CHALMERS

Offshore Oil and Gas Activities in Arctic areas

An Investigation of Best Available Techniques for Reducing Environmental Impacts

Master of Science Thesis in the Master Degree Programme
Industrial Ecology and Mechanical Engineering

EMMA KARLSTRÖM THYLANDER

Department of Shipping and Marine Technology
Division of Maritime Environment
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2013

Report No.X-13/298

MASTER'S THESIS

Offshore Oil and Gas Activities in Arctic areas

-An Investigation of Best Available Techniques for Reducing Environmental Impacts

Master's Thesis within the Industrial Ecology and Mechanical Engineering programme

EMMA KARLSTRÖM THYLANDER

SUPERVISORS

Karin Andersson (Chalmers University of Technology)

Siv Haukebø (Det Norske Veritas)

Valentin Vandenbussche (Det Norske Veritas)

EXAMINER

Professor Karin Andersson

Department of Shipping and Marine Technology

Division of Maritime Environment

CHALMERS UNIVERSITY OF TECHNOLOGY

Göteborg, Sweden 2013

Offshore Oil and Gas Activities in Arctic areas
-An Investigation of Best Available Techniques for Reducing Environmental Impacts
Master's Thesis within the Industrial Ecology and Mechanical Engineering programme

EMMA KARLSTRÖM THYLANDER

Report No. 2013:X-13/298
Department of Shipping and Marine Technology
Division of Maritime Environment
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 10 00

Cover photo: Ship in Arctic, DNV/Magne Roe

Printed by:
Chalmers Reproservice
Göteborg, Sweden 2013

Offshore Oil and Gas Activities in Arctic areas
-An Investigation of Best Available Techniques for Reducing Environmental
Master's Thesis within the Industrial Ecology and Mechanical Engineering programme

EMMA KARLSTRÖM THYLANDER
Department of Shipping and Marine Technology
Division of Maritime Environment
Chalmers University of Technology

Abstract

The aim of this thesis report is to investigate how existing Best Available Techniques (BAT) for some key systems are affected by Arctic conditions and future expected requirements in Norway. The thesis report is focusing on assessing three systems with the most planned emissions to air and discharges to sea in oil and gas production facilities; Power and Heat generation, Flare system and Produced Water system. The thesis has been conducted in cooperation with Det Norske Veritas in Høvik, Norway during spring of 2013.

This report consists of two parts; the first part involves the context and general settings on the Norwegian Continental shelf and the Arctic areas. This includes the oil and natural gas industry in Norway, identified environmental impacts and Arctic conditions. The existing regulation and guidelines on the Norwegian Continental shelf have been summarized and future requirements and guidelines for the Arctic areas have been considered and assessed to as large extent as possible. The second part consists of the findings of existing BAT and expected changes due to Arctic conditions for the key systems studied. By comparing the technical constraints and the environmental requirements the alternatives have been assessed if appropriate for Arctic conditions.

The findings include expectations of stricter requirements for the Arctic areas in Norway at present and, depending on case, probably even stricter in the future. This will affect the existing BAT when applied with the expected requirements and the Arctic conditions. In general there are increased requirements when it comes to discharges to sea where the target of zero discharges is emphasized. Norway has both long term target to reduce emissions to air and to be carbon neutral in the future and to protect flora and fauna in the Arctic areas. What in general can be said from the findings are that there will probably be changes and effects on the existing BAT alternatives with Arctic conditions, mainly due to lower temperatures, remoteness and increased requirements regarding emissions and discharges to sea. There is also the question whether or not BAT is good enough for the Arctic? What is considered BAT is changing with time and perhaps there is a need for developing and implement techniques which currently are not presently regarded as BAT.

There are large uncertainties when it comes to impacts and effects from offshore activities on the Arctic environment. What is considered BAT today might not be the same tomorrow and collaboration between different stakeholder such as governments, companies and nations are important for the future to be able to decrease the environmental impacts from oil and gas industry.

Keywords: Best Available Techniques, BAT, Arctic, Environment, Offshore, Oil and gas production, Power and Heat generation, Energy efficiency, Flare system, Produced Water

Acknowledgements

This master thesis has been a part of the master's programme Industrial Ecology as well as within Mechanical engineering as Chalmers University of Technology in Göteborg. The thesis has been carried out at the Division of Maritime Environment at the Department of Shipping and Marine technology and in cooperation with Det Norske Veritas AS at the Section for Environmental Risk Assessment and Technology in Høvik, Norway.

I would like to thank my examiner and supervisor, Professor Karin Andersson for her time and feedback and supervision to my work. I would also like to specially thank my supervisors at DNV, Siv Haukebø and Valentin Vandenbussche at the division of Environmental Risk Assessment and Technology for all support. Moreover, I would also like to thank Torild Nissen-Lie, Head of the Section, and everyone at the department of Environmental Risk Management.

Finally I would like to thank my friends and family for all the support they have given me during this spring.

Høvik, May 2013

Emma C.K. Karlström Thylander

Contents

Abbreviations and Definitions

AC	Alternating current
Albedo	Ability to reflect sunlight
Arctic area	In this thesis report referred to the Arctic areas which are officially and legally under Norwegian boarders. This includes parts of the Barents Sea, Greenland Sea and the northern part of the Norwegian Sea
Arctic council	An intergovernmental forum which addresses issues faced by the Arctic governments and indigenous people of the Arctic. There are eight member counties: Canada, Denmark (Greenland), Finland, Iceland, Norway, Russia, Sweden, United States
BAT	Best Available Techniques
Black Carbon (BC)	Pure carbon in different forms which absorbs heat in atmosphere when left on snow and ice, this reduces albedo which leads to warming of the Earth
BREF	BAT Reference document
BTEX	Benzene, toluene, ethyl benzene and xylenes are included in VOCs (Volatile organic compounds) and found in petroleum derivatives
CH_4	Methane
CO_2	Carbon Dioxide
CO_2-equivalents	Describing the amount of CO_2 a certain mixture and amount of a GHG would be equivalent to, with the same GWP under given time
DC	Direct current
DNV	Det Norske Veritas
Downstream process	Further use of the produced oil and gas, e.g. refineries
Energy efficiency	Can be considered at different levels. In this thesis either a system’s energy efficiency, thermal energy efficiency or the overall energy efficiency have been considered.
Existing situation	Today in year 2013
FEED	Front End Engineering and Design
FPSO	Floating Production, Storage and Offloading
FPU	Floating Production Unit
Future situation	In this project assumed to be the nearest future of about 5 to 7 years
GHG	Greenhouse gas

GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
Hydrocarbons	Organic compound consisting of hydrogen and carbon, majority found on earth in crude oil from decomposed organic matter
IEC	International Electro technical Commission
IMO	International Maritime Organisation
IPCC	Intergovernmental Panel on Climate Change
IPPC Directive	Integrated Pollution Prevention and Control, first adopted as EU Directive 96/61/EC
ISO	International Organization for Standardization
Klif	Klima- og Forurensningsdirektoratet (Climate and Pollution Agency in Norway)
MARPOL	International Convention for the Prevention of Pollution from Ships
N_2O	Nitrous Oxide
Natural gas	Naturally occurring hydrocarbon gas mixture
NCS	Norwegian Continental shelf
NH_3	Ammonia
NMVOC	Non-methane Volatile Organic Compounds
NORSOK	Standards developed by the Norwegian petroleum industry
NO_x	Various nitrogen oxide compounds, mostly NO and NO_2
Oil	Also called Petroleum or Crude oil is naturally occurring hydrocarbon liquid mixture
OSPAR	Oslo- Paris Convention for protection of the maritime environment of the North-East Atlantic
PAH	Polycyclic aromatic hydrocarbons, which occurs in oil and coal
PFCs	Perfluorocarbons
PLONOR	List over chemicals which are considered to Pose Little Or No Risk to the Environment
PM	Particulate matter
Ppm	Parts per million
PTIL	Petroleumstilsynet, in English Petroleum Safety Authority (PSA)
Reserves	Discovered economical and technical available natural resources

Resources	Total resources is estimations of both discovered and undiscovered natural resources
SF_6	Sulphur Hexafluoride
Sm^3 o.e.	Standard cubic metres of oil equivalents is used for example in summarizing resources of oil, gas and condensate
SO_x	Various compounds, SO_2 mostly
Techniques	Refers to the way of doing an activity, operation as well as including the technology concept.
Technology	Refers to complex processes and principles of science used in devices and applications.
Upstream process	Oil and natural gas production
VOC	Volatile organic compounds

1 Introduction

This introduction chapter is divided between four parts to give the reader an outline for this master thesis investigation project.

1.1 Project background

This master thesis project was initiated due to the present interests in possible future oil and gas activities in the Arctic areas. Because of the unique environment and conditions in the Arctic, new challenges have to be faced to preserve the environment and minimize risks of impacts from future offshore activities.

The increasing energy demand worldwide has led to increased renewable energy production besides further extraction of fossil fuel. The increased demand has also lead to increasing oil price and it is now more economically viable to extract previously unavailable oil and natural gas reserves and new discovered resources. Oil is a non-renewable energy source which is very competitive when it comes to energy content, economy, transportation and storage. At present there are no alternatives which can fully work as a substitute, and therefore there is still a high demand for this resource. Moreover, the increasing global emissions to air which are leading to climate change are high on the agenda and something which should be addressed at present time. It is important to extract and produce oil and natural gas in the best possible way when it comes to both environmental and safety issues, in order to reduce the risk of affecting the surrounding environmental. Since the offshore and marine activities in the Arctic are expected to increase in the coming years there is a need for sustainable and safe technologies and operations. The increasing demand of energy in addition to increased oil and gas prices have led to previously unrecoverable resources becoming economically and technically feasible. The Arctic has a rough condition in form of low temperatures, ice, hard winds and currents, remoteness and darkness in the winter it offers other challenges when having increased activities in the area. The Arctic also possesses one of the least affected ecosystems in the world and combining preservation and petroleum activities at the same time in a sustainable way might be challenging.

This project was initiated by Det Norske Veritas (DNV) in Høvik, Norway, when seeing an increased discussion and a need for knowledge around the future potential of the Arctic areas. Especially the Barents Sea has been an interesting area for many years and several international and national research projects and initiatives have been conducted for the area.

Norway is one of the major oil and natural gas exporter nations and has from its first production facility Ekofisk in 1969 developed several offshore regulations, standards and guidelines for the Norwegian Continental shelf (Olje- og Energidepartementet & Oljedirektoratet, 2012).

One of the EU-directives regarding the environment is The European Integrated Pollution Prevention and Control (IPPC) which states that the Best Available Techniques (BAT) should be used to minimize the impacts for the "environmental as a whole" (European Parliament and Council of the European Union, 2008). The IPPC-directive regarding BAT is integrated in the Norwegian regulations in the guidelines for Activities Regulations (Aktivitetsforskriften) from Petroleum Safety Authority, (Petroleumstilsynet, 2012-12-20).

1.2 Objective and Purpose

The main purpose of this project is to get a deeper knowledge and overview of the future potential techniques, for some key systems, according to BAT when considering the Arctic conditions and expected policy instruments.

This includes studying existing regulations, standards and guidelines applicable to environmental issues for petroleum production, and how these are associated to existing Best Available Techniques on the Norwegian Continental shelf. Further on, the project investigates the expected future guidelines and regulations as well as management plans and recommendations for offshore production in the Arctic areas. Subsequently, an addition can be performed to the existing BAT for each system, with Arctic condition and issues. By comparing the existing setting at the Norwegian Continental shelf and the Arctic setting, challenges can be identified.

The following key systems will be evaluated on a conceptual level:

- Power and Heat generation and Energy Efficiency,
- Flare system,
- Produced water treatment system.

Following activities are performed:

- Listing existing environmental regulations applicable to offshore production in Norway,
- Register existing guidelines and standards concerning environmental issues applicable and frequently used for the Norwegian continental shelf,
- List the BAT and alternative techniques for each key system,
- Collect environmental recommendations and expected present and future guidelines with regards to Arctic offshore production,
- List the additions and changes to the BAT and alternatives for each key system.

For the Arctic conditions the area of focus is the Barents Sea, Greenland Sea and the northern part of the Norwegian Sea, see map in Figure 1.

