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Wisting FPSO FEED

BAT Assessment Report

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Revision history

Rev	Section	Changes
F01		First revision
F02		Comments from Company implemented
F02	3.2	BAT Screening colour coding added

Hold list

Hold	Description
	Uncertain if there is a need of an exhaust cooler

1 DEFINITIONS AND ABBREVIATIONS

Table 1: Definition and abbreviations

Abbreviation	Definition
BAT	Best Available Techniques
CAPEX	Capital Cost
CIP	Clean-in-place
Company	Equinor AS
Contractor	Aker Solutions AS
FEED	Front End Engineering and Design
FPSO	Floating Production Storage Offloading vessel
GHG	Greenhouse Gas
GIS	Gas Insulated Switchboard
GOR	Gas-to-oil
HVAC	Heating, ventilation & air conditioning
HVDC	High voltage direct current
kW	Kilowatt
MW	Megawatt
NCS	Norwegian Continental Shelf
NMVOC	Non-methane Volatile Organic Compound
NORSOK	Norwegian Standard developed by the Norwegian Petroleum Industry
OPEX	Operating cost
PSA	Petroleum Safety Authority
RO	Reverse Osmosis
SF6	Sulphur hexafluoride
SRU	Sulphate removal Unit
TEG	Triethylene glycol
VFD	Variable frequency drive
VOC	Volatile organic compound
VRU	Vapor Recovery Unit
VSD	Variable speed drive

2 INTRODUCTION

The Wisting Production Licence (PL537/537b) is located on the Norwegian Continental Shelf (NCS) in the Barents Sea, approximately 300 km off the northern coast of Norway. The water depth is approximately 400 m. The environment is characterized by a lack of existing infrastructure and a relatively harsh Arctic climate.

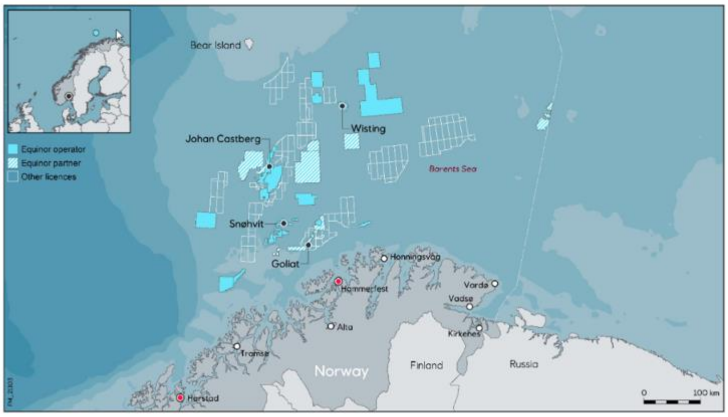

Figure 1: Wisting FPSO and location map

The Wisting field development project comprises the Wisting Central and Hanssen fields. The drainage strategy is based on combined sea and produced water injection for pressure support. The gas management philosophy is to export gas. The development concept involves subsea facilities tied back to a new-built circular floating production unit (FPSO) for storage and offloading to shuttle tankers. The subsea facilities comprise a Central Processing Station (CPS) to which the Central and Hanssen production wells are tied back. The offshore facilities are supplied with electrical power from the onshore grid through a converter station in Hyggevann, Finnmark.

The FPSO facility design life is 30 years. The main objective of the Wisting field operations is to maximize the asset value for society and for the PL 537 license holders. This will be achieved by a digitally enabled operating model that will ensure that operations are:

- Always safe
- Establishing and maintaining low offshore manning
- Delivering low OPEX
- Delivering overall low carbon emissions
- Delivering specified Production Efficiency
- Maximizing value and recovery
- Supporting sound risk management
- Supporting strategic local benefits

The overall operations and maintenance strategy for Wisting is based on highly automated, low manned and low maintenance facilities with high regularity.

2.1 OBJECTIVE

The objective of this report is to describe the environmental requirements and impacts during the operation of the Wisting floating production storage offloading unit (FPSO) and document the environmental evaluations that have been performed during Front End Engineering and Design (FEED) phase. BAT evaluations performed in Concept and by Company are referred to where relevant. For all technologies concerned, the optimum solution is the Best Available Techniques (BAT) principle.

The assessment performed shall ensure that the environmental performance of all technologies/techniques are as good as possible, taking maturity, cost, and practicalities into considerations. BAT evaluations are to be used as a part of the decision-making process and as a tool to continuously improve the design of the installation. Additionally, it is required by the Norwegian Environmental Authorities to perform BAT assessments in application for operation permits.

This report is based on the Design Basis for Wisting FPSO [3], and BAT evaluations performed in Concept phase [11]. Environmental Aspects were identified and evaluated in the Environmental Design Review [2]. Quantification of emissions to air and discharge to sea during operation can be found in the Environmental Budget Report [9] and the Waste handling is described in the Waste Management Report [10].

2.2 SCOPE

The scope for Aker Solution is the entire FPSO. However, where there is an interface of environmental significance, a BAT discussion will be included.

2.3 REGULATIONS, REQUIREMENTS AND GUIDELINES

The order of priority of interpreting governance of standards is defined as follows:

- Authority laws, rules and regulations
- Design Basis
- Functional requirements
- Technical requirements
- Frame agreements
- NORSOK and national/international guidelines

Authority laws, rules and regulations

Norwegian legislation regarding health, safety and the environment is covered by the regulations by the Petroleum Safety Authority (PSA).

In Norway it is required that the design of all new installations shall be in accordance with the Directive on Industrial Emissions 2010/75/EU (IED). Emission limits in The Discharge Permit granted by The Norwegian Environment Agency will be based on BAT.

International regulations for FPSOs are governed by the MARPOL regulations (Maritime regulations).

Company requirements

- Design Basis for Wisting FPSO [3]
- Functional and design requirements Topside Wisting [12]
- Functional and design requirements Living quarter area and helideck [13]
- Functional and design requirements Hull [14]
- TR1011, Environmental requirements for offshore installations [15]

Company guidelines

- GL0300 Guideline for Best Available Techniques [4]

Other governing guidelines

- BREF guideline Best Available Techniques (BAT) developed under the IED [17]
- NORSOK Standard S-003: Environmental Care [16]

3 WORK METHOD

3.1 BAT DEFINITION

BAT is defined in the Norwegian pollution regulation §36, appendix II. This definition is aligned with the definition in the Directive 2010/75/EU on industrial emissions [5] and is described below:

"Best" - Most effective alternative in achieving a high general level of protection of the environment as a whole.
"Available" – Those techniques developed on a scale which allow implementation in the relevant industrial. sector, under economically and technically viable conditions, taking into consideration the costs and advantages, whether or not the techniques are used or produced in Norway, as long as they are reasonably accessible to the activity
"Techniques" - Shall include both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned.

Alternative concepts and technologies shall be identified and evaluated according to the BAT principle in order to find the best technical solutions to protect the environment, based on a balance between the environmental benefits they bring, the costs to implement them and the practicalities of using them. Technology selection shall be prioritised in the following order: prevent, minimise, mitigate and compensate.

The process requires input from several disciplines, where the evaluation process and the suggested BAT solutions shall be documented.

3.2 METHOD FOR BAT EVALUATIONS

This report follows the BAT assessment methodology, which is described in the Norwegian Oil and Gas guideline no 147 [1]. The assessment process is illustrated in Figure 2 below and consists of the following four main steps:

- Identify systems/equipment relevant for BAT assessment
- Screen possible alternatives
- Assess the alternatives: environmental performance, economy, technical applicability
- Select the best technique/option

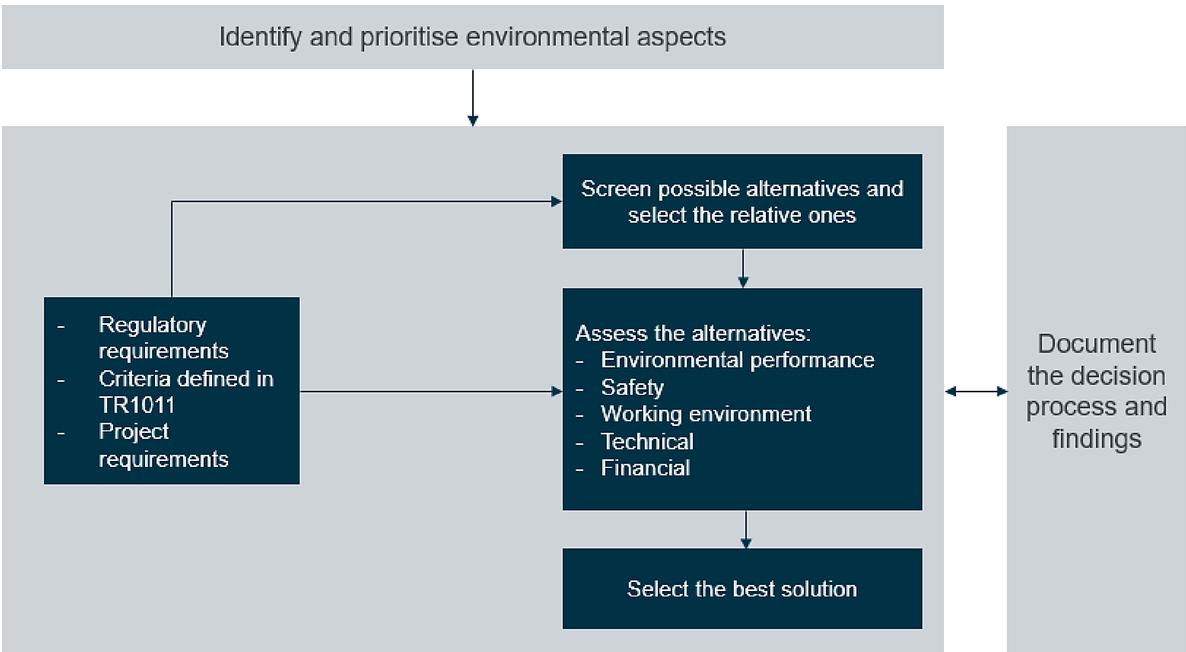

Figure 2: Methodology for the BAT assessment process [1]

A simple colour coding screening is used as the highest level of assessment. The screening will screen out the alternatives that are found not applicable, for instance if any solutions are non-compliant with regulatory requirements, technically not feasible or economically impossible. The different colours give a visual overview of the key findings, and it is often an intuitively way to interpret a ranking [1].

Table 2: BAT Screening colour coding [1]

Performance
Good performance/low impact, technically and economically feasible
Challenging performance/moderate impact, technical availability issues, economically challenging - or high uncertainty
Not acceptable/feasible
Not relevant

3.3 ENVIRONMENTAL DESIGN REVIEW

An Environmental Design Review was performed to ensure proper attention to the environmental issues. The review was performed in two parts, one for Topside and Hull in February and one for living quarter (LQ) in March. The Environmental Design Review from Concept phase was used as a basis and environmental aspects and corresponding mitigating measures were reviewed and updated [2]. New aspects and measures were also identified. The GL0300 checklist [4] was used to structure the review and the focus was energy management and energy efficiency, discharges to sea, emission to air and waste. The actions from the review have been included in the Product Assurance Register (PAR) system for follow-up and close-out. The results have been used as a basis for BAT assessment report.

4 PROJECT DESCRIPTION

4.1 DESIGN BASIS

The development for the Wisting FPSO shall be designed for the capacities [3] listed in the table below.

