMMENDATIONS

A BAT evaluation has been performed and documented for all identified significant environmental aspects. The conclusion is that all identified points where found to comply with BAT in accordance to project scope of work and no future recommendations is included as a part of this report. All points evaluated during the environmental design review and throughout the project are listed in chapter 6.3

Detailed environmental calculations are not performed for any of the identified items as they are evaluated to comply with BAT in accordance to project scope of work.

4 BEST AVAILABLE TECHNIQUES (BAT)

The Norwegian Environment Agency, NEA (Miljødirektoratet) requires that all new installations shall demonstrate that the design is in accordance with the Directive 2010/75/EU (IED) /8/ which is a part of the "EØS"-agreement (EEA) in the Norwegian Legislation. Emission limits in The Discharge Permit granted by NEA will be based on BAT, and energy efficiency will be considered as part of the Discharge Permit.

BAT is defined by the Industrial Emissions Directive (IED) as: 'Best available techniques' and means the most effective and advanced stage in the development of activities and their methods of operation. This indicates the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable generally to reduce emission and the impact on the environment as a whole:

- **'best'** shall mean most effective in achieving a high general level of protection of the environment as a whole,
- **'available techniques'** shall mean those techniques developed on a scale which allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the cost and advantages, whether or not the techniques are used or produced inside the Member State in question, as long as they are reasonably accessible to the operator,
- **'technique'** shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

4.1 BAT PRINCIPLE AND TOOLS

BAT is a fundamental principle when dealing with external environment, and a tool for evaluating external environmental aspects in systematic and organized way. A BAT evaluation compares different alternatives with respect to environmental issues and takes an overall approach considering relevant factors such as cost/benefit analysis, technical feasibility environmental gains/reductions, and social/ political plays (national/local community) where relevant GL0300 /3/.

The BAT evaluation is performed in order to identify relevant alternatives technique and design solutions that can satisfy the environmental goals and requirement for the project.

The BAT evaluations will be ongoing activities in the design development, and will follow the project development plan.

5 BAT ASSESSMENT METHOD

5.1 IDENTIFICATION OF BAT ITEMS

Based on NORSOK S-003/1/ and BAT evaluation checklist from Statoil Guideline (GL0300)/3/ specific BAT items have been identified for further assessments to recommend specific design solutions and equipment.

5.2 EXECUTION ON BAT EVALUATIONS

The BAT is and will be performed to identify relevant alternative techniques and design solutions that can satisfy the environmental goals and requirements and to evaluate the different BAT items as described in IED directive. Quantitative evaluations of cost aspects related to the project are performed when relevant.

5.3 IED CHECK LIST

According to the Industrial Emissions Directive (IED), it is recommended that the following items should be given special consideration when determining BAT:

1. Use of low waste technology
2. Use of less hazardous substances
3. Recovery and recycling of substances generated and used in the process and of waste, where appropriate
4. Comparable processes, facilities and methods of operation which have been tried with success on an industrial scale
5. Technological advances and changes in scientific knowledge and understanding
6. The nature, effects and volume of the emissions concerned
7. The commissioning dates for new or existing installations
8. The length of time needed to introduce the best available technique
9. The consumption and nature of raw materials (including water) used in the process and their energy efficiency
10. The need to prevent or reduce to a minimum the overall impact of the emissions on the environment and the risks to it
11. The need to prevent accidents and to minimize the consequences for the environment
12. The information published by the Commission pursuant to Article 17(2) or by international organizations.

6 Environmental Design Review & BAT Check List

6.1 General

As a part of the BAT evaluation, an Environmental Design Review was as performed at Sandsli, Bergen the 22th of September 2016.

Systems subject to modification were reviewed with respect to emission/discharge to sea and air, energy consumption and waste. The BAT evaluation checklist from GL0300/3/, with a few project adjustments, where used during the review, reference is made to chapter 6.5

The objective of this review is to:

- Discuss the modifications and ensure compliance with natural environment requirements.
- Identify environmental issues
- Identify technical solutions to be subject to BAT evaluations

6.2 Guidewords

A list of guidewords was used during the review to ensure all relevant issues were identified and discussed. The following guidewords are explained in detail in checklist from GL0300 /3/:

- Energy management
- NOx control on engine/turbines
- Flaring and venting
- Oil storage and loading
- Fugitive emissions and cold vents
- Well testing/well clean-up
- Produced water
- Drain system
- Displacement water
- Discharges from drilling and well operations
- Produced sand
- Chemicals and materials
- Cooling water
- Waste
- Decommissioning
- Subsea installations