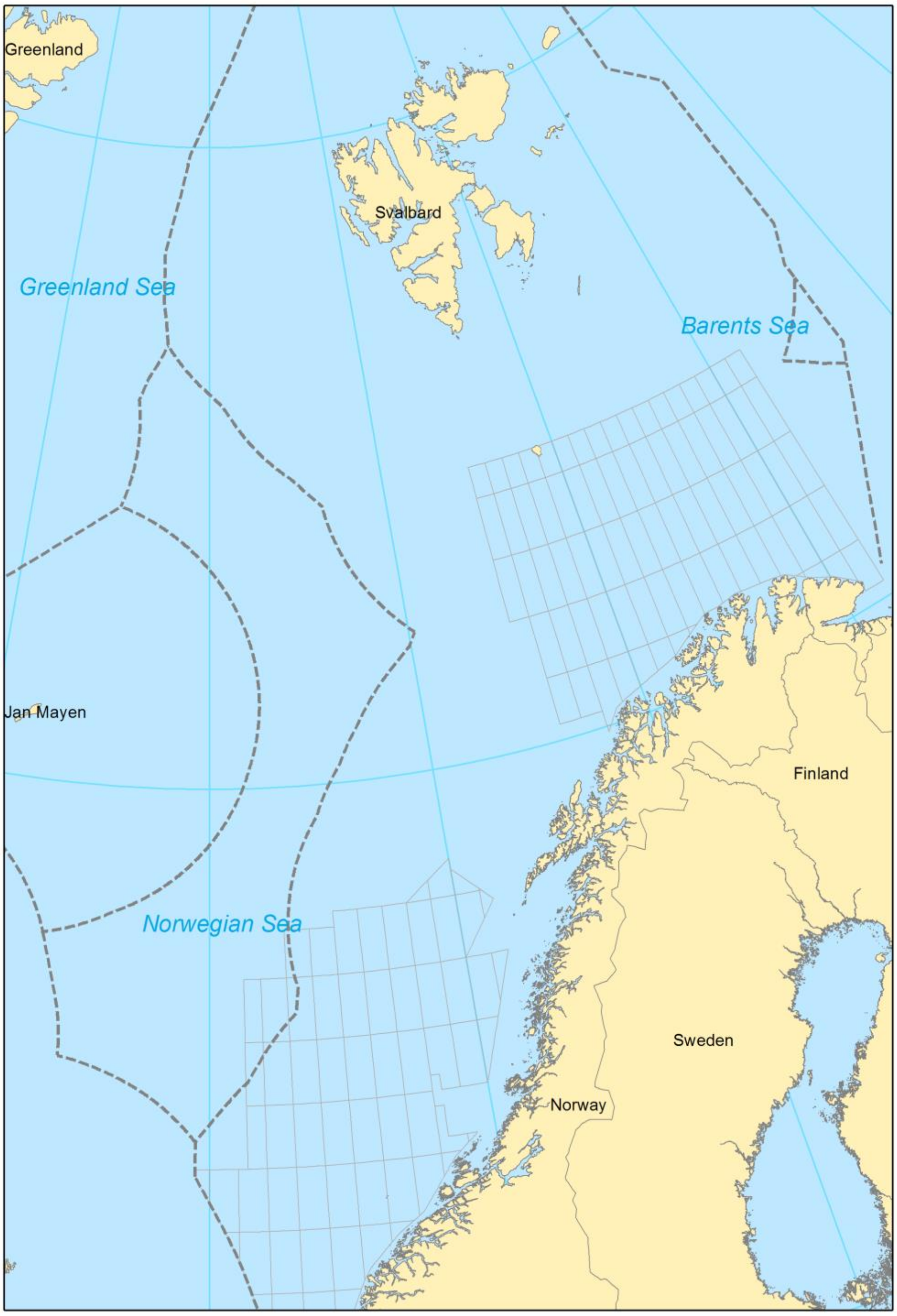

Figure 1: Map over the studied Arctic areas; Barents Sea, Greenland Sea and the northern part of the Norwegian Sea. The map includes the Norwegian maritime boundaries (--) and the present division of quadrants and blocks, (Source: © Esri Data & Maps/DeLorme and Kartgrunnlag: Kartverket).

1.3 Limitations

Some limitations have been drawn to this project mainly due to time constraints. This investigation will only look into Norwegian regulations and directions. International guidelines and standards which are applicable and commonly used for the Norwegian Continental Shelf will also be included.

- The time frame is defined as the near future of 5-7 years (approximately 2013 to 2020) and involves the available technologies and techniques within this time.
- This project will only involve oil and natural gas production operation and does not include other operations such as drilling or transport.
- This thesis is aimed to get an overview on a conceptual basis over the areas of legislations, standards, environmental science and technology.
- Mainly, planned environmental discharges (such as emissions to air, discharges to sea) are included.
- Risks due to unplanned events may be incorporated in BAT, but no clear risk assessment will be included in this project.
- The base case which has been studied is an oil and natural gas production facility on the Norwegian continental shelf with production under regular operation.

1.4 Research questions and investigation areas

The following questions will be answered in the master thesis project.

The existing situation is referring to the current condition, which is the spring in 2013. The future situation is referring to a time horizon of up to seven years, which means to the year 2020.

Research questions for the existing settings:

1. What kind of existing environmental regulations and requirements are currently present for offshore projects on the Norwegian continental shelf (overview)?
2. What are the environmental and BAT guidelines in addition to the law requirements that can be seen as recommendations?
3. What are the existing BAT-techniques for some common systems (earlier described as key systems) in oil and natural gas production facilities on the Norwegian Continental shelf?

Research questions for the future situation:

4. What is the probable and expected development of the existing regulations, guidelines and standards for future projects in the Artic areas?
5. What is the likelihood of changes to BAT-techniques (previously studied) due to the Arctic challenges and conditions?

2 Method

This project investigation has been performed by comparing the existing technologies and techniques considered BAT and the future requirements and guidelines for the Arctic area and its conditions. This is to evaluate if there are any difference in the environmental impacts, performances and constraints for future BAT.

2.1 Execution

This master thesis is part of the master programme Industrial Ecology as well as the master engineering programme Mechanical Engineering at Chalmers University of Technology.