Table 3: Wisting field capacities [3]

Capacity	**Requirement**
Oil production	23 850 Sm3/d
Produced water production	25 000 Sm3/d
Liquid production	35 000 Sm3/d
Gas production	1 700 000 Sm3/d
Gas export treatment & compression	1 700 000 Sm3/d
Gas export pipeline	2 500 000 Sm3/d
Seawater Injection	28 750 Sm3/d
Water Injection	32 000 Sm3/d

4.2 MAIN PROCESS OVERVIEW

The figure below offers a simplified overview of the main process systems topside, which are addressed in this report. Oil is stored in the hull and periodically offloaded to a shuttle tanker.

Produced water is injected for pressure support, supplemented by treated seawater. Seawater treatment is not represented in figure 3.

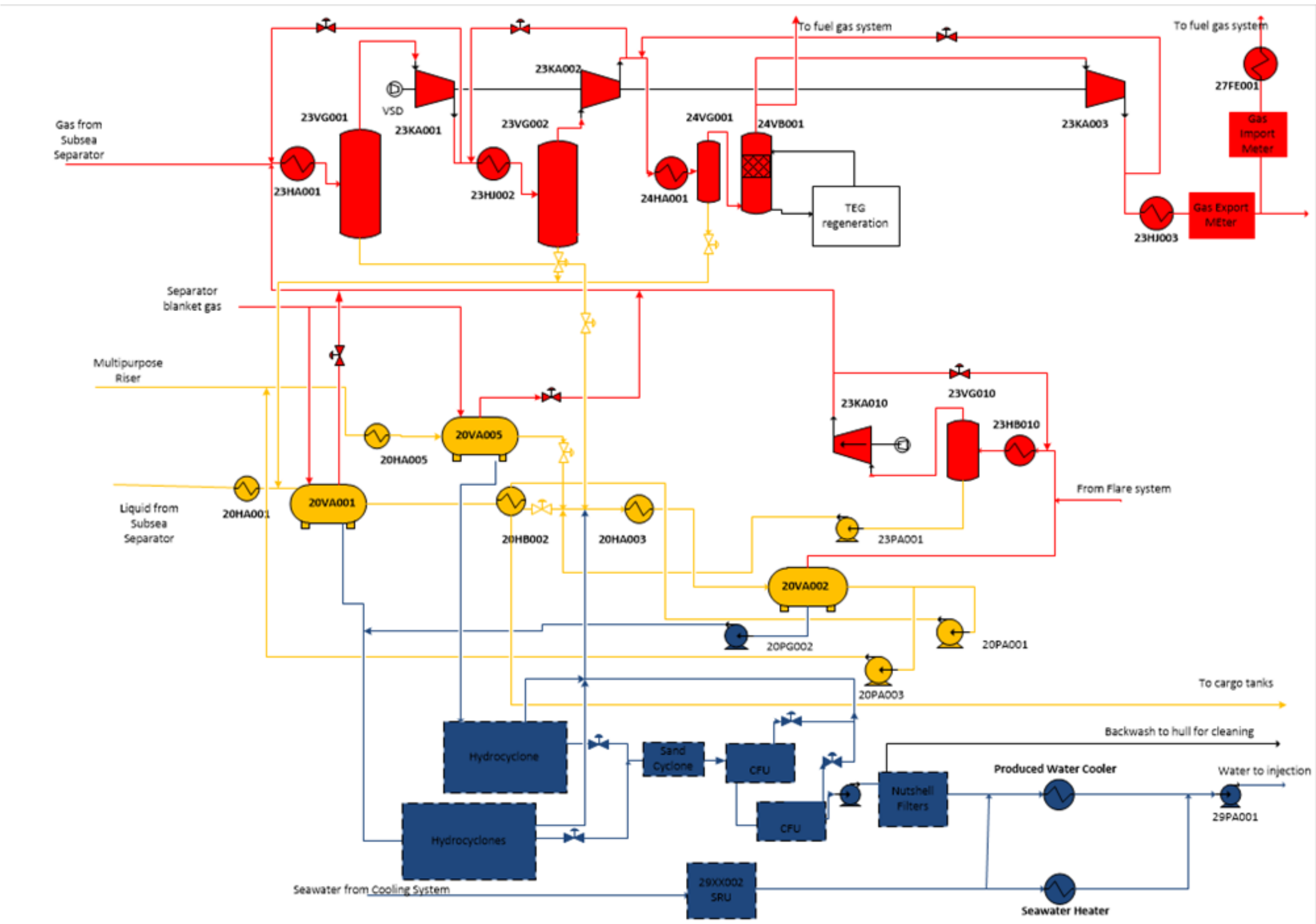

Figure 3: Simplified block diagram of main process systems [6]

5 ENERGY MANAGEMENT AND ENERGY EFFICIENCY

Wisting is supplied with power from shore which covers all power and heat consumers during normal operations, meaning no local emissions associated with energy use. However, energy management and energy efficiency are still an important factor with regards to environmental impact and sustainability, as well as expenses.

5.1 GOALS AND REQUIREMENTS

Table 4: Requirements for energy management and energy efficiency

Standard/ Guideline	Chapter	Requirements
TR1011 (v.7.02)	2.2	Facilities and systems shall be designed and operated to minimise energy demand and optimise energy efficiency. Combined heat and power, waste heat recovery and integrated or shared power generation with other facilities shall be included in design studies.
TR1011 (v.7.02)	Tables A1 & A2	Provides minimum performance standard for emissions from small combustion facilities and thermal power plants.
NORSOK S-003 (rev.04)	5.1	Improve overall energy efficiency of the facility by reducing the energy demand/intensity, increase the efficiency of energy generation and utilization, in order to minimise emissions to air

5.2 POWER AND HEAT SUPPLY

The FPSO is supplied with power from shore, and it covers all power and heat consumers during normal operation. Power from shore is considered BAT and has normally no local emissions associated with energy use. This means that no fired heaters or waste heat from power generators is available in normal operation and all heating requirements will be supplied by electrical power. Therefore, it is important to minimize heat requirement since heat is much more expensive than on a traditional installation with power generated by gas turbines with waste heat units [6].

Process heat is provided by heating medium being circulated to the process heat exchangers via a closed loop system. Heating medium is heated by use of electrode heater heating system. The warm cooling medium from the compressor discharge coolers are also used for heating of the secondary heating medium for HVAC and the amount of heat available to the secondary heating medium [6].

5.3 POWER DEMAND

The average power consumption is expected to be between 50 and 60 MW for the peak years and between 40 and 50 MW in late life after re-bundling of compressors. The figure below demonstrates that heat is the most dominant energy consumer [6].

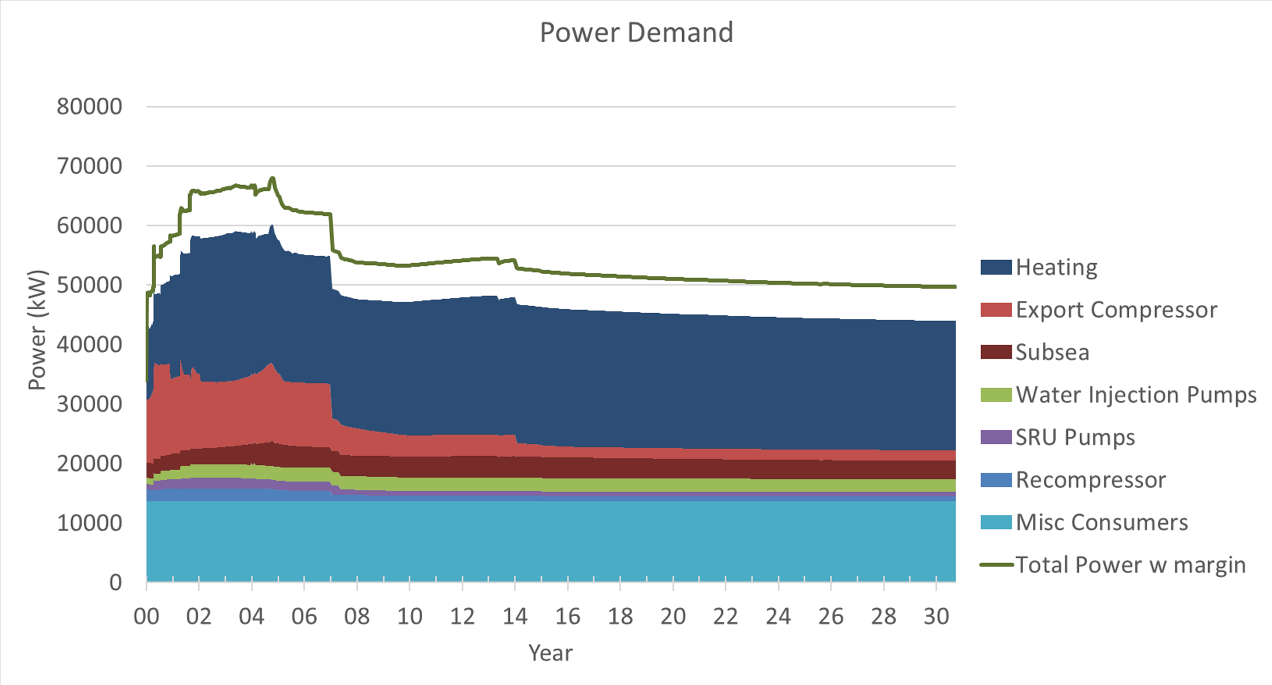

Figure 4: Wisting expected power consumption (without offloading) [6]

Re-bundling is due to the rapidly declining gas production. Without re-bundling there would be more excess heat available for secondary heating medium, but the peak power is not affected by re-bundling of compressors. The re-bundling affects late life power consumption. The late life power consumption is reduced from ~55 MW to ~45 MW by the re-bundling, which will reduce OPEX considerably. The actual time of re-bundling naturally needs to be considered during production and based on the updated production profiles in production. Re-bundling of compressors should be prepared for [6].

Offloading is generally not considered in the profiles but is included in the profile below to see the effect on maximum power.