  - Degree of compliance of what is considered BAT should be documented (colour code):
    - Green (G) - Compliant
    - Yellow (Y) - Partially Compliant
    - Red (R) - Not Compliant
    - Clear (N/A) - Not Applicable

6.3 Participants

The following personnel attended the Environmental Design Review at Sandsli, September 22, 2016

Name	Position	Company
Bjørn Vidar Grande	Safety and Environment	Aker Solutions
Brit Vårin Guttormsen	Safety and Environment	Aker Solutions
Gunnar Elholm	Process	Aker Solutions
Dagfinn Kallevik	Electro	Aker Solutions
Johan Rune Lenschow	Mechanical	Aker Solutions
Cecile Surdal	Miljøteknologi	Statoil
Knut Robberstad	Miljø og konsekvensutredning	Statoil
Steinar Seljebø	Prosess	Statoil
Kjell Arne Haugen	Mekanisk	Statoil
Terje Hovland	Elektro	Statoil

6.4 Process Systems / Design Requirements

As a part of the modification, the following changes will be performed in the main process system; a new increased motor for the 3rd stage compressor will be installed, 1st and 2nd stage compressor will be rebundled and a new electrical oil heater will be installed downstream the 2nd stage separator. A simplified process flow diagram is present in figure 6-1 to illustrate the changes in the main process system. In addition a new increased pump will be installed in the water injection system and a second technology of water cleaning; a compact floating unit (CFU) will be installed in the produced water system to increase the produced water quality before discharged to sea, for illustration, see figure 6-2.