The project was performed at the DNV head office in Høvik, Norway and at Chalmers Lindholmen in Göteborg at the division of Maritime Environment and performed from February to June in 2013.

2.2 Theory and Background research

This investigation first involved literature search and reading general information about the oil and natural gas industry, technologies and techniques, the industry in Norway and the Arctic. This was mainly performed by information research, various articles and reports, mini-workshops and discussion sessions.

Information gathering for the study was involving literature search, published articles and reports, regulation documents and guideline documents. Also various publications from the Norwegian Government, Klima- og Forurensningsdirektoratet (Klif), DNV and Oil and gas companies along with other organisations such as the Arctic Council were reviewed.

Background about the BAT concept was investigated by studying the IPPC directive and several other reference documents produced by the EU Commission.

Both general as well as more technical document have been studied to get a deeper knowledge and background about the oil and natural gas industry, on-going debate and discussions in addition to future innovations.

2.3 Procedure

The procedure, as a form of multi criteria analysis, has been developed during the first period of the project and concluded in a number of steps. These steps are also being visualised in a chart showing the different phases and their interconnection, see Figure 2.

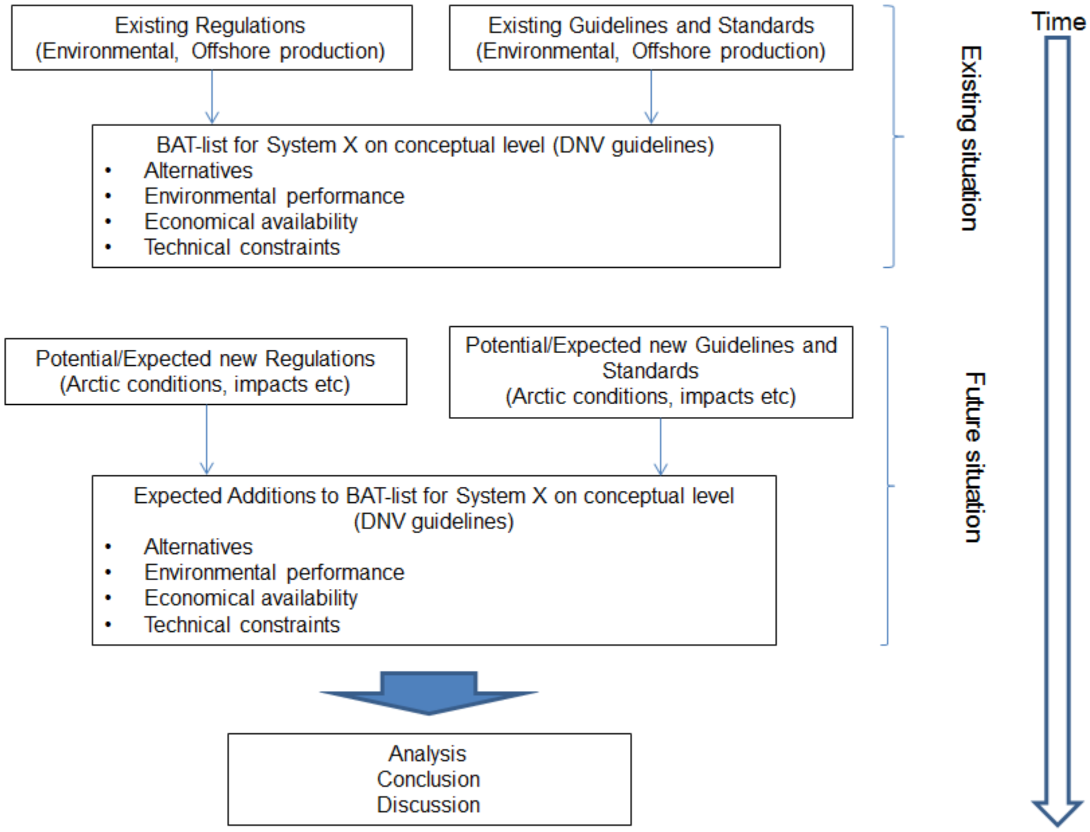

Figure 2: Methodology chart over the methodology of the performance for the thesis.

These steps can be concluded as following points:

- Background information collection of the oil and gas industry, the technical systems, BAT guidelines and recommendations for assessments.
- Existing regulations, guidelines and standards collection.
- Systemize and organize the information using MS Excel.
- List different alternative techniques and technologies for each system and emphasize those considered as BAT. This is achieved by assessing each system and possible subsystems with DNV's BAT Guidelines. Each alternative's performance will be compared by the use of a base case alternative.
- Background information collection on Arctic areas.
- Collection of information and expectations with regards to future regulation, guidelines and standards.
- Re-evaluate the BAT assessment list for the systems with regards to the Arctic conditions and the findings of expected future regulations, guidelines and standards.
- Provide answers and findings referring to the research questions.
- Analyse and draw conclusions from the findings.
- Discuss and make recommendations for further work and include aspects which might not been covered furthered in this thesis.

3 General settings and context

To understand the background settings and context is an essential part of this project. Since there are several different areas to cover, it is important to get a holistic overview to cover the essentials. This chapter includes an introduction to the oil and gas industry in Norway, environmental aspects and impacts, Arctic conditions and challenges, BAT, regulations, standards and guidelines. This background chapter will also include an adapted BAT assessment plan due to the fact that this project thesis is only including BAT at a more conceptual level without any location-specific details which are needed to conclude a fully BAT assessment.

One of the parts of this project was to gather and summarise the national regulations, international guidelines and standards referring to environmental issues, see Chapters 3.53.6 and 3.7.

3.1 Oil and gas industry in Norway

This chapter has been divided into the history of the oil and gas activities in Norway and a general description of oil and gas facilities and processes.

3.1.1 Norway’s oil and gas history

The oil and gas industry in Norway started in the 1960’s when the exploration of the North Sea started. The first oil and natural gas field was Ekofisk which started production in 1969. In the beginning of the 1970’s Norwegian government established a principle of a 50% state participation in each license, which has led to unique financial benefits for the country as a whole. Also several state-owned companies were formed; one of the largest is Statoil, (Olje- og Energidepartementet & Oljedirektoratet, 2012).