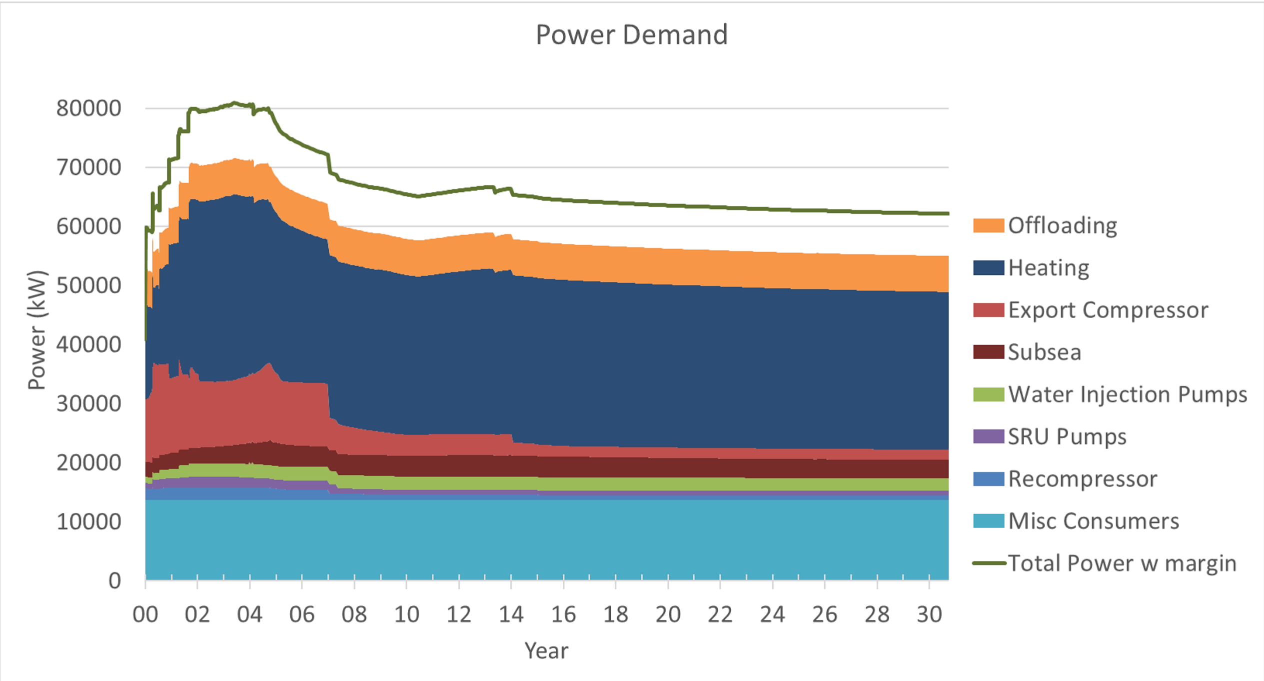

Figure 5: Power consumption with offloading [6]

5.4 HEAT DEMAND

The average heat consumption is expected to be approximately 25 MW. There are process heaters upstream the Inlet Separator, the Test Separator and the 2nd Stage Separator in the oil train. The Inlet Heater and the Oil Stabilisation heater are the main continuous heat consumers on the topside since the Test Separator Inlet Heater is not used in normal operation. Dependent on the temperature requirement for water injection the seawater heater can also be in operation in normal mode. There is also heat requirement in the hull, mainly to keep the oil cargo above 25 °C. All compressors and pumps at the facility are electrically driven. There are also some small electrical heaters, e.g. heaters in the fuel gas system and heaters being integrated in vessels for winterization purposes (e.g Flare KO Drum and Closed Drain tank) [6].

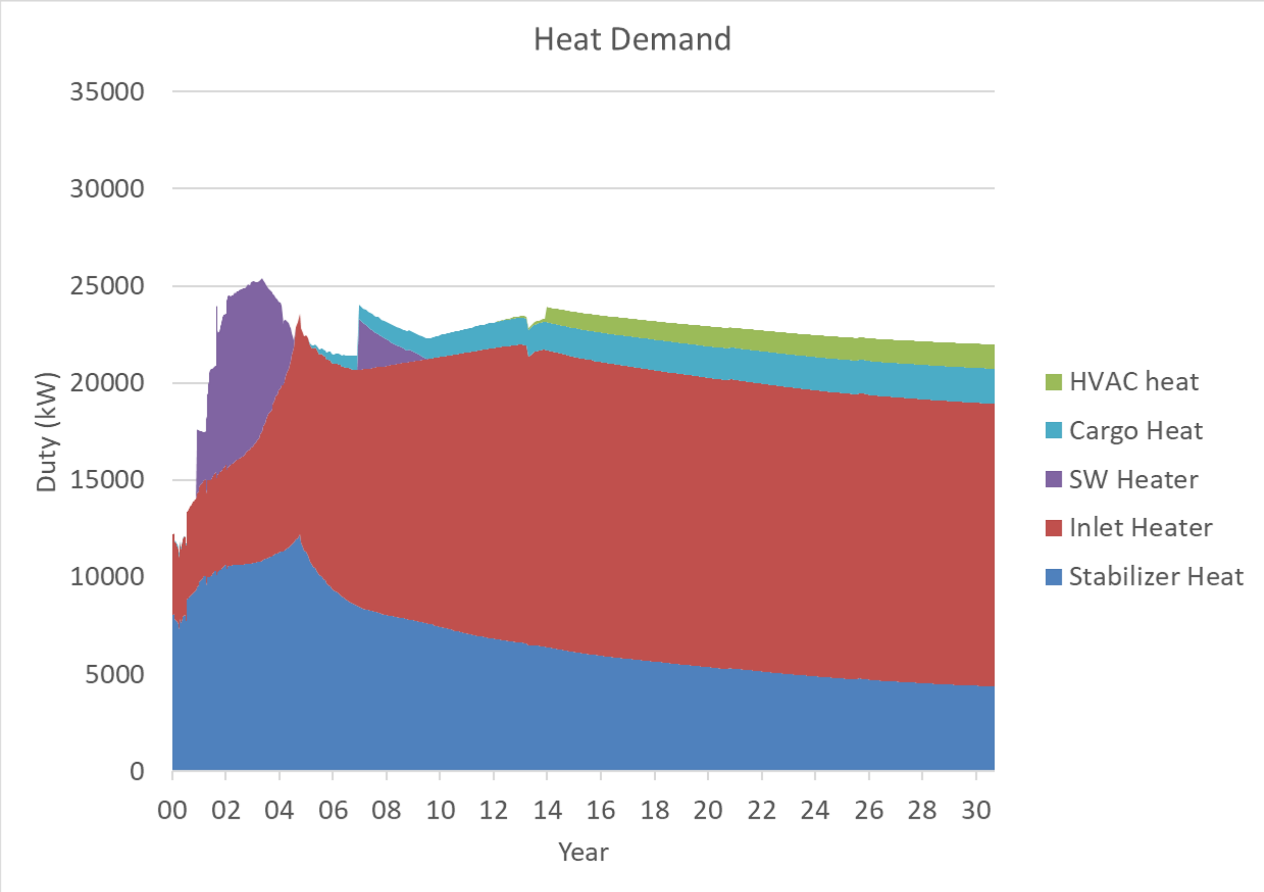

Figure 6: Wisting average expected heating requirement [6]

Every heating duty in the figure above is heated by the main heating medium system, with one exception: the HVAC. HVAC is supplied via the secondary heating medium, which is heated by recovered heat from the cooling medium in system 40. Different scenarios have been simulated to estimate the total electrical heat requirement. Since it is possible to heat the secondary heating system by using the electrode boiler, for when it is not sufficient heat in system 40 or system 40 is not in operation, the total duty shown in the figures below will be the total load on the electrode boiler skids. With maximum load on HVAC the total heat demand in the heating medium system (without margin) is given in Figure 4 and Figure 5 for the minimum and maximum seawater injection temperatures [6].

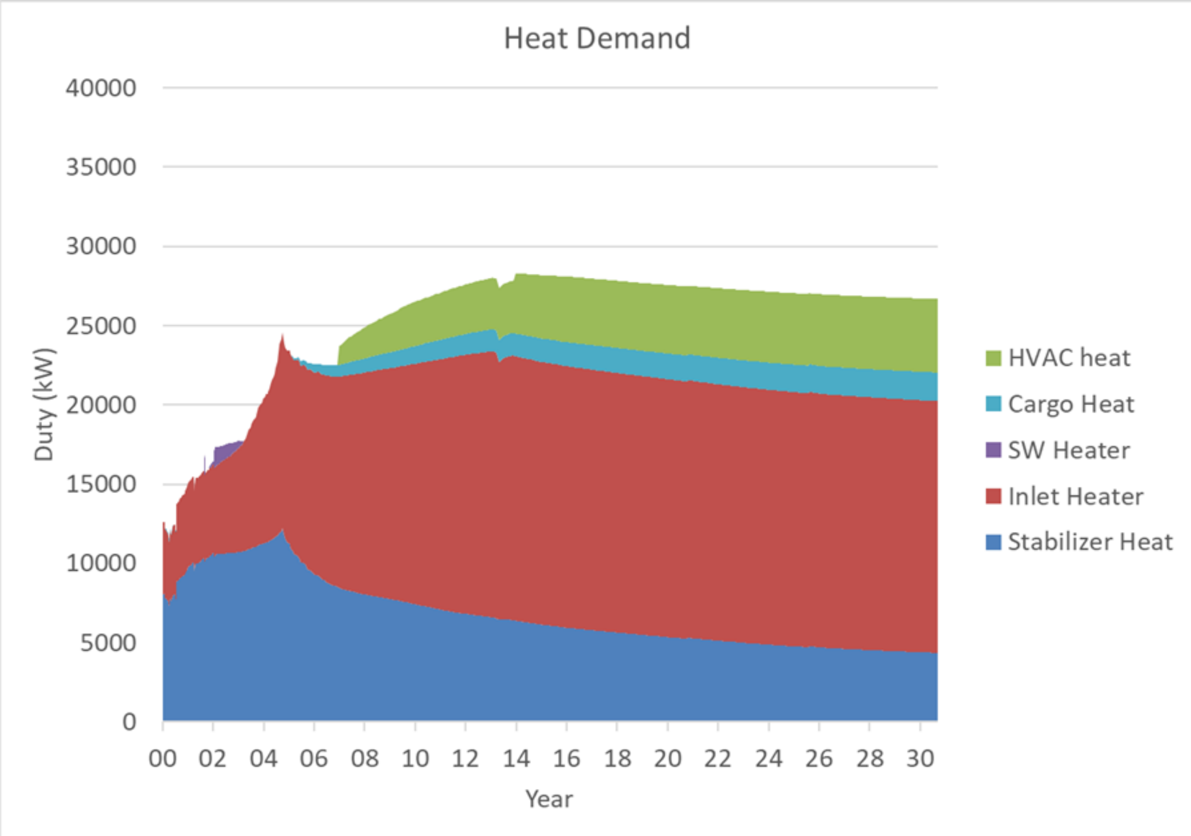

Figure 7: Heat Demand, 11 °C injection water temperature, 3 °C seawater temperature, maximum HVAC heat load, maximum export pressure [6]

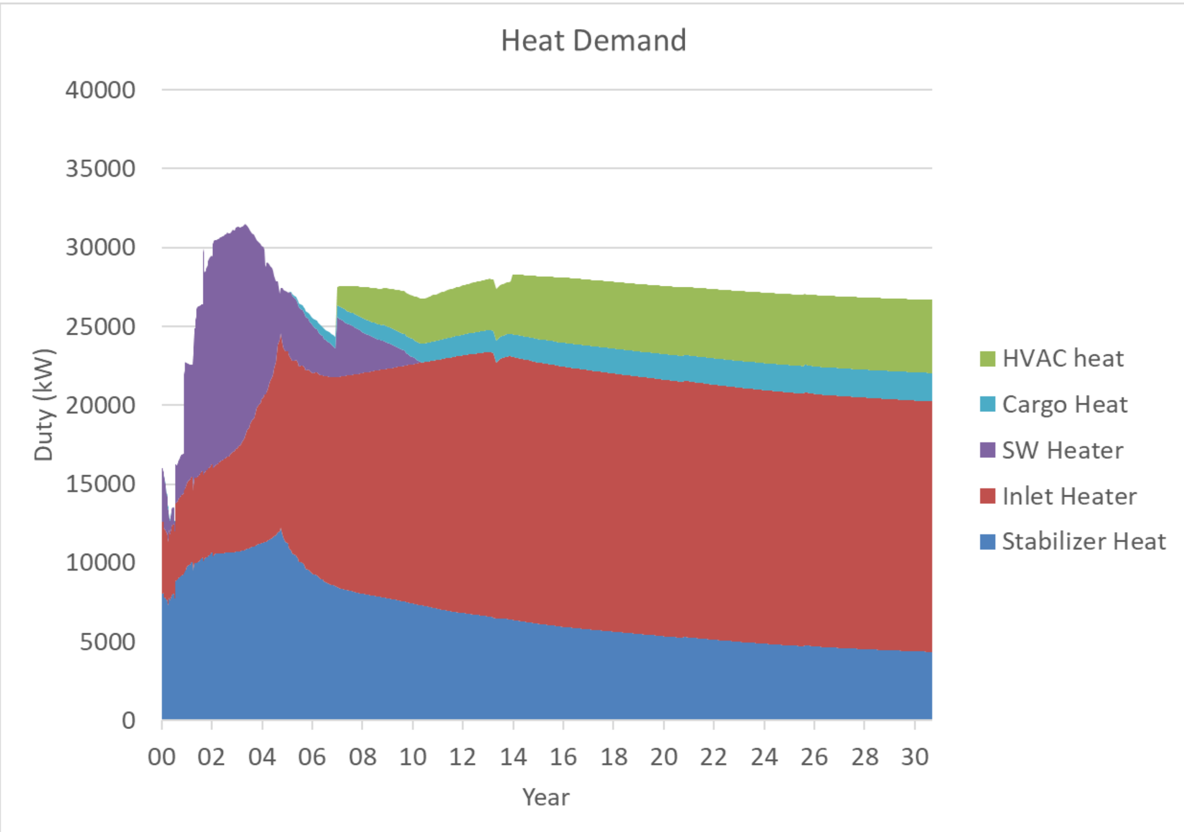

Figure 8: Heat Demand, 20 °C injection water temperature, 3 °C seawater temperature, maximum HVAC heat load, maximum export pressure [6]