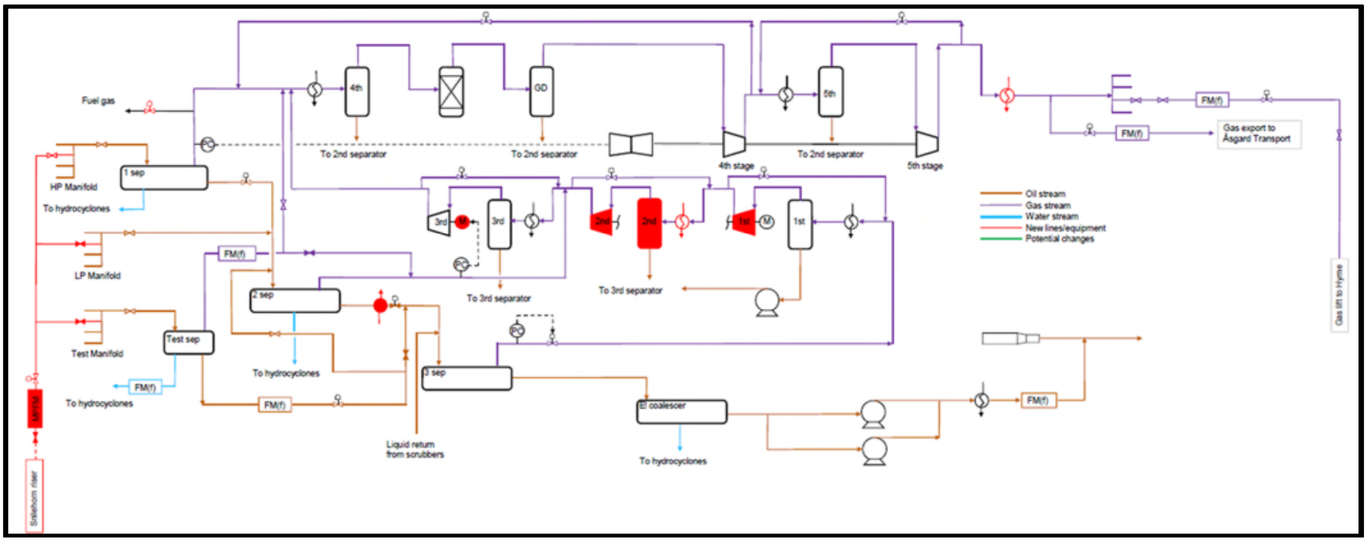

Figure 6-1 Scope of Work Main Process

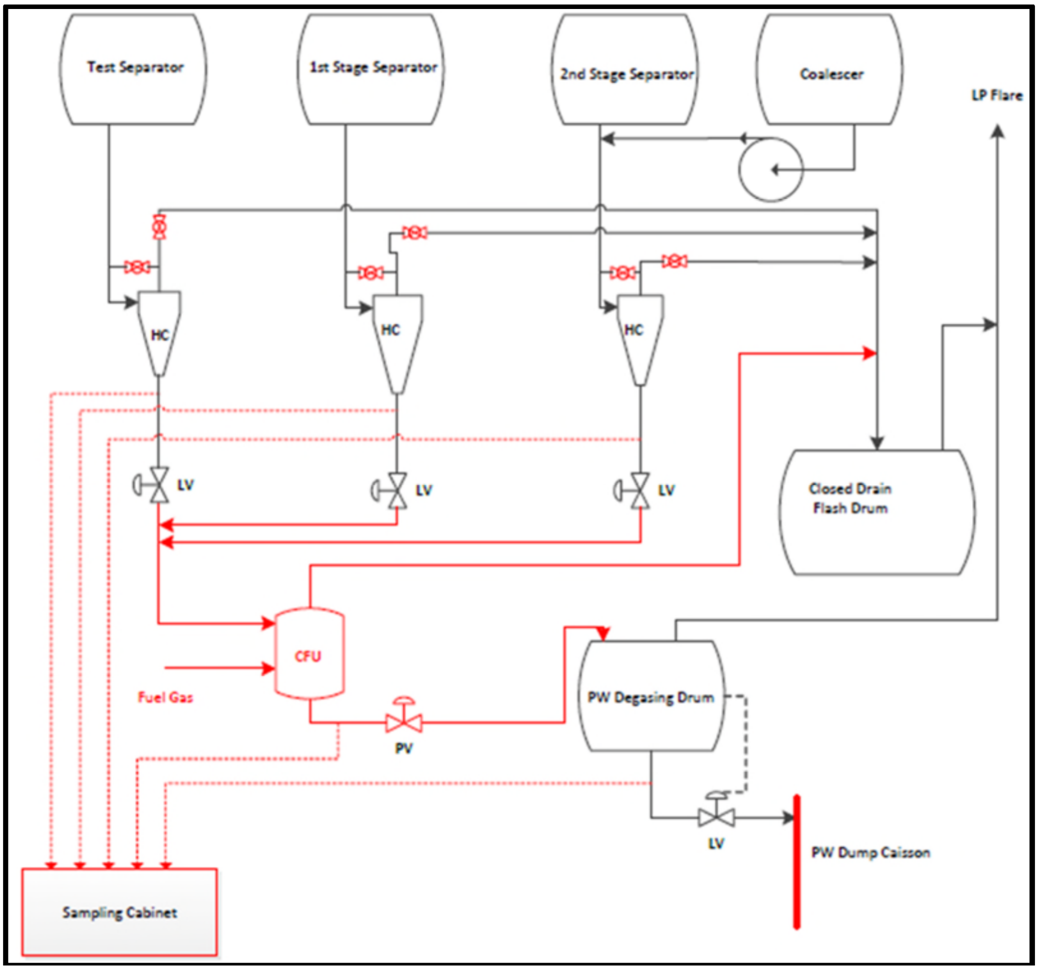

Figure 6-2 Scope of Work Produced Water

6.5 BAT Evaluation Check List for Njord FEED

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
	1 Energy management (Participants: Process, mechanical and electro)			
1.1.	Have a power and heat requirement analysis been performed comprising the process and utility systems over the lifetime of the production facility?	Snilehorn: Simulations based on production profiles (2020-2036) have been performed for 6 separate cases, aiming to optimize process and meet process specifications. Cases simulated in HYSYS: - April 2021 “max Snilehorn” - Jun 2022 “max oil” - Jan 2025 “max gas” - Jun 2025 “high oil and high LP gas” - Jan 2027 “late life” - Feb 2027 “Snilehorn LP” Electrical power profile is estimated for modifications and Snilehorn tie-in. Pil: Simulation based on production profiles (2019-2037) has been performed for eight separate cases, aiming to optimize process and meet process specifications. Cases simulated in HYSYS: - August 2021 “max oil PIL – New 1. +2. Stage compressor curves” - November 2022 “max HP gas PIL – New 1.+2.stage compressor curves” - October 2024 “max HP gas PIL – New 1.+2.stage compressor curves” - June 2025 “Existing 1. and 2. Comp. curves” - October 2025 “max LP gas –Existing 1. and 2.	(G)	The environmental budgets/6,9/ is based on power profiles and simulations in HYSYS.