The Norwegian Continental shelf is divided into blocks for which national and international companies can apply for exploration and production licenses, individually or in collaboration with each other. Norway was, as a nation, in 2010 the second largest natural gas exporter and the sixth largest oil exporter in the world. The incomes from oil and gas industry stands from about 25 % of the total governmental revenue per year (and over 20% of GDP) and are placed in a governmental pension fund to secure a long term plan for the use, (Olje- og Energidepartementet & Oljedirektoratet, 2012).

To get an overview and idea of the future possibilities of oil and natural gas exploration there are estimates of the total resources and reserves made for the Norwegian Continental shelf. Often the total resources are the total quantity of a substance, both discovered and those yet undiscovered. The reserves are the amount of discovered and recoverable part of the resources, see Figure 3. The reserves can increase due either to new discoveries or to new technology and/or economic feasibility.

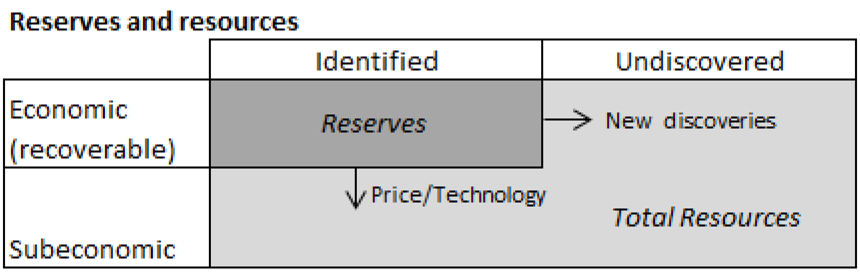

Figure 3: Reserves and Resources connection.

The total estimated resources (both discovered and undiscovered) on the Norwegian Continental shelf are 13,1 billion standard cubic metres of oil equivalents (billion Sm^3 o.e.), where already produced and delivered are 5,7 billion Sm^3 o.e. (about 44 %) of the total and 56% are still to be produced and discovered. From the contingent and the estimated, yet undiscovered resources there are approximately equal distribution between oil and natural gas (3,9 and 3,5 billion Sm^3 o.e.), see Figure 4, (Olje- og Energidepartementet & Oljedirektoratet, 2013). However these numbers may change in the future depending on new findings or reviewed estimations.

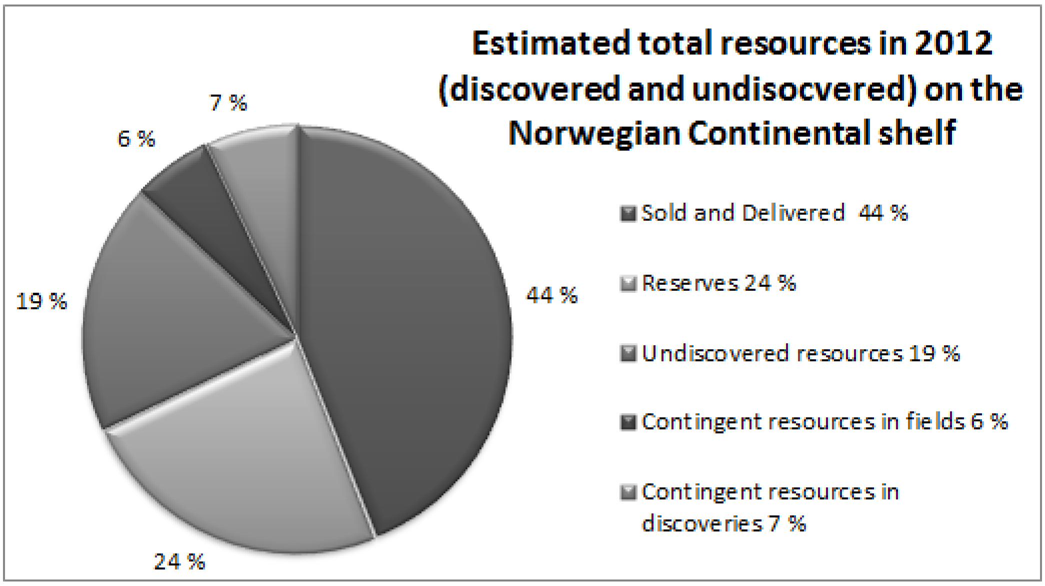

Figure 4: Distribution of Total Estimated resources in Norway, numbers from Norwegian Petroleum Directorate, (Olje- og Energidepartementet & Oljedirektoratet, 2013).

At present there are about 70 producing fields on the Norwegian Continental shelf. The most north situated are the natural gas field Snøhvit and the forthcoming oil field Goliat in the Barents Sea, (Olje- og Energidepartementet & Oljedirektoratet, 2012).

3.1.2 Oil and gas production facilities and processes

Fluids extracted from the subsurface usually consist of a mixture of oil, natural gas and water together with traces of sand and sometimes naturally-occurring radioactive materials and other compounds.

Oil and natural gas reserves in the world are getting more and more located in the deep ocean. In Norway, the activities are moving towards the north parts (northern Norwegian Sea and Barents Sea), although there have been new discoveries in developed areas in the North Sea, (Vandenbussche, Introduction to the offshore Oil and Gas industry, 2013-02-06).

There are a large range of options when it comes to exploration and production facilities design. These can be fixed, jack-ups (movable platforms) or floating (e.g. semi-submersible or drilling ships) for a drilling facility. This depends on for example depth, other design choices and location-specific conditions, (Vandenbussche, Introduction to the offshore Oil and Gas industry, 2013-02-06). Some of the different platforms designs are shown in Figure 5.