It is also seen from the two figures above that an injection water temperature of 11 °C requires no or low additional heating, while maximum seawater injection rates at 20 °C requires more than 10 MW of additional heat. This also means that the seawater injection temperature is one of the main parameters to be optimized to save power on the facility during the first years of operation. No additional HVAC heating is required before re-bundling of the compressors as there is sufficient heat from the coolers, and in the first five years of production there is also sufficient heat in the oil to cargo to avoid using the cargo heating coils [6].

5.5 ENERGY EFFICIENCY EVALUATIONS

5.5.1 Heat integration

Oil stabilisation (inlet heat and stabiliser heat in Figure 6, 7 and 8) is the dominant heat consumer, with notable other consumers being HVAC, seawater injection and cargo heating. Aside from cargo heating, all significant consumers benefit from heat integration to minimise the demand on the heating medium, which is supplied by electrode boilers.

5.5.1.1 Oil stabilisation

The Crude-Crude Exchanger (20HB002) reduces the heat demand for oil stabilisation by up to 18 MW during plateau production. This exchanges heat between the hot oil exiting the 2nd Stage Separator, which must be cooled before reaching the cargo tanks, with the cooler oil upstream of the same separator, hence relieving the load on the Crude Oil Stabiliser Heater (20HB003A/B) which is supplied from the heating medium [11].

The Inlet Heater (20HA001) is also supplied from the heating medium and is required to raise the inlet oil from 13-15°C to 25°C for the benefit of the 1st Stage Separator. The base case design does not include any heat integration to minimise this heater's duty, however Aker Solutions have quantified that over 1 200 GWh would be saved by integrating heat from the produced water stream entering the Produced Water Coolers (44HB001A/B) at around 25°C (assuming a 13°C arrival temperature)[11].

The duty on the inlet heater generally increases through the production years, which correlates with the increasing rates of produced water handled. Although this is a very good fit from a heat integration perspective, its implementation will not affect the design duty of the heating medium system (i.e. the electrical boilers would not be reduced in size since their sizing case is not affected), lessening the attractiveness from a CAPEX perspective despite the OPEX benefits [11]. Company will gain operational experience before concluding on this matter. A new BAT assessment will be conducted after a few years of production, when the production of produced water has reached a significant amount.

5.5.1.2 Gas compression

The gas compression system is not a heat consumer, however it does handle both hot gas that needs to be cooled, and cold liquid knock-out from the scrubbers which must be returned to an oil stabilisation system which demands heat. In principle this provides an opportunity for heat integration, however Wisting's low gas-to-oil ratio (GOR) means that the liquid knock-out flowrates are very small compared to the oil passing through the separators. Hence there are marginal gains in terms of heating medium duty (10's kW) but significant implications in terms of CAPEX to implement the additional heat exchangers required. Such opportunities have hence not been pursued [11].

5.5.2 Driver selection

Table 5: Driver selection for main loads [18]

Equipment	Tag	Configuration	Shaft power each (MW)	Driver selection
Recompressor	23XX010	1 x 100%	1.65	Electrical motor with VSD (Variable Speed Drive) Voith Vorecon
1st,2nd,3rd stage Export Compressor	23XX104	1 x 100%	14	Electrical motor with VFD (Variable Frequency Drive)
Water Injection Pumps	29PA001A/B/C/D	4 x 25%	0.53	Fixed speed electrical motor
Water Injection/Fracking Pump	29PA001E	1 x 25%	0.6	Electrical motor with VFD (Variable Frequency Drive)
VOC Recovery Compressor Package	43XX001	1 x 100%	0.34	Fixed speed electric motor
Seawater lift pumps	50PS601A/B/C	3 x 50%	1.15	Fixed speed electric submersible motors

Speed control – either mechanical variable speed drives (VSD) or electrical variable frequency drives (VFD) is selected for all of the largest loads, allowing the shaft power to be optimised for varying fluid flowrates through the equipment.

5.5.2.1 Gas compressors

For the Recompressor, a “Voith Vorecon” unit has been selected, which is a form of mechanical speed control which connects a fixed speed electrical motor to the compressor via a hydraulic coupling / torque converter. Its efficiency at 100% speed is identical to the VFD alternative and remains similar down to 70% of the maximum compressor speed, after which the efficiency drops significantly [11]. Compressor speed ranges are normally limited, hence it is anticipated that the Voith Vorecon’s efficiency is not significantly different to a VFD within the operating speed range. Any efficiency gap is expected to be limited to an order of 10’s kW. Given that the Voith Vorecon offers lower area, weight and maintenance frequencies compared to VFD, its selection is considered appropriate.

5.5.2.2 Water injection pumps

The Water Injection Pumps handle both produced water and seawater and are, in practice, configured as 5x25% - the “E” pump benefits from VFD to enable higher pressures for fracking operations, and otherwise can be utilised as a regular injection pump. The remaining four pumps are driven by a fixed speed motor (i.e. no speed control). This has not been challenged from an energy efficiency perspective because of the limited variation in water injection rates. The pumps will be operating at an almost constant duty point, hence there is almost no energy efficiency benefit to be gained by speed control. On the contrary, the losses across a VFD are typically 4% (REF). which are omitted by choosing fixed speed [11]. As long as the Water Injection Pumps (A//D) are procured with their best efficiency point correctly targeted, fixed speed is expected to be the most efficient option.

5.5.2.3 Seawater lift pumps

The variation in sea water flow during operation of the Wisting platform is considered to be marginal. The throttling alternative is therefore the solution that appears most attractive. It is also feedback from operation that variable speed capabilities for sea water lift pumps may complicate start up and operation of the sea water system. The recommendation for these pumps is to use fixed speed motors[11].

6 EMISSIONS TO AIR

Power and heat will be supplied from shore via the high voltage direct current (HVDC) module. This will supply Wisting with 105 MW and will result in no local emissions.

6.1 GOALS AND REQUIREMENTS

Table 6: Requirements and standards related to emissions to air

Area of env. impact	Standard/ Guideline	Requirements
General	TR1011 (v.7.02)	Emissions to air shall be minimised. Cold venting (venting of unburned gas) shall be avoided. Improvement targets and action plans shall be established, based on identified significant environmental aspect of the technology/plant.
	NORSOK S-003 (rev.04)	Mitigating measures shall be identified and implemented according to BAT principle. Focus shall be given to reduce emissions by design features and through energy optimisation.
CO2	TR1011 (v.7.02)	Recommended intensity target level for upstream facilities for conventional oil and gas production is 8 kg CO2/barrel oil equivalent (boe) exported over expected lifetime
NOx & SOx	TR1011 (v.7.02)	Target levels shall be based on local/national requirements, critical loads in the actual area or International Finance Corporation (IFC) General EHS Guidelines. BAT assessment should be completed and documented for each plant/installation. NOx and SOx reducing measures shall be evaluated.
VOC	TR1011 (v.7.02)	VOC recovery shall be evaluated for hydrocarbon storage and loading.
Flaring	TR1011 (v.7.02)	Production flaring/continuous flaring for gas disposal is not acceptable. Flare gas recovery shall be evaluated. Systems shall be designed and operated to avoid cold venting (venting of unburned gas). Methods for controlling and reducing leaks and fugitive emissions shall be studied and implemented in design, operations and maintenance. Detection and repair programs for leaks and fugitive emissions shall be implemented.

	NORSOK S-003 (rev.04)	The process system shall be designed to minimize flaring.

6.2 AUXILIARY POWER – DIESEL ENGINES

Auxiliary power for Wisting will be:

- Essential generator 7,4 MW (1x100%)
- Emergency generator 3,5 MW (1x100%)
- Firewater generators 2,2 MW each (4x50%)

These generators are expected to only operate for very short durations. However, a discussion whether to comply with IMO Tier II or Tier III requirements from MARPOL to reduce NOx emissions will be performed when all the relevant information has been received from potential suppliers. Tier II is now standard for new marine diesel engines and has lower NOx emissions than standard offshore emissions reported in Norsk Olje og Gass Guidelines [19] whilst Tier III has even lower emission requirements. The Tier III requirement could especially be relevant for the essential generator, as this generator could be operated for longer periods of time. The other generators will normally only be operated for shorter periods.

Another measure that was identified and briefly discussed in the Environmental Design Review [2] to reduce emissions from the diesel generators is the use of biodiesel. Biodiesel is biodegradable and produces fewer pollutants than petroleum diesel fuel. However, this matter needs to be properly assessed. There are several concerns regarding biodiesel, just to mention a few:

- Water Use
- Food Security
- Deforestation

6.3 GAS INSULATED SWITCHBOARD (GIS)

A gas insulated switchboard (GIS) is a necessary part of a robust and flexible energy system and it is also included to enhance safety. The gas that is most used as the insulation medium is Sulphur hexafluoride (SF6) and this gas is the most potent one of all the greenhouse gasses. SF6 is listed in Equinor's TR1668 "Prohibited and restricted chemicals" and shall only be used if SF6-free alternatives are documented as unfeasible.

Siemens' SF6-free GIS, called "Blue GIS", uses clean air as insulation medium and consists of 80 percent N_2 and 20 percent O_2 cleaned and free of humidity. The clean air insulation medium is not toxic, nor harmful. It is a safe medium, meaning there is not a need for any special safety precautions or training.

The "Blue GIS" technology from Siemens has been assessed and a summary can be found in the table below. This technology is evaluated to be BAT for Wisting.