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
		Stage compressor curves" - January 2027 "low production – Existing 1. + 2.stage compressor curves" - July 2029 "max water" - September 2036 "late life" An electrical power profile is established for the tie-in of Pil.		
1.2	BAT: optimum number, size and design of turbines	The total load demand will increase due to the modification and the tie-in of Snilehorn. Both turbines have to be in operation in some cases but it's assumed that only one turbine needs to be in operation during normal conditions. For the tie-in of Pil the power demand will increase due to additional load on the compressors, additional load ion the water injection pump, additional load in 690V switchboard and additional load due to the Flow line Heating (PiP EHT) The last mentioned will only be in operation during start-up, the power demand is approximately 1,2MW Main power turbines will be upgraded as a part of an ongoing program from Statoil. This is a mechanical upgrade. Change in output effect due to this upgrade is included in Design basis. The mechanical upgrade will result in a marginal positive change for the as one turbine in operation have better efficiency than two generators in operation and therefore lower emission to air. Load shedding system will be installed due to increased load. This will reduce the risk for overload and process	(G)	Total load demand has to be further studied in accordance to peak load and coincidence of operations. Some activities, as loading, will only demand power periodically. The drilling activities will only be relevant for some year, not the entire production life time. Power profile is revised during the study. Emission to air from power generation is summarized in environmental budgets [6,9]

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
		shut down, and consequently the need for flaring. If one generator fail the other generator will "take over" the power generation in accordance to the defined shedding system, (fore cases when both generators are in operation).		
1.3	Have the following measures been considered for minimizing energy demand (when relevant)?			
1.3 a	BAT: well design to minimize water cut and minimize pressure loss	N/A, Snilehorn wells are designed for minimum water-cut.	(N/A)	
1.3 b	Subsea or downhole separation;	N/A.	(N/A)	Client's decision/philosophy.
1.3 c	Subsea compression or pumping;	N/A.	(N/A)	Client's decision/philosophy.
1.3 d	BAT: maximized operating pressure in first stage separator	To meet the oil specifications (RVP) the process is optimized by reducing pressure in 1st stage separator and thereby reduces the power demand and also the operational need for the new electrical heater (HA-23-0003). (To be able to reach the RVP<0.79 an electric oil heater	(G)	The capasity of the gas compression system is pending on the operating pressure in the separators. At lower operating pressures in the 1st

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
		is required downstream of the 2nd Stage Separator for some simulated cases.		stage separator, the compression capasity is lower and limited by either the available power (General Electric Nuovo Pignone LM2500/PGT25 gas turbine, or the maximum compressor speed. Lower pressure in 1.stage separator will therefore result in increased demand for the compressor. At the same time, reduction in pressure in 1.st stage separator will reduce the power demand for the new electrical heater (HA-23-0003) as well as the need for the electrical heater; the electrical heater will not be in operation through all the simulated years of production.) Lower pressure will result in higher/faster production and potential reduce the

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
				CO_2 emission per unit of production. Reduced pressure in 1.stage compressor will improve the stabilization and reduce the emission of VOC.
1.3 e	BAT: partly separate process trains for high and low pressure wells	Snilehorn: The process is designed with separate HP and LP manifolds, from 2027→ only LP will be used The electrical motor for 3rd stage compressor will be changed with a new electrical motor with increased capacity to meet new operation conditions. New motor for 3rd stage compressor is optimized in accordance to updated production profiles.	(G)	
1.3 f	BAT: use of turbo-expanders to utilize well pressure	N/A.	(N/A)	The existing system is designed with coolers and scrubbers to meet gas export specifications.
1.3 g	BAT: correct sizing of power demanding equipment to achieve maximum efficiency	Power demanding equipment evaluated: - Electrical heater - Compressors 1st stage compressor 2nd stage compressor	(G)	Electrical heater: The new electrical heater (HA-23-0003) will be thyristor controlled. The heater will be installed with four heating element of which three of these

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
		- Fresh Water generator - Water injection pump - Water injection booster pump		heating elements will be connected by circuit-breaker, the fourth heating element will be controlled by power electronics. The power consumption will by this be linear. The electrical heater will not be in operation through all the production years; pressure in 1st stage separator is reduced to reduce the power demand and the need for the new electrical heater. <u>Compressors:</u> 1st stage and 2nd stage compressor will be re-bundled to meet the flow rate and to minimize the need for recycling. <u>New Fresh Water (FW) Generator:</u> New Fresh Water Generators (2x100%) will replace existing Fresh Water