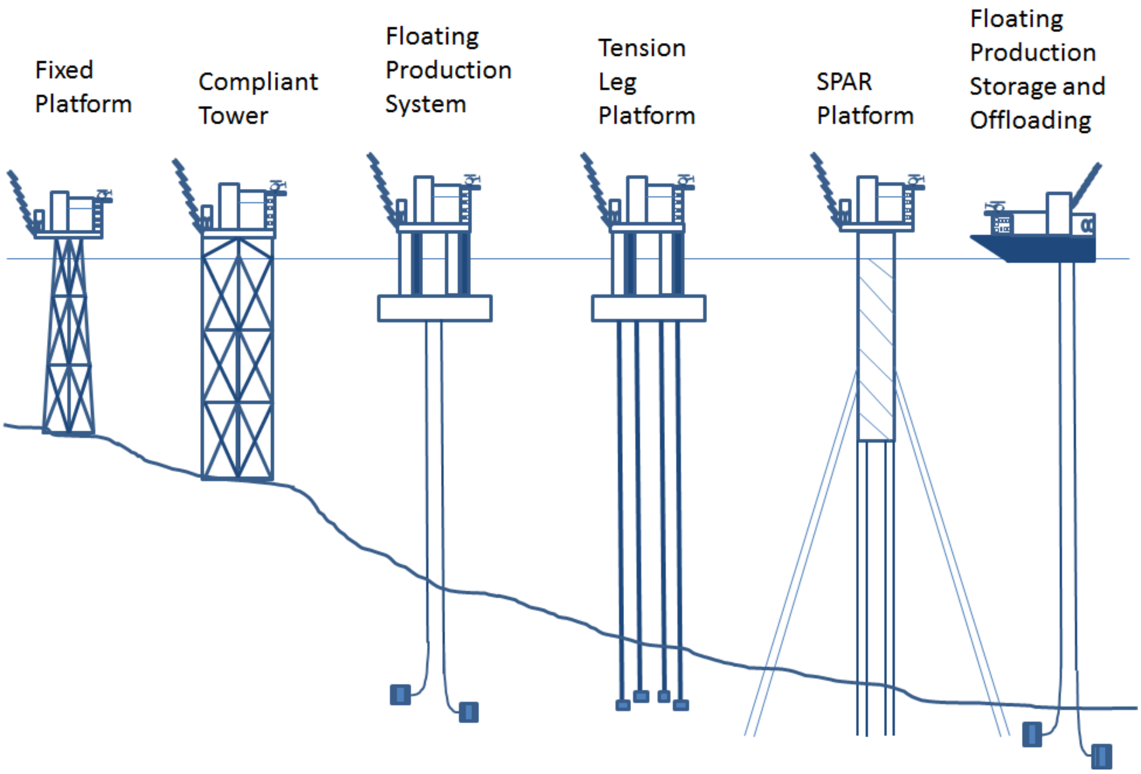

Figure 5: Various platform designs. From left: Fixed Platform (FP), Compliant Tower (CT), Floating Production System (FPS), Tension leg Platform (TLP), SPAR Platform (SP), Floating Production Storage and Offloading (FPSO).

A future scenario is that floating and moveable platforms are getting more common due to increased production in deeper areas (Vandenbussche, Introduction to the offshore Oil and Gas industry, 2013-02-06). This is also beneficial in terms of re-use and lifetime of installations, as the mobility of the installation may enable it to be used on a new field when the original field is ending its production.

A typical process, see Figure 6, starts with a mixture coming up to the production platform from the production well by the high pressure in the reservoir. The mixture consists of oil, natural gas, water and some other substances which are then separated through a process system. The different separated substances may be treated further on board, such as removing water from gas. After treatment, the natural gas is either exported trough e.g. subsea gas lines or injected back to the wells (for increased well production). The oil is transported either to a storage facility or directly exported by transportation units. The produced water is, after the treatment, either re-injected back to the well (to increase oil and gas production and avoid discharge to the environment in sensitive areas) or discharged to the sea. The produced water can only be discharged to sea, after appropriate removal of oil, so that regulatory and project specific limits of the oil concentration are reached. For most of the processes in Figure 6, there is a need for sufficient and secure energy supply in form of electricity and heat (Vandenbussche, Introduction to the offshore Oil and Gas industry, 2013-02-06).

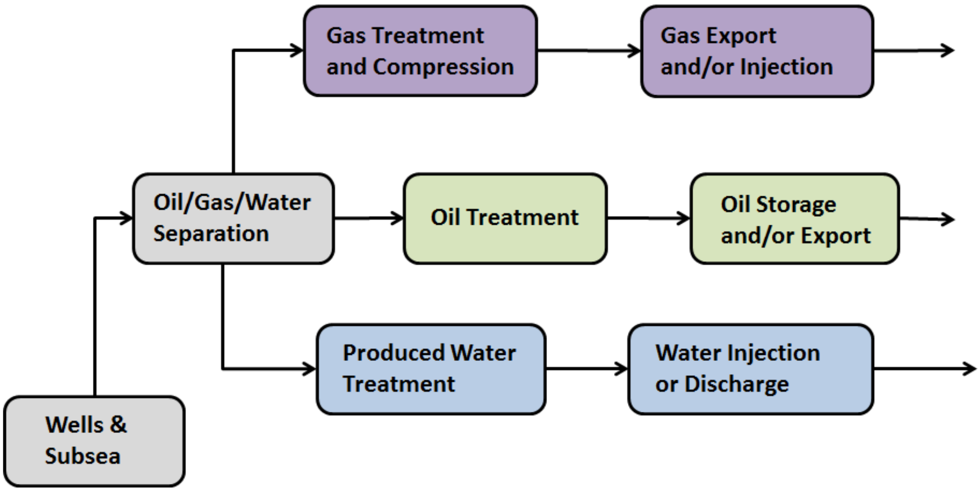

Figure 6: General process for offshore oil and gas production, after interview, (Vandenbussche, Introduction to the offshore Oil and Gas industry, 2013-02-06).

The environmental impacts from oil and gas production (not including drilling, transportation or downstream processes, like refineries) mostly consists of emissions to air and discharges to sea. The oil and gas industry in Norway stands for 29% of the national CO_2 emissions in 2011 and also stands for the largest increase in CO_2 – emissions from 1990, see Figure 7, (Statistics Norway, 2013-02-07).