Table 7: BAT summary GIS

Technique/ Aspect	Sub-criteria	SF6 GIS	SF6-free GIS
Environmental	Consumption of materials/substances	SF6. Quantity not known at this time	Clean air used as insulation medium, 80 percent N_2 and 20 percent O_2

Technique/ Aspect	Sub-criteria	SF6 GIS	SF6-free GIS
	Spill/Leakage	SF6. About 0,3-0,5 % loss. Quantity not known at this time	None of concern
Technological	Technological maturity	Long experience, many references	Several in operations, proven technology
	Operability – Complexity/Experience	Good. Low complexity, a lot of experience	Good. In the process of collecting experience from others who have this technology in operation
	Reliability	Good, well-known technology	No issues known at this stage
	Maintainability	Good, well-known technology and routines	No issues known at this stage, maintenance-free operating mechanism
	Physical footprint – Size and weight	OK – No concerns regarding size and weight	Approx. 30% bigger than SF6 GIS
	Safety – Technical/Operational	OK	OK – High operational safety
	Working environment	SF6 exposure may happen due to leakage	Good, no special training or special concerns

6.4 ESSENTIAL HEAT

The Secondary Heating Medium requires heat during essential mode, at which point the normal sources of heat (recovery from the cooling medium and 2 MW electrical back-up heater) are not available. The design duty for the secondary heating medium system is set to 5618 kW [6] – an unusually high demand due to the large extent of mechanically ventilated modules. Conventionally this would be provided by an electrical heater, however this would double the essential load [11](without contingency) and hence require multiple essential generators to be installed. An 8 MWe diesel engine essential generator may not produce sufficient waste heat to cover the demand and would involve a relatively complex system integration. As a result, a diesel fuelled Secondary Heating Medium Fired Heater (54FZ001) is included in the design. The performance of the heater is not known at this stage, however its efficiency will foreseeably be almost double that of essential power generation, hence from an environmental perspective the heater is preferable compared to an electrical alternative [11]. Its use will foreseeably be limited to periodic testing unless and short periods of essential operation.

6.5 FLARE

The flare and vent systems are required to collect, recover, or dispose of safely, hydrocarbon gases and liquids from the gas- and oil-processing systems and the produced water treatment system. These gases are derived from process venting, relief, and blowdown/depressurisation [20].

The flare system (system 43) consists primarily of two independent subsystems: a closed flare system and an atmospheric vent system.

The facility is not intended to be run with continuous (long-term) flaring. No such need/case is identified, and the process systems are design to minimise flaring. There will only be occasional short periods of production flaring during upsets and compressor trips. The system is also designed to avoid cold venting (venting of unburned gas), except for non-recoverable atmospheric discharges and for some small discharges during upset conditions.

In normal operation the flare system is isolated from the flare tip by means of an FOV (fast opening valve), and a line located upstream of the FOV recovers continuous sources to the flare system by sending the recovered gas to the recompressor.

The flare system also includes a VOC Recovery Compressor Package which compresses VOC from the Cargo Tanks and off-gas from the TEG regeneration system (sent via the Closed Drain Drum) up to the 2nd Stage Separator pressure. Well clean-up fluids are routed to the closed drain; the flashing that occurs from reducing the pressure will be routed to the VOC [20].

Two ignition systems are implemented, only one of which utilises pilots. It is not clear which will be selected at any particular time. Number of pilots and pilot gas rate is dependent on selected flare tip size, which has not yet been confirmed. There might be 2 or 3 pilots.

A closed flare system is considered BAT.

6.6 COLD VENTING AND FUGITIVE EMISSIONS

Hydrocarbon gases are classified by two emission groups:

- Methane (CH_4)
- NMVOC (Non-Methane Volatile Organic Compounds)

These two gasses are waste gases in a number of processes in the oil and gas production. They are called direct emissions if they are emitted to the atmosphere via atmospheric vents/cold vents or as fugitive emissions. Employing better technology is usually not how these emissions are being reduced, but it is rather a question of practical solutions, such as either returning the exhaust gas to the process and recover it or send to flare where it will be burned. Both of these solutions eliminate the methane and NMVOC from the process. Flaring them will result in a release of exhaust gases like CO_2 and NOx [7].

Looking at the Greenhouse Gas (GHG) effect, methane is 28 times more potent than CO_2 (28 CO_2- equivalents). Emissions of NMVOC has an indirect GHG effect as the gas will be oxidised to CO_2 in the atmosphere. It is estimated that the NMVOC has a GHG potential of 4,5 CO_2-equivalents. The methane emissions from NCS are estimated to be around 2% of the total GHG emissions from the Norwegian oil and gas industry [8].

The BAT assessments of cold venting and fugitive emissions in this report are based on the “Cold Venting and Fugitive Emissions from Norwegian Offshore Oil and Gas Activities Module 3A – Best Available Techniques (BAT) assessments” [7] report.

Table 8: Status BAT direct emissions Wisting

Main process	Sub-process	Proposed BAT	Status Wisting
TEG regeneration	Degassing tank	Recovery	**Considered BAT** Recovered into the main process via the flare system and recompressor

Main process	Sub-process	Proposed BAT	Status Wisting
	Regenerator	Recovery	**Considered BAT** Recovered into the main process via the closed drain drum and VOC Compressor (43XX003)
	Stripping gas	Recovery	**Considered BAT** Recovered into the main process via the closed drain drum and VOC Compressor (43XX003)
Produced water treatment	Degassing tank	Recovery	NA
	CFU / atm. Flotation tank	Recovery	**Considered BAT** Recovered via the 2nd stage separator
	Flotation tank	Recovery	NA
	Discharge caisson	Reduce pressure in the upstream degassing tank Recovery	**Considered BAT** Last stage CFU run in special operating mode at as low pressure as possible
Seal oil centrifugal compressors	Degassing pots	Recovery	NA
	Holding-/storage tanks	Recovery	NA
Dry compressor seals	Primary seal Secondary seal	Recovery of waste gas Use N2-gas as seal gas When HC-gas as seal gas: Recovery	**Considered BAT** Recovery of primary seal gas vent included via the VOC compressor
	Leakage primary → sec seal gas	Use leak-proof seal gas system (internal labyrinth)	To be included in design
Seal oil reciprocating compressors	Separator chambers	Recovery	NA
	Shaft house	Recovery	NA
Flare gas not burnt	Extinguished flare/ignition of flare	Ensure the use of effective ignition mechanisms	**Considered BAT** Two ignition mechanisms included (pilots and ballistic)
	Non-combustible flare gas	Recycling of waste gas from sub-sources with no or low levels of HC gases	NA
	Open cold flare purged with inert gas	This will be a trade-off between CO2 and CH4/NMVOC emissions	NA
MEG regeneration	Degassing tank	Recovery	NA
	Regenerator	Recovery	NA
	Stripping gas	N2 as stripping gas	NA

Main process	Sub-process	Proposed BAT	Status Wisting
Gas analysators		Side stream to recovery	Under consideration
Crude oil storage tanks on FPSOs	Gas freeing during inspection	Purge until the criteria related to inert or HC gas is met	**Considered BAT** No applicable technology available for capturing the emissions during this operation.
	Abnormal operating conditions	VRU with high availability	**Considered BAT** VRU with high availability
Gas freeing of the process	Gas freeing	Flare until flare extinguishes	**Considered BAT** Automatic depressurisation of the main process, which is sent to flare and burnt
Purge and blanket gas	HC-gas	Change gas to N2	**Considered BAT** Nitrogen used for all non-hydrocarbon systems where purge or blanket is required. If fuel gas is used, it is recovered.

As shown in the table above, the technical solutions that are chosen at this stage of the project are considered BAT. For the crude oil storage tanks on FPSO and the sub-processes, there is no applicable technology available for capturing the emissions from this operation and the waste gas cannot be recycled due to the contamination of exhaust gas. If this gas is sent to flare, the inert gas will extinguish the flare. However, the cargo tank vapour will be released through the control valve and the BAT minimising these releases is the VRU. The status for Wisting is therefore a VRU with high availability.

7 DISCHARGE TO SEA

On the Norwegian continental shelf there is a goal of zero harmful discharge to sea, and the overriding principle in design is BAT. The discharge limits in the Discharge Permit granted from The Norwegian Environmental Agency will be based on BAT and all new installations must demonstrate BAT-evaluations (IED Directive).

7.1 GOALS AND REQUIREMENTS

Table 9: Requirements for discharge to sea

Area of env. impact	Standard/ Guideline	Requirements
General	TR1011 (v.7.02)	Discharged water shall comply with local/national discharge requirements and the IFC liquid effluent levels. All water discharge points shall be located and designed in order to minimise environmental effects.

Area of env. impact	Standard/ Guideline	Requirements
Produced water	TR1011 (v.7.02)	The order of priority for produced water management is: 1. Minimisation of water production 2. Re-injection to reservoir to maintain pressure 3. Injection to other geological formations 4. Treatment (cleaning) and discharge to sea. Dilution as a mean to reach contamination concentration limits is not allowed
Produced water - Limit of dispersed oil in the discharge water	TR1011 (v.7.02)	Discharge to sea maximum one day oil and grease discharge should not exceed 42 mg/l; 30 day average should not exceed 29 mg/L. Design basis specifies the oil content to be below 10 mg/L
Drain water	TR1011 (v.7.02)	Contaminated drainage water shall not be routed directly to discharge. Measures to be studied should include: • injection together with cuttings from drilling to a geological formation, • containment and shipment to shore for treatment/disposal, or • routing to the hazardous open drain system for treatment (cleaning) and discharge to sea.
Chemicals	TR1011 (v.7.02)	The design of facilities and the material selection shall challenge the need for added chemical use. Chemical usage shall be minimised. Ecotoxicological documentation shall confirm with HOCNF format or similar internationally recognised system. Measures to minimise risks and impacts associated with chemicals and additives shall be implemented according to the mitigation hierarchy and principle of Best Available Techniques (BAT). Chemicals containing substances of very high concern listed in Prohibited and Restricted Chemicals (TR1668) shall not be used.
Sanitary water	TR1011 (v.7.02)	Sanitary water (grey and black water) shall be handled in compliance with MARPOL 73/78b

7.2 PRODUCED WATER

The produced water shall be treated in the produced water treatment package and then re-injected into the reservoir for pressure support. Produced water from 1st stage separator is mixed with produced water from 2nd Stage Separator (20VA002) and routed to dedicated hydrocyclones within the Produced Water Hydrocyclone skid (44XA001) for treatment. Produced water from the test separator is also routed to dedicated hydrocyclones within the Produced Water Hydrocyclone skid (44XA001) for treatment. The water stream from the Produced Water Hydrocyclone skid is then further routed to two stages of CFUs.

After two stages of CFUs the water pressure is increased by produced water injection booster pumps (44PG001A/B/C) before it is routed to the Nutshell Filter Skids (44XA100/200/300) which is the last stage of treatment before the treated produced water is cooled and routed to the water injection manifold. The produced water shall be treated to contain maximum 10 ppm hydrocarbons before it can be injected into the reservoir. The Nutshell Filter Skids consists of three units (44XA100/44XA200/44XA300). Each unit consist of two filters.

The Nutshell Filter Package (44XX006) is not common within the offshore industry and requires backwash fluids to be appropriately handled. It is assumed that each hour, one of the 6 filters will be taken out of operation for a backwash program. These fluids are collected in the Nutshell Filter Backflush Buffer Tank (44TB002) before being sent to the Nutshell Backflush Treatment Skid (44XX608) where oil and particles are separated from the water by centrifuge. Reclaimed oil is routed to a cargo tank, and the treated water is routed either to dirty slop tank (and then to slop treatment) or directly into the main process system. The waste stream containing particles, oil, and water from the Treatment Skid (44XX608) should be collected and routed to a tote tank.