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
				Generation Skid During study two different solutions have been evaluated; Traditional evaporator design solution and Vapour Compression (VC) Evaporator design solutions. The traditional evaporation design is a solution where heating of sweater is done by the “traditional” heating: by use of external heating supply in general. For Njord A this would have been by use of electrical heaters. The Vapour Compression (VC) Evaporator design is a design with an internal heat loop in the system, generated by an integrated centrifugal compressor. The vapour compression

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
				process uses its own compressed steam as its primary heat sours, resulting in significant reduction of the electrical power consumptions; almost 1 MW, compared to the traditional design. The Vapour Compression (VC) Evaporator design is the preferred and also the chosen solution, meaning a power demand reduction of approximately 1MW compared to the traditional solution. <u>Water injection pump</u> Existing water injection package (XX-29-0004A) will be updated with new water injection pump. Since the start-up of Snilehorn tie-in is after the production start of Njord (Njord field and Hyme) the new Water Injection Pump will be

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
				designed for two bundles deigned for 5000 m^3/d and 10000 m^3/d respectively. <u>Water injection booster pump</u> Water injection system will be installed with a second Water Injection Booster pump. The number of pumps in operation will vary dependent on requirement.
1.3 h	BAT: use of variable speed drives on larger equipment with variable loads	Existing 1st stage and 2nd stage compressor are fixed speed, 3rd stage compressor is installed with VSD today.	(G)	The 1.st and 2nd stage compressor will be re-bundled. To meet the new increased capacity due to Snilehorn-tie in the 3rd. stage compressor will be changed with an increased electrical motor; the new motor will be installed with VSD. Other equipment relevant for VSD is not identified in accordance with scope

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
				of work in this FEED study.
1.3 i	Direct turbine drive or electric drive on large compressors, including consideration of future electrification	N/A, not part of scope, reference to Power from shore-study.	(N/A)	Unchanged.
1.3 j	BAT: waste heat recovery /process integration to minimize the need for fired heaters or electrical heaters	N/A, not part of the scope, WHRU. WHRU have been evaluated at an earlier phase of the project, for more detail see "Snilehorn tie-in to Njord A Concept Study Extension", Work package 1 – Oil Stabilisation with depletion production profile, (Technical Note no: Snilehorn WP1 Rev. 01.)	(N/A)	Electrical heater selected in concept study.
1.3 k	Multiphase pumping compared to gas-lift;	N/A, not part of scope. Hyme uses gas lift, Snilehorn extension on Hyme system.	(N/A)	
1.3 l	Use of flow improvers for oil export pipelines;	N/A.	(N/A)	Oil export pipelines are not changed, ref. SOW.
1.3 m	BAT: Energy use monitoring and control systems to allow optimum operation and tuning.	N/A, No change in monitoring and control systems, existing design.	(N/A)	
1.4	In order to increase the efficiency of energy production, have the following measures been considered:			
1.4 a	Gas turbine cycle enhancement, e.g. combined cycle	N/A	(N/A)	
1.4 b	Integrated or shared power generation with other installations, as well as the possibility of power supply from shore.	N/A, not part of scope. Reference is made to Power from shore study.	(N/A)	
	2 NOx control on engines/turbines (participants; Process and Mechanical)			

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
2.1	For larger engines (> 1 MW) that will normally be in operation (not stand-by or emergency use), NOx reducing measures should be considered, such as:			
2.1 a	BAT: selection of engine make with a low NOx emission rate	N/A. No new engines except fire water generators (emergency)	(N/A)	Fire water generator will normally not be in operation.
2.1 b	BAT: use of gas fuel if available at the installation	N/A.	(N/A)	
2.1 c	Has selective catalytic reduction or similar been used?	N/A.	(N/A)	
	3 Flaring and venting (participants; Process and partly Mechanical)			
3.1	The following elements should be evaluated:			
3.1 a	BAT: flare gas recovery systems (recycling of gas from high /low pressure relief systems during normal operation)	Existing design	(N/A)	
3.1 b	BAT: planning of start-up activities to reduce flaring;	N/A, design in accordance with Hyme and in accordance to flaring strategy. Start-up/shutdown of Snilehorn wells do not require flaring due to design consideration in pipeline design and hydrate philosophy.	(N/A)	
3.1 c	BAT: recovery of hydrocarbon gas used as blanket gas	Existing design	(N/A)	
3.1 d	BAT: avoid use of cold vent (venting of unburned gas)	Existing design	(N/A)	
	4 Oil storage and loading	**NA, not part of scope, separate project**		
4.1	Have FPSO, floating storage units, shuttle tankers, offshore and onshore loading systems been designed to minimize emissions of methane and NMVOC? This is considered BAT.	N/A	(N/A)	