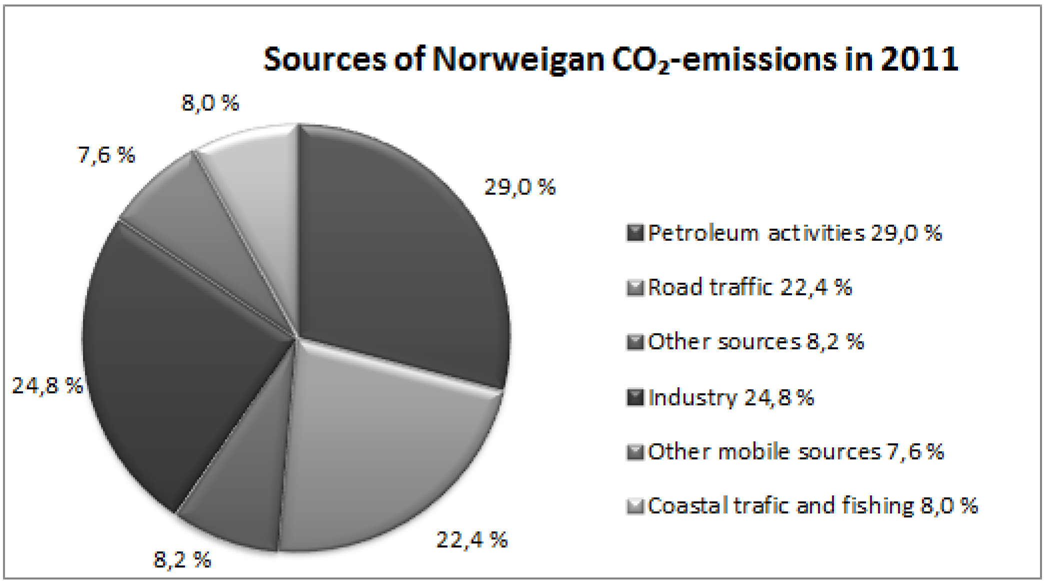

Figure 7: Sources to CO_2 emissions in Norway 2011, numbers from Statistics Norway, (Olje- og Energidepartementet & Oljedirektoratet, 2013).

Other emissions to be mentioned are NO_x (mainly NO_2 and NO) and NMVOC, particular matters (PM, including Black Carbon) and SO_2. These emissions lead to both local and global impacts, such as global warming (from GHG emissions), acidification and poor air quality. Discharges to sea are mainly oil-compounds and chemicals from produced water and drilling, which can have an impact on the local environment (algae, corals, fungus, fish etc.) and animal life which will affect the ecosystem. One of the main issues in the oil and gas industry is also to reduce the risk of acute discharges such as oil spill, (Olje- og Energidepartementet & Oljedirektoratet, 2012).

Other aspects in the oil and gas industry are waste minimization, energy efficiency measures and safety. In recent years, Norway has focused on environmental technologies, within both the oil and gas industry and in the shipping industry. This with the intention that "The use of environmental technologies shall contribute to the demand of economic growth is met without increasing the environmental impacts", (SINTEF - Teknologi og samfunn, 2008).

3.2 Environmental aspects and impacts

To be able to identify important environmental impacts, different environmental stressors have been identified relevant to the scope of this project. Since the project is concentrating on a conceptual level and is not referring to any site specific material, the stressors and performance are limited. It is recommended that for each case there should be a thoroughly investigation of possibly environmental stressors and performance-specific issues.

The structure to organising performance measures with environmental stressors, impacts and sustainability issues have been built upon the report of DNV’s BAT guidelines, (Karlsson & Westin, 2010) and following number of issues have been evaluated in the BAT, both for existing conditions on the Norwegian Continental shelf and addition to Arctic specific conditions.

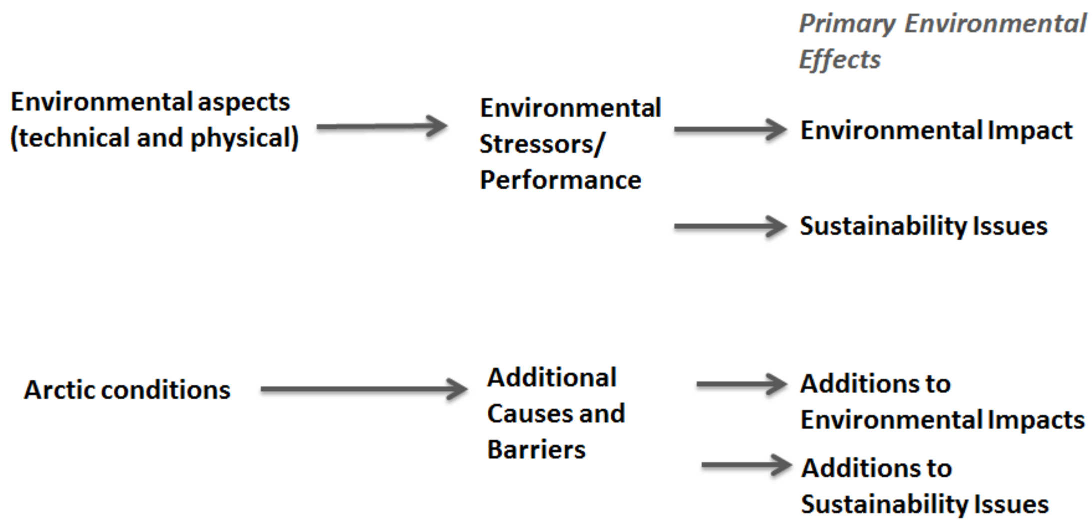

Figure 8: Connection and links between Aspects, Performance, Stressors, Impacts and Issues. The additions due to the Arctic conditions are presented in Chapter 3.3.

Main drivers are the technical and physical aspects of the production process and the Arctic conditions. They will lead to release of stressors or performance which will give rise to different Environment impacts or Sustainability Issues and Environmental risks, see Figure 8.

Some technical and physical aspects have been identified which will result in central stressors and their following environmental impacts, shown in Figure 9.