Extensive and continuous water injection is a part of the production strategy with an availability for re-injection of 98%, and the treatment prior to injection is to ensure reservoir containment of injected water. De-oxygenated and de-sulphinated seawater (SRU) will be used for supplementary seawater injection and will be mixed with produced water topside. In case of downtime of the SRU, sea water injection shall be stopped. No untreated sea water shall be injected into the reservoir. In the event of operational downtime of the injection system, treated produced water is discharged to sea. This is considered BAT.

7.3 DRAIN WATER

The Open Drain system is designed to provide sufficient drainage capacity for all the liquid loads anticipated for all occurrences on the FPSO i.e., rainwater, fire water, wash down water, including spillage of liquid from deck areas, equipment drip trays and bunded areas. The Open Drain System is a safety system that prevents spreading of flammable liquids and maintaining separation of fire areas. The system also prevents oil spill to the environment and minimizes exposure of harmful substances to personnel. The Open Drain System collects these liquids of contaminated water and then transfers them to slop treatment package before discharge to sea.

The collection system is segregated into the following:

- Non-hazardous open drain from service block
- Non-hazardous open drain from utility areas
- Hazardous open drain from process areas
- Rainwater from non-polluted areas will be routed directly to sea

The open drain piping from hazardous area consists of a normal drain collection system as well as a fire drain collection system. Rainwater, wash water and minor oil spills are collected in the normal drain collection system and routed to hazardous open drain tank. Firewater is routed directly overboard by firewater overflow lines from each drain box. The firewater overflow lines are connected to large firewater drain collection headers on each deck and routed overboard.

Adequate segregation between the non-hazardous and the hazardous open drain systems is provided to reduce the risk of hydrocarbons migrating to safe areas through the drain system.

Drains from different fire areas within the hazardous area are provided with fire seals to prevent gas migration from one fire area to another.

Non-hazardous drain from service block is collected in a non-hazardous tank (56TB602) before pumped to Drain and Slop Treatment unit (56XA601) on main deck.

Non-hazardous drain from utility areas is collected in Non-hazardous Drain tank on main deck (56TB603) before routed to the Drain and Slop Treatment unit (56XA601).

Drain from hazardous area is collected in Hazardous Open drain tank (56TB601) before routed to Drain and Slop Treatment unit (56XA601).

Open drain on main deck is collected in gutters and pumped to Hazardous Open drain tank (56TB601). Deluge on main deck is routed directly overboard by large firewater overflow lines from the gutters, penetrating the ballast tanks.

The Drain and Slop Treatment unit (56XA601) is a centrifuge separating the liquid into an oily water phase, a clean water phase, and a sludge phase. The oily water phase is routed to cargo tanks, the clean water from the treatment unit is routed directly overboard and the sludge phase is pumped to tote tanks for transport to shore.

7.4 CHEMICALS

The least toxic/environmental harmful chemicals shall be chosen. Requirements must be included and followed up towards package specifications and contracts. Environmentally black chemicals shall not be used, and the project has a target to eliminate the need for red or yellow Y2 chemicals under operation and seek to minimise the use of chemicals in general. Materials should as far as possible be selected to minimise need for corrosion inhibitors. Specifically focus will be given on elimination and substitution of chemicals categorised as red with respect to health hazards.

7.4.1 General process chemicals

Chemicals are selected by Company and is therefore not Contractor's responsibility. With regards to substitution of environmentally harmful chemicals as per GL0300, Company evaluations will determine the outcome.

Chemicals that are injected to the process will follow the oil or water streams, depending on how water soluble each chemical is. Discharge of water-based production chemicals to sea will be via the produced water discharges, maximum 2% (98% reinjection time).

An overview of the production chemicals to be employed on Wisting is taken from the Design basis and is shown in table below.

Table 10: Production chemicals Wisting [3]

Chemicals	Injection Location	Combined rate (assumed)	Expected HOCNF colour	Injection Basis	Rate/dosage for injection system design	Water Affinity (%)
Production						
Demulsifier	U/S 1st Stage Separator	Continuous	Y2/R	Oil + PW	5-50 ppmv	3
	U/S Test Separator	Intermittent	Y2/R	Oil + PW	5-50 ppmv	3
	U/S 2nd Stage Separator	Continuous	Y2/R	Oil + PW	5-50 ppmv	3
	U/S Subsea Separator	Continuous	Y2/R	Oil + PW	5-50	3
Antifoam	U/S 1st Stage Separator	Continuous	R	Oil	1-20 ppmv	0
	U/S Test Separator	Intermittent	R	Oil	1-20 ppmv	0
	U/S 2nd Stage Separator	Continuous	R	Oil	1-20 ppmv	0

Chemicals	Injection Location	Combined rate (assumed)	Expected HOCNF colour	Injection Basis	Rate/dosage for injection system design	Water Affinity (%)
	U/S Subsea Separator	Continuous	R	Oil	1-20	0
Scale Inhibitor	U/S 1st Stage Heater	Continuous	Y2	PW	10-100 ppmv	100
	U/S Test Heater	Intermittent	Y2	PW	10-100 ppmv	100
	U/S Inter-Stage Heater	Continuous	Y2	PW	10-100 ppmv	100
	U/S PW/SW Mixing Point	Continuous	Y2	PW+SW	10-100 ppmv	100
	Injected SW	Continuous	Y2	SW	10-100 ppmv	100
	Downhole OP (with backup point on XT)	Continuous	Y2	PW	10-100	100
Flocculant	U/S Hydrocyclone	Continuous	R	PW	5-30 ppmv	20
Biocide	FPSO consumers	Batch	Y	N/A	1 000 ppmv	100
Wax Inhibitor	Wellhead (Hanssen)	Continuous	Y2	Oil	50-500 ppmv	0

The HOCNF classification and the water affinity is based on the Johan Castberg project [8], since the chemicals are not chosen at this point.

7.4.2 Sulphate Removal Unit (SRU)

The purpose of the Sulphate Removal Unit (SRU) is to treat seawater to meet the required specification for injection. The SRU will produce high quality filtered, low sulphate, deoxygenated seawater to specified requirements. In order to do so, the SRU requires the use of several chemicals. The chemicals can be found in the table below.

Table 11: SRU chemicals

Chemicals	Operation	Expected HOCNF colour	Yearly consumption (m3)
Sodium Hypochlorite	Intermittent	Red	16,5
SRP Scale Inhibitor	Continuous	Yellow	39,3
Biocide (DBPNA)	Intermittent	Red	0,44
Sodium Hydroxide	Intermittent	Yellow	10,4
Chlorine Scavenger	Continuous	Green	88,1
Membrane CIP Cleaning (Acid)	Intermittent	Yellow	6,4
Membrane CIP Cleaning Chemical (Alkali)	Intermittent	Yellow	4,2

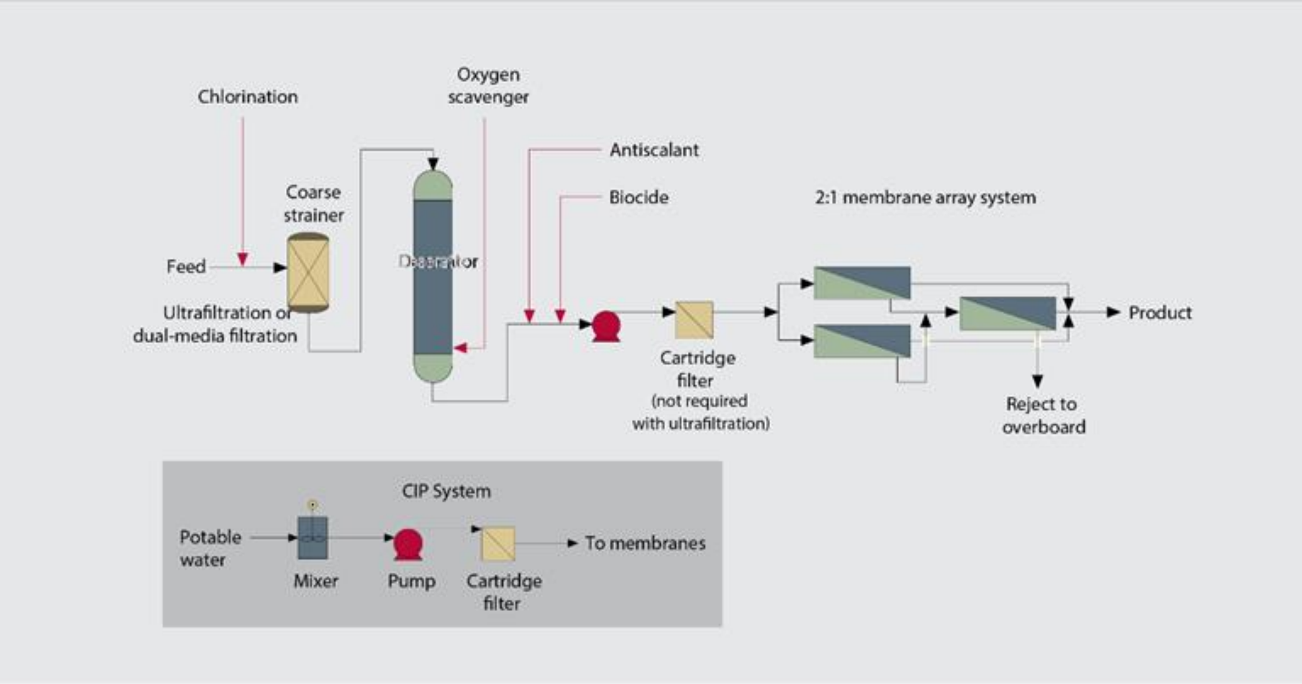

Figure 9: SRU plant illustration

Offline treatment

Online treatment would require continuous biocide injection and hence much larger quantities. The alternative takes one train offline for a clean-in-place (CIP) operation, where the biocide is dosed into a limited wash water volume for a period of closed-loop treatment after which the fluid is discharged to sea. This is expected to be performed weekly for each train, depending on the pressure differential across the nanofiltration membranes. Offline treatment is considered BAT.

UV – light

A study regarding the use of UV light as a mitigating measure to reduce the use of sodium hypochlorite and DBNPA in the plant has been performed by Company. UV light was proposed as an extra disinfection stage upstream before the NF membranes, but the effect was minor. The study compared the UV light with no biocide and the result was approximately a 5-10% lower flux decline. The study also compared the UV light with UF/chlorination, and the result was no effect. The study concluded that good pre-treatment has a delaying effect on the biofouling after cleaning and that Chlorination/UF is the best solution. Further biocidal treatment will not have any effect. Lastly, no residual effect through membrane, one bacterium is enough to establish biofilm, and this will be the basis for further biofouling.

Replacement of the DBNPA – Trial

The DBNPA biocide which is proposed for usage is classified as red, so Schlumberger is in the process of evaluating a substitute. This product has been applied online/intermittent online for several years on Reverse Osmosis (RO) systems and has the potential to provide a less toxic membrane biofouling control for sulphate removal membranes. The sulphate removal membranes are generally more sensitive than RO membranes and therefore a continuous compatibility test at the labs is required. This test phase is due to start imminently, and supplier will keep Schlumberger (SLB) informed of its progress. It is believed that the product would be best dosed at a low continuous dose, but other application methods are also used.

For now, the supplier has completed the following steps:

- Achieved CEFAS certification for UK use
- Obtained NEMs certification under a yellow category

This will be followed up as soon as Schlumberger have received any updated information regarding the trial.

7.5 SANITARY WATER

A sewage system for collection of black, grey and wastewater generated on board shall be included. The system will comprise water from the toilets, showers, wash basins, galley, and laundry.