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
4.2	The following measures should be considered, but not be limited to:			
4.2 a	BAT: sequential loading/unloading of oil	N/A	(N/A)	
4.2 b	BAT: optimized geometry of tanks with respect to evaporation of hydrocarbons	N/A	(N/A)	
4.2 c	BAT: loading/discharge rate with respect to evaporation	N/A	(N/A)	
4.2 d	BAT: use of hydrocarbon gas as blanket gas in floating storage tanks, with recovery	N/A	(N/A)	
4.2 e	BAT: installation of a VOC recovery plant to return NMVOC to crude oil (different technologies available).	N/A	(N/A)	
4.2 f	BAT: installation of a VOC recovery plant to condense NMVOC and use condensed liquid as fuel (different technologies available).	N/A	(N/A)	
4.2 g	BAT: incineration of VOC during loading operations (different technologies available).	N/A	(N/A)	
4.3	Is design optimized for Reid vapour pressure and true vapour pressure and temperature of the oil, in order to minimize emissions of methane and NMVOC? This is considered BAT.	N/A	(N/A)	
	5 Fugitive emissions and cold vents (Participants: Process and Mechanical)			
5.1	The process system should be designed to minimize emissions to air of hydrocarbon gas from different sections of the system. The gas should be either contained or routed back to the process system, if the pressure level and safety considerations allow this. This is considered BAT.			
	This applies, but is not limited to			
	• gas from seal oil traps,	To flare, recovered in flare system	(N/A)	
	• gas from sampling points,	To flare, recovered in flare system	(N/A)	
	• purge gas and leak gas,	To flare, recovered in flare system	(N/A)	
	• gas from start-up of the fuel gas system,	To flare, recovered in flare system	(N/A)	

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
	• gas from compressor seals,	To flare, recovered in flare system	(N/A)	
	• gas from produced water.	To flare, recovered in flare system	(N/A)	
5.2	Emissions of hydrocarbon gas to the air, including glycol and BTEX, from stripping processes should be minimized.			
	This is considered BAT. This can be done e.g. by use of:			
	• systems that do not require stripping gas (e.g. trace water extraction process)	N/A	(N/A)	
	• systems using low glycol concentrations,	N/A	(N/A)	
	• glycol recycle systems,	TEG regenerator system is recovered in flare	(N/A)	
	• systems that recover hydrocarbon stripping gas,	To flare, recovered in flare system	(N/A)	
	• systems based on vacuum deaeration systems using inert gas.	N/A	(N/A)	
	6 Well testing/well clean-up (Participant; Process)			
6.1	For testing on a mobile rig, have at least the following options been evaluated?			
	• downhole testing and separation;	N/A	(N/A)	
	• injection of the well fluid at location or at a nearby field, when test separators are designed to handle well stream from testing for this option;	N/A	(N/A)	
	• use of facilities with possibility to collect the oil produced during testing.	A start-up choke will be used in test phase and then replaced with a new, clean one. Disposal sand from seawater flushing through subsea pipelines will be collected.	(G)	

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
		Well clean-up is planned towards Njord A. All fluid/gas will be processing during the clean-up operation, some lower extend of degree of separation and with that lower product quality have to be expected during the clean-up operation, (WiO and OiW).		
	7 Produced water (Participant; Process)			
7.1	The order of priority for produced water management is:			
	1. Minimisation of water production.	Snilehorn well is planned with shut-off from water producing zones due to high barium content in formation water (risk for scaling). The water production will be low.	(G)	
	2. Re-injection to reservoir to maintain pressure.	No available reservoir witch can stand re-injection for Njord A.	(N/A)	
	3. Injection to other geological formations	No available reservoir witch can stand re-injection for Njord A.	(N/A)	
	4. Treatment (cleaning) and discharge to sea	Produced water will be cleaned before discharged to sea. Njord A uses hydro cyclones and degasser.	(G)	A dual stage CFU will be installed in the produced water system between the hydro cyclones and the degassing drum, this CFU will improve the quality of the produced water dumped to se. The oil in water leaving the CFU will have an oil content <10 ppm. The cleaning