The Maritime regulations and the MARPOL Polar Code states that discharge of sewage within polar waters are prohibited except when performed in accordance with MARPOL Annex IV. Wisting have considered the probability of having sea ice at less than 12nm relatively low, meaning a Sewage Treatment Plant is not needed in the design.

It is also prohibited to discharge sewage into the sea from category A and B ships as well as all passenger ships constructed after January1st, 2017 but Wisting is neither an A or B ship nor a passenger ship. Therefore, black water will be discharged directly to sea from the vacuum pumps and grey water will be discharged directly to sea by gravity.

7.6 SEAWATER

There are two Seawater Systems onboard Wisting:

- Main Seawater System
- Utility Seawater System

7.6.1 Main Seawater System

Seawater is provided by 3x50% Main Seawater Lift Pumps (50PS601A/B/C) located in caissons and submerged in the sea. The seawater discharge from the pumps is routed to the Main Seawater Filter Package (50XX001) with coarse filtration of the seawater down to 1000 µm. The filter package includes 2x100% filters with automatic backwash. A 50 m long hose is connected to the seawater inlet to each pump, the seawater intake is then minimum 72 m when FPSO is ballasted and max 82 m when FPSO is loaded.

Main Seawater System is mainly supplying seawater to Produced Water Coolers (44HB001A/B), Process Cooling Medium Coolers (40HB001A/B/C), and to the Sulphate Removal Unit (29XX002). There are also supply line provided to the Fresh Water Makers (53XX601A/B) and Electrochlorination Package (47XX601).

The seawater temperature for the Main Seawater System inlet varies between 3°C and 7°C. Temperature of warm seawater return from Process Cooling Medium Coolers is about 35°C, while the outlet from the Produced Water Coolers is about 20°C in normal operation. To minimize dumping warm seawater from these coolers is reused and routed to Sulphate Removal Unit for further injection into the reservoir. Excess warm seawater is discharged overboard via the Aft Seawater Dump Caisson. Maximum return temperature is about 55°C.

The Main Seawater System has a total capacity of 4000 m3/h. The Seawater supply temperature to Sulphate Removal Unit (SRU) is depending on the temperature for Water Injection (System 29). The amount of water to be dumped is dependent on the Seawater intake temperature and the temperature and flowrate supplied to SRU. With higher supply temperature to SRU more hot water is reused and not directed overboard.

In early life the maximum amount of water being dumped is around 800 m3/h if water injection temperature is 11°C and reduced to 400 m3/h if water injection temperature is 20°C. During plateau phase the maximum amount of water being dumped is around 1200 m3/h if water injection temperature is 11°C and reduced to around 600 m3/h if water injection temperature is 20°C.

In late life less seawater is injected into the reservoir because of higher water production rate. Therefore, the flowrate to SRU is reduced and more hot water is dumped during this phase. The maximum amount of water being dumped is around 1700 m3/h if water injection temperature is 11°C and reduced to around 1100 m3/h if water injection temperature is 20°C. Seawater intake temperature is varying and affecting the seawater dumping.

7.6.2 SRU

In addition to seawater dumping from Seawater system it is expected discharges from the UF and SR membranes in the SRU package. These are explained in the following.

SR membranes

Reject water from SRU is continuously routed to the Aft Seawater Dump Caisson. SR membranes reject flow is 400 m3/h continuous at peak inlet flow and the maximum operating temperature is 20°C.

The product flow (low sulphate seawater) from the SR / MDA membranes will be initially discharged to the seawater dump caisson during start-up of the system and once the water quality meets the downstream requirement it can be sent forward to the water injection system. The total product flow is 1200m3/h based on peak inlet flow. Both the reject and the product flows are discharged at the seawater operating temperature of 11-20 °C.

Ultrafiltration membranes

The Ultrafiltration membranes in SRU undergo regular backwashes and clean-in-place activities to ensure removal of foulants from the membrane surface. The discharges from the activities shown in the table below are sent overboard through the Seawater Dump Caisson. The residual chlorine in the discharge water will depend on the fouling conditions (organic matter) of the membranes.

Table 12: Discharge to sea through the Seawater Dump Caisson

Activity	Frequency	Flowrate	Fluid	Temperature (°C)	Notes
Backwash	Every 30 mins per UF skid (6 UF skids backwashed every 30mins)	484 m3/h (low backwash) for approx. 35 secs 605 m3/h (high backwash) for approx. 35 secs	Seawater + Chemical	11 – 20	Every 3rd backwash **15ppm of sodium hypochlorite** will dosed into the low backwash flow.
CEB (Clean Enhanced Backwash)	Once a week per UF skid	161 m3/h (low backwash) for approx. 35 secs 605 m3/h (high backwash) for approx. 35 secs	Seawater + Chemical	11 – 20	Up to **50ppm of sodium hypochlorite** is dosed into low backwash flow.
(CIP) Clean in Place – High pH	Every month per UF skid	Volume of 11.7m3 of solution per UF rack (*)	Freshwater + Chemical	35	High pH solution consists of **200ppm of sodium hypochlorite + 0.2% of sodium hydroxide** @ pH 11

7.6.3 Utility Seawater System

Seawater is provided by 2x100% Utility Seawater Lift Pumps (50PS602A/50PS602B) located in caissons and submerged in the sea. The seawater discharge from the pumps is routed to the Utility Seawater Filter Package (50XX600) with coarse filtration of the seawater down to 1000 µm. The filter package includes 2x100% filters with automatic backwash. The seawater intake for the Utility Seawater System is at FPSO keel, draft will vary between 22 m and 32 m.

Utility Seawater System is serving consumers located in Hull areas:

- Emergency Power Generator Skid (84XX601)
- Potable Water Cooler (53HB601)
- Electrochlorination Package (47XX601)
- Fresh Water Makers (53XX601A/B)
- Firewater Jockey Pumps (71PA100A/B)
- HVAC Cooling Medium Coolers (40HB602A/B)
- Utility Cooling Medium Coolers (40HB601A/B)
- Inert Gas Generator Scrubber (51XX601)

The Utility Seawater System has a total capacity of 970 m3/h. The seawater inlet temperature varies between 2°C and 9°C. In normal operation the return temperature from the Utility Cooling Medium Coolers is about 30°C. The return lines are collected to a return header with a total capacity of around 600 m3/h. The water is either discharged overboard or routed to Inert Gas Generator Scrubber for intermittent use when required. The seawater discharge from the Inert Gas Scrubber is around 600 m3/h and maximum return temperature is about 40°C.

7.6.4 Chlorine Level Sampling

A Electrochlorination Package (47XX601) is providing chloride dozing to the Main Seawater Lift Pumps, Utility Seawater Lift Pumps and Firewater Pumps to control biological growth. Chlorinated seawater is directed to the pump impeller level.

There are two sampling points included in each Seawater System, on the discharge header of the pumps and the main return header in both Main and Utility Seawater System. The purpose of the sampling point on the discharge header is to check chlorination level and seawater quality from the pump suction, while the sample connection on the return headers is to measure residual chlorine content before discharge to sea.

Chlorine content is regularly checked by operations and adjusted to avoid overdosing (changing due to blooming season etc.). During FEED phase it will be investigated if auto sampling in both Seawater systems is possible to implement to ensure continuously sampling of chlorine level. Number and location of additional sampling points will be part of the evaluation.

7.6.5 Submerged pumps

There are different options available for the technology for submerged pumps. An environmental concern regarding these pumps is the known leakage of either an insulation/isolation oil, or a glycol/water mix to sea. Five different alternatives from two different supplier have been assessed. The different alternatives are as follows:

- Alternative 1: Single seal pumps with a black classified lube oil
- Alternative 2: Single seal pumps with a yellow Y2 classified lube oil
- Alternative 3: Double seal and cofferdam with a yellow Y2 classified lube oil
- Alternative 4: Single seal pumps with a green classified glycol/water mix
- Alternative 5: Single seal pumps with a yellow classified glycol/water mix

According to the Norwegian Environmental Agency, emission free pumps are BAT. They specify that there are known leakages of both black and yellow chemicals to sea, and they expect Company to choose a zero-emission option. They do not specify the leakage of a green chemical, but it is interpreted that a planned leakage of a green chemical is still a discharge and would not be categorised as an emission free alternative.

All the single seal alternatives that are being assessed in this report have a known leakage of either a black, yellow or a green categorised substance, leaving the double seal alternative with the cofferdam arrangement to be the only zero emission option. This technology is regarded as a mature technology, but it has fewer operating hours and less experience. Nevertheless, there are no known challenges that raises a concern for choosing the cofferdam arrangement for the sea water lift pumps and is therefore considered BAT for these pumps.

However, for the fire water pumps, the fewer operating hours and less experience raises a concern regarding the operability due to safety reasons. The cofferdam arrangement introduces more components and routines that at this point have been evaluated to be too high of a risk for a safety equipment. It has been concluded that a higher number of operating hours and more experience is needed to eliminate the uncertainty related to the reliability of the pumps. Meaning, at this point, the cofferdam arrangement is not BAT for the fire water pumps.

Comparing the single seal alternatives for the fire water pumps, all of the alternatives have a small amount of planned release to sea. This is because of the number of operating hours. These pumps are normally not in operation and are only run for testing. Alternative number 1 is not acceptable due to the black classified oil, but the yellow and green alternatives are considered as acceptable alternatives due to their low environmental impact.

One of the single seal alternatives can be retrofitted the cofferdam arrangement. This needs to be confirmed by the supplier, but if this is the case, a single seal pump can become an emission free pump at a later point if the cofferdam arrangement is considered a reliable alternative for a safety equipment. To keep this alternative open, the supplier that offers the cofferdam solution needs to be the supplier of the single seal alternative for the fire water pumps.

Another matter that has been discussed regarding the number of suppliers is the risk and challenges related to having to deal with two different ones. Wisting is a low manned plant, and it will require more time to follow up two different suppliers for maintenance and other enquires, than just one. Two different suppliers would also mean two sets of spare parts and special tools.

An aspect that is uncertain at this point is the need of an exhaust cooler, HOLD. This aspect needs to be included as a part of the total assessment, but the preliminary BAT assessment shows that the single seal alternative from the same supplier as the dual seal alternative is BAT for the fire water pumps.

A summary can be found in the table below.

The colour coding that has been used is explained in Table 2, where green represent low impact.