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
				effect/degree of cleaning of existing hydro cyclones on Njord A will be increased due to installation of automatic back flush on hydro cyclones Sampling facilities for the produced water system will be improved; one new sampling point will be installed downstream CFU. All sampling point will be connected to a new sampling cabinet. The risk for personnel exposure due to sampling will therefore be reduced.
	Points 2-4 have to be evaluated for each project to conclude on which is BAT. Point 1 is considered BAT.	See point 4.	(G)	
	8 Drain system (Participant; Process)			
8.1	Have the number of stages for water from the	N/A, not part of scope	(N/A)	

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
	open drain system been evaluated?			
8.2	Have injection of contaminated drainage been considered, especially drainage from the drilling area, which may be injected together with contaminated cuttings.	N/A	(N/A)	
8.3	Have the deck drainage system been sized to accommodate above average rainfall events for location?	Tie in to existing drain system.	(G)	Deck drainage will be ensured for new areas and in accordance with new firewater rates. New/increased drain areas will be connected to existing drain system. Scope of work is limited to capacity check of existing system, but no further evaluation for the existing drain system.
8.4	Has the handling of drilling effluents been separated from the deck drainage system?	N/A	(N/A)	
	9 Displacement water (Participant; Process)			
9.1	Have treatment of displacement water been evaluated?	N/A	(N/A)	
9.2	Have the need for separate treatment of the emulsion/slop phase near the water/oil contact been evaluated?	N/A	(N/A)	
	10 Discharges from drilling and well operations (Participant; Process)			
10.1	BAT: Minimization of discharges of drilling waste to sea.	N/A not part of scope	(N/A)	
10.2	Have the following technologies been	N/A not part of scope	(N/A)	

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
	evaluated?			
	• slim hole drilling;			
	• branched drilling;			
	• batch drilling;			
	• injection of drill cuttings and used drilling mud;			
	• injection of cementing chemicals (excess mix-water);			
	• injection of completion chemicals;			
	• injection of slop- and drainage water;			
	• BAT: reuse of drilling mud;			
	• BAT: heavy metal free pipe dope.			
10.3	• BAT: Mud and cuttings handling systems designed to minimize waste generation and the risk of spills.	N/A, new conventional shakers based on decision in c-study.	(N/A)	Compliant based on scope of work
10.4	BAT: Discharges from cementing is minimized.	N/A not part of scope	(N/A)	
	11 Produced sand (Participants; Process)			
11.1	Has disposal options for produced sand been considered:			
	• injection into a subsea geological structure,	N/A, not part of scope	(N/A)	
	• cleaning and discharge to sea,	N/A, a new separator internal sand removal system is planned introduced as part of modifications to 1st stage separator	(N/A)	
	Minimization of sand production	The Njord wells are generally completed with cemented perforated liner, oriented perforation in slanted wells as sand control measure. The Hyme producer is completed with stand-alone screens (SAS). The water injector is completed with gravel packed screens/7/.	(G)	

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
		The producer wells will be completed with cemented liner and oriented perforations in the zones prone to sand production/7/.		
	Monitoring of sand in the production flow	Sand probes will be installed to monitor the level of sand in the flowlines.	(G)	
	• shipment ashore for treatment and disposal.	NA	(N/A)	
	12 Chemicals and materials (Participants; Process)			
12.1	BAT: Choice of materials not requiring corrosion inhibitor	NA, included in design	(N/A)	
12.2	BAT: Material selection to limit the use of chemicals.	NA, included in design	(N/A)	
12.3	BAT: System designed with heat tracing to limit use of chemicals,	Safety critical heat trace included where applicable.	(G)	
12.4	BAT: Direct Electrical heating (DEH)	PiI: Pipe in pipe electrical heat trace (PIP EHT) will be used for the flowline.	(G)	As for DEH system, the PIP EHT will reduce the need for chemical injection for prevention of hydrate or wax formation; in addition the EHT is considered more energy efficient compared to the DHE system, due to the low U-factor. As an

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
				example DHE system is given to have an overall heat transfer coefficient of 5W/m^{2}K while an ETH PIP system (Technip's data used as an example) is given to have a U-values performance down to 0,6W/m^{2}K.
12.5	BAT: Use of environmental friendly chemicals	Snilehorn: No new chemicals identified in this FEED study. Existing chemicals will be used (Scale inhibitor and MEG) Pil: The tie-in of PIL will require chemical injection of the following chemicals: - Asphaltene inhibitor EPT-3035; Downhole injection, subsea flow control valve. Pump capacity 800 l/d - Scale inhibitor SI-4471; Downhole injection, subsea flow control valve. Topside injection upstream choke. Pump capacity 200 l/d - Emulsion breaker EB-8580; subsea manifold injection, Topside injection upstream choke. Pump capacity 500 l/d - Pour point depress/WAX inhibitor EPT-3345; Subsea injection upstream choke, subsea flow control, Topside injection downstream oil export pumps. Pump capacity 5000 l/d /Pump capacity 2400 l/d downstream oil export pumps or from subsea pump	(G)	The amount of chemicals used in production will increase in proportion with the increased production. Chemicals will be further followed up in next project phase Chemicals used on Njord today is a part the yearly substitution evaluation performed by Company.

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
		- H_2S scavenger (Future scope) The H_2S proposed injection point is on the gas outlet from the 1st stage separator, downstream inlet from test separator and 3rd stage compressor. Chemicals; Asphaltene inhibitor (EPT-3035), Scale inhibitor (SI-44-71) and Emulision breaker (EB-8580) is not classified as environmentally hazardous, however this does not exclude the possibility that large or frequent spill can have harmful or damaging effect on the environment. The emulsion breaker may be harmful to aquatic life with long lasting effects. The pour point depress/wax inhibitor is classified as a category 2 chemicals in accordance to environmental hazard, the chemical is very toxic to aquatic life with long lasting effects Proposed H_2S chemicals HR-2709 or HR-2510 is not classified as environmentally hazardous, but large or frequent spill can have a harmful or damaging effect on the environment. Total MEG consumption will increase due to increased number of consumers; MEG will only be required for startup and shut-down operations.		
12.6	Design of in-deck spill tank	Design from C-study was to have overflow from chemical in-deck spill tank to the bilge system, meaning a possibility for chemicals dumped to sea, new evaluation is performed for the design in the FEED study.	(G)	Design in FEED: In deck spill tank will be increased in size in accordance to the first proposed design, in deck spill tank will be optimized with a volume of 21,9m^3. Any

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
				overflow from in-deck spill tank will accumulate on deck level in watertight room.
	13 Cooling water (Participants; Process)			
13.1	Has the intake of cooling water (depth) been optimized with respect to minimize the need for use of chemicals to prevent marine fouling, i.e. growth of algae, mussels, etc.? This is considered BAT.	The highest point on the strainer will be at elevation -40m to ensure that the water temperature is cold and contains a minimum amount of organic material (existing philosophy)	(G)	
	14 Waste (Participants; Process, Mechanical and electro)			
14.1	Has waste been minimized through the design and the choice of materials and chemicals? This is considered BAT.	Reuse of equipment is a continuous evaluation throughout the project.	(G)	
14.2	Has equipment and facility maintenance been addressed with regard to generation, containment and storage, and handling of waste materials?	As existing philosophy	(G)	
14.3	BAT: Discharge of slop water to sea.	As existing philosophy	(N/A)	
	15 Decommissioning (Participants; Process, Mechanical and electro)			
15.1	Have decommissioning been considered in design for reuse, recycling or final disposal on land?	N/A	(N/A)	
15.2	BAT: Design for easy decommissioning.	N/A	(N/A)	
	16 Subsea installations (Participants; Process)			
16.1	Has a system for leak detection been included in design?	Snilehorn; acoustic monitoring/PALL in flowline	(G)	

	Technique	Status/Report reference	Compliance with BAT (G/Y/R)	Actions/Comment
16.2	Has the environmental impact of the subsea installation(s) been considered	N/A, sea-bed inspections is performed in area.	(N/A)	

7 REFERENCES

/1/ Statoil TR011 Environmental requirements for offshore installations

/2/ NORSOK S-003 Environmental Care

/3/ Statoil GL0300 Guideline for evaluation for Best Available Techniques (BAT)

/4/ Njord Future Project Framework Agreement No. 4600055357, Call-off Contract FEED Contract No. 4503385581, Appendix A, Annex A1 Scope of Work

/5/ PM566-PMS-050-009 Master Design Basis – Njord Future Project, Draft Ver. 2

/6/ 100081-KS-3002 Environmental Budget Njord Future FEED

/7/ Design Basis – Snilehorn project – PM508-PMS-050-001 Rev 4

/8/ IED; Directive 2010/75/EU, 17 December 2010, established as a general framework for the control of the principal industrial activities/processes with a view to controlling emission to air arising from the industrial installation into air, water and oil.

/9/ 100081-KS-5030 Environmental Budget Pil tie-in