Table 13: BAT summary sea water lift pumps

Technique/ Aspect	Sub-criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
		Single Sealing oil based (black)	Single Sealing oil based (yellow Y2)	Dual Sealing oil based (yellow Y2)	Single Sealing glycol based (green)	Single Sealing glycol based (yellow Y2)
Environmental	Releases to sea, expected leakage/spill of chemicals during operation	Leakage of insulation/ isolation oil to sea 40 ml/hr (Experience based numbers) (300 l/y)	Discharge of insulation/ isolation oil to sea 40 ml/hr (Experience based numbers) (300 l/y)	Zero emissions	Minor release of insulation/ isolation oil to sea, glycol/water mix (Experience based numbers) 20-50 l/y	Minor release of insulation/ isolation oil to sea, glycol/water mix (Experience based numbers) 20-50 l/y
Technological	Technological maturity	Long experience, many references	Long experience, many references	Not as long experience, but enough hours in operation to be a mature technology	Long experience, many references	Long experience, many references
	Operability – Complexity/ Experience	Good. Low complexity, long experience	Good. Low complexity, long experience	Good, but limited experiences	Good. Low complexity, long experience	Good. Low complexity, long experience
	Reliability	Good	Good	Good, but fewer references	Good	Good
	Maintainability	Well established routines, nothing of concern	Well established routines, nothing of concern	No major concerns, but new routines need to be established and to be optimised	Well established routines, nothing of concern	Well established routines, nothing of concern

Technique/ Aspect	Sub-criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
		Single Sealing oil based (black)	Single Sealing oil based (yellow Y2)	Dual Sealing oil based (yellow Y2)	Single Sealing glycol based (green)	Single Sealing glycol based (yellow Y2)
	Physical footprint – Size and weight	OK – No concerns regarding size and weight	OK – No concerns regarding size and weight	OK – No concerns regarding size and weight	OK – No concerns regarding size and weight	OK – No concerns regarding size and weight
	Safety – Technical/ Operational	OK	OK	OK	OK	OK
	Working environment	OK – No concerns regarding working environment	OK – No concerns regarding working environment	OK – No concerns regarding working environment	OK – No concerns regarding working environment	OK – No concerns regarding working environment

Table 14: BAT summary fire water pumps

Technique/ Aspect	Sub-criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
		Single Sealing oil based (black)	Single Sealing oil based (yellow Y2)	Dual Sealing oil based (yellow Y2)	Single Sealing glycol based (green)	Single Sealing glycol based (yellow Y2)
Environmental	Releases to sea, expected spill of chemicals during operation	Minor leakages of sealing/isolation oil to sea 40 ml/hr (Experience based numbers) (2-3 l/y)	Minor leakages of sealing/isolation oil to sea 40 ml/hr (Experience based numbers) (2-3 l/y)	Zero emissions	Minor release of insulation/isolation oil to sea, glycol/water mix (Experience based numbers) 20-50 l/y	Minor release of insulation/ isolation oil to sea, glycol/water mix (Experience based numbers) 20-50 l/y

Technique/ Aspect	Sub-criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
		Single Sealing oil based (black)	Single Sealing oil based (yellow Y2)	Dual Sealing oil based (yellow Y2)	Single Sealing glycol based (green)	Single Sealing glycol based (yellow Y2)
Technological	Technological maturity	Long experience, many references	Long experience, many references	Not as long experience, but enough hours in operation to be a mature technology	Long experience, many references	Long experience, many references
	Operability – Complexity/ Experience	Good. Low complexity, a lot of experience	Good. Low complexity, a lot of experience	Limited experiences, unsure of the exact complexity	Good. Low complexity, a lot of experience	Good. Low complexity, long experience
	Reliability	Good	Good	Fewer references, unsure of the exact reliability	Good	Good
	Maintainability	Well established routines, nothing of concern	Well established routines, nothing of concern	New routines need to be established and to be optimized	Well established routines, nothing of concern	Well established routines, nothing of concern
	Physical footprint – Size and weight	OK – No concerns regarding size and weight	OK – No concerns regarding size and weight	OK – No concerns regarding size and weight	OK – No concerns regarding size and weight	OK – No concerns regarding size and weight
	Safety – Technical/ Operational	OK	OK	OK	OK	OK
	Working environment	OK – No concerns regarding working environment	OK – No concerns regarding working environment	OK – No concerns regarding working environment	OK – No concerns regarding working environment	OK – No concerns regarding working environment

8 WINTERIZATION

A winterization strategy will be developed for Wisting to define design and operational principles to ensure suitability for operations in cold climate [3]. The main priorities for the winterization scope shall be safety, operational efficiency, and low manning, meaning that e.g., the extent of heat tracing shall be minimised.

Due to the high energy requirement associated with anti-icing measures, operational snow/ice removal measures are suggested to be implemented. The operational de-icing measures that have been proposed at this moment includes utilisation of shovels and mobile snow removal units, calcium chloride to be utilised when feasible and steam (if included in rig design). The snow is to be moved to designated areas. This section of the report will be updated when the winterization strategy is final.

9 WASTE

9.1 WASTE MANAGEMENT REPORT

A Waste Management Report [10] has been prepared for the FPSO. The main objective is to assure an efficient waste handling system on the FPSO that aims for minimization of waste generation, safe and proper waste handling and logistics, and little impact on the environment.

The waste that will be generated on the FPSO shall be classified into hazardous and non-hazardous waste groups, and a system for waste segregation shall be established. Hazardous waste is waste that cannot be handled together with non-hazardous waste without the risk of pollution or health risk to humans or animals. Waste handling facilities and designated waste storage areas shall have allocated space in layout. This is described in the Waste Management Report for the Wisting FPSO [10].

The main production waste types will be out-separated oil and sand. There will also be some waste from pigging operations.

The out-separated oil will be returned to the production process. Pigging waste must be handled as hazardous waste.

There will also be waste from maintenance activities in the production areas and workshop in addition to waste from the activities in the Living Quarter. Areas are allocated on the FPSO for segregation, storage and handling of waste containers. This is further described in the Waste Management Report.

9.2 PRODUCED SAND

It is stated in design basis that sand production is not predicted for any completion, inclination or well direction. Water weakening is not expected, but for design purposes a sand loading of 5ppmW of total fluid and grains size of 250 µm shall apply [3]. If production of sand occurs, the sand handling method will be collection and transport to shore and is considered as BAT.

If sand production would have been handled on the FPSO, it would require a much more sophisticated (hence more expensive and space/weight consuming) equipment. It is also understood to be a challenge to take representative samples of sand for testing purposes to validate that the regulatory limit has been met. Supply vessel takes any sand back in return load, therefore no/negligible additional emissions [11]. Based on the above and the expectation of little/no sand production, onshore disposal is considered BAT.

9.3 WELL CLEAN-UP

The Design Basis states that the topside and storage facilities shall be prepared for handling of clean-up fluids which will contain particles and chemicals, co-produced with reservoir fluid [3].

Well clean-up and scale squeeze operations will route fluids containing particles to the Test Separator. The separator includes jetting hence the particles will be routed to the Sand Treatment Package (44XX003) where solids will be bagged for disposal onshore [11]. This is considered BAT.

Fluids from the Test Separator can also be routed to the Closed Drain via the water outlet. The Closed Drain Drum (57VD001) is assumed to copy the Castberg design by including internals to help avoid particles from following the liquid outlet. From the Closed Drain Drum the Well Clean-Up Pump (57PA002) either returns these fluids to the main process (1st Stage Separator) or to a Slop Tank in the hull [11].

9.4 WASTE FROM PIGGING

There will be pigging of the flowlines due to wax build-up. The flowlines shall be pigged during production in order to remove any debris and to control the wax build-up. Facilities for pigging main production lines (including multipurpose line) shall be possible for temporary installation. Facilities (pig launcher) for pigging gas export line shall installed as a permanent solution [3]. During wax pigging, the fluid will be routed to the test separator and the pigging waste for hazardous waste disposal, this is considered as BAT.

9.5 NUTSHELL FILTER

The Nutshell Filter Package is presumed to require renewal after a period of time.

The Nutshell Backflush Treatment Skid (44XX608) is expected to accumulate particles (presumably in a slurry) from the Nutshell Filter Package which is collected in tote tanks for disposal onshore [11]. This is considered BAT.

10 BAT SUMMARY

Overall, Wisting offers a good environmental performance. Power from shore covers all power and heat consumers during normal operations, meaning no local emissions associated with energy use.

Energy efficiency

Heat integration is implemented widely in design, but heat remains as the largest energy consumer for the facility. Injection water temperature of 11 °C requires no or low additional heating, while maximum seawater injection rates at 20 °C requires more than 10 MW of additional heat. This means that the seawater injection temperature is one of the main parameters to be optimized to save power on the facility during the first years of operation.

Another opportunity that will be optimised during the first years of operation is recovery of heat from produced water into the inflow to the 1st Stage Separator. Aker Solutions have quantified that over 1 200 GWh will be saved by integrating heat from the produced water stream entering the Produced Water Coolers (44HB001A/B) at around 25°C (assuming a 13°C arrival temperature). A new BAT assessment will be conducted after a few years of production, when the production of produced water has reached a significant amount.

Speed control – either mechanical variable speed drives (VSD) or electrical variable frequency drives (VFD) are selected for all of the largest loads, allowing the shaft power to be optimised for varying fluid flowrates through the equipment.

Emissions to air

An assessment whether to comply with IMO Tier II or Tier III requirements from MARPOL to reduce NOx emissions from the auxiliary power will be performed when all the relevant data has been received from the potential supplier, to see which one of the Tier requirements that will be BAT for Wisting.

SF6 is the most potent of all the greenhouse gasses and is listed in Equinor’s TR1668 “Prohibited and restricted chemicals”. Siemens’ “Blue GIS” has been evaluated to be BAT for Wisting and it is expected that this solution will be implemented.

Discharge to sea

In accordance with the Design Basis, produced water is treated to 10 ppm(w) before normally being reinjected into the reservoir.

A preliminary BAT assessment for the submerged pumps has been conducted. The dual sealing with the cofferdam arrangement is BAT for the sea water lift pumps while the single seal alternative from the same supplier is BAT for the fire water pumps.

The planned biocide to be used in the SRU membrane cleaning is a red chemical and discharge to sea have to be minimised. Evaluation of a substitute is ongoing to minimise the environmental impact.

Waste to land

Process waste generated on Wisting will be transferred to shore for disposal and this is regarded as BAT.

11 REFERENCES

Table 15: Reference list

Reference / Document no.	Document title
[1] Norwegian Oil and Gas Guideline no 147	147 – Norwegian Oil and Gas Recommended guidelines for Best Available Technique (BAT) assessments, rev 00
[2] C277-AS-S-RA-00001	Wisting FPSO FEED – Environmental Design Review Report
[3] PM757-PMS-050-001	Design Basis – Wisting, Rev 03
[4] GL0300 – Equinor Guideline	Guideline for evaluation of Best Available Techniques (BAT) v 1.01
[5] 2010/75/EU	Directive on Industrial Emissions (IED)
[6] C277-AS-P-RA-00009	Wisting FPSO FEED – Power and Heat Report
[7] M-665 2016	Cold Venting and Fugitive Emissions from Norwegian Offshore Oil and Gas Activities Module 3A – Best Available Techniques (BAT) assessments
[8] C143-AS-S-RA-00019	Environmental Budget Report Johan Castberg
[9] C277-AS-S-RA-00003	Wisting FPSO FEED – Environmental Budget Report
[10] C277-AS-S-RA-00004	Wisting FPSO FEED – Waste Management Report
[11] 160025-21-AS-S-RA-00009	Wisting FPSO Concept – BAT assessment Report
[12] PM757-PMS-051-002	Wisting FPSO FEED – Functional and design requirements Topside
[13] PM757-PMS-051-012	Wisting FPSO FEED – Functional and design requirements living quarters area and helideck
[14] PM757-PMS-051-013	Wisting FPSO FEED – Functional and design requirements Hull
[15] TR1011 – Equinor technical requirement	Environmental requirements for offshore installations
[16] NORSOK S-003	Environmental Care
[17] BREF Guideline	Best Available Techniques guideline
[18] C277-AS-R-RA-00001	Wisting FPSO FEED - Driver selection Report (draft)
[19] Norwegian Oil and Gas Guideline no 044	Recommended guidelines for emission and discharge reporting, ver. 19
[20] C277-AS-P-RA-00010	Wisting FPSO FEED – Flare and Closed Drain System Report