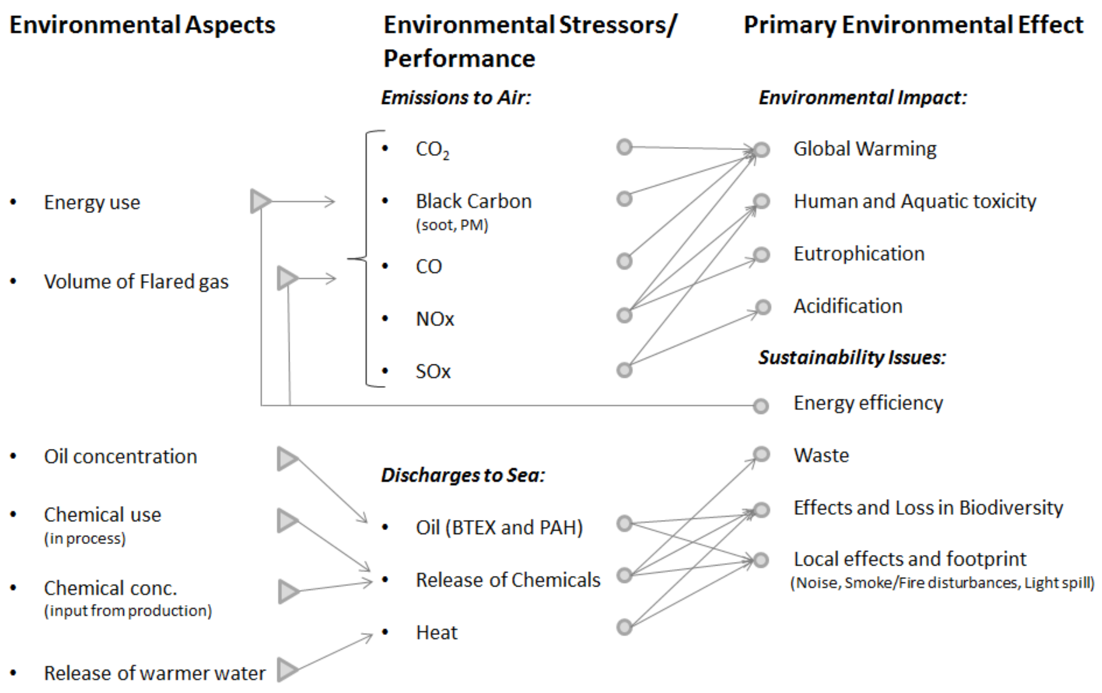

Figure 9: Different aspects, stressors/performances and their primary effects, identified in this project.

The different classifications of aspects, stressors and their effects are explained as followed.

Environmental Aspects are defined as a component of an organization's activities, products or services that can interact with the environment, (International Orgianization for Standardsization, 1996). The environmental aspects considered in this project are:

- Energy use,
- Volume of flared gas,
- Oil concentration,
- Chemical use in processes,
- Chemical concentration, inputs form production operations,
- Release of warmer water.

Environmental Stressors or Performance are defined as discharges of substances that lead to environmental impacts. The stressors can be divided into a number of impact categories (e.g. acidification), (Karlsson & Westin, 2010). The Environmental Performances are measures of performances which can lead to consequences of a sustainability character. Some of the most relevant stressors and performances of this thesis are shown above in Figure 9. There is a division between Emissions to Air and Discharges to Sea as following:

Emissions to Air:

- CO_2,
- Black carbon (in this project report also included in Soot and Particulate matter),
- CO,
- NO_x,
- SO_x.

Discharges to Sea:

- Oil (including substances like Benzene, toluene, ethyl benzene and xylenes (BTEX) and Polycyclic aromatic hydrocarbons (PAH)),
- Release of chemicals,
- Heat release (warmer water).

The **Primary Environmental Effects** have been divided into Environmental Impacts and Sustainability Issues. The Environmental Impacts are a more direct measure of the consequences from stressors while the Sustainability Issues are another type of effect which can lead to environmental effects in their next stages. Some deeper explanations of Sustainability Issues and different Environmental Impacts are described in the following paragraphs.

Sustainability Issues are classifications which can be evaluated from performance measures, (Karlsson & Westin, 2010). Sustainability can be defined as "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" in the Brundtland report (also called Our Common Future) from 1987, (International Institute for Sustainable Development, 2010). The term Sustainability consists of three pillars; Environmental, Economic and Social, (International Institute for Sustainable Development, 2010). Some of the sustainability issues mostly relevant to this project are shown in Figure 9. The sustainability impacts considered in this thesis are:

- Energy efficiency,
- Waste,
- Effects and losses in Biodiversity,
- Local effects and footprint (such as noise, smoke/fire disturbances, light spill).

The sustainability issue of increasing global energy demand puts focus on the importance of increasing energy efficiency and energy management. Noise, such as low frequency noise from engines and turbines, can have a local effect on the environment in form of disturbing different kinds of animals, fish and mammals. This might be an issue in new exploration areas which have relatively low existing disturbances from activities like petroleum production, shipping and increased transports, (Giampaolo, 2006). There might also be an increased noise issue affecting sea animals and fish with further development of subsea techniques.

Environmental impacts are defined as any change to the environment, either adverse or beneficial resulting fully or partly from activities, products or services, (International Orgianization for Standardsization, 1996). These impacts can both have shared stressors or separate stressors.

The following Environmental Impacts have been evaluated in this project:

- Global warming,
- Human and Aquatic toxicity,
- Eutrophication,
- Acidification (here mainly to Sea).

The impacts can have several connecting stages as for example:

Increased albedo ("whiteness" and possibility to reflect) $\rightarrow$ *Increased radiative forcing* $\rightarrow$ *Increased short wavelength absorption* $\rightarrow$ *Increased mean temperatures* $\rightarrow$ *Global warming e.g. melting ice and increased sea level* $\rightarrow$ *Increased albedo*

As demonstrated here, often one environmental impact is a part of a chain reaction and can result in even higher and exponential rate degree of the impacts. There are several other environmental effects and impacts but not all of them have been included, see earlier presented, Figure 9 for impacts considered in this project.

Following are explanations of the considered environmental impacts:

Global warming: Emissions from GHGs, like carbon dioxide (CO_2) and methane (CH_4), released from example burning of fossil fuels are emitted to the atmosphere.

In the atmosphere the GHGs are absorbing the outgoing radiation from the Earth and re-emits radiation back to the earth surface. With increasing GHGs the re-emitted radiation back to earth surface are increasing and this will cause an increased temperature on earth, see Figure 10. Another way to explain what can lead to global warming is an increase in *radiative forcing*, which is the difference between the energy radiated to earth and the energy radiated back to the atmosphere. When this radiative forcing is positive the temperature is increasing and when it negative the temperature is cooling. When there is an imbalance in the radiative forcing, this is not due to naturally causes but anthropogenic, positive radiative forcing leads increased temperatures and global warming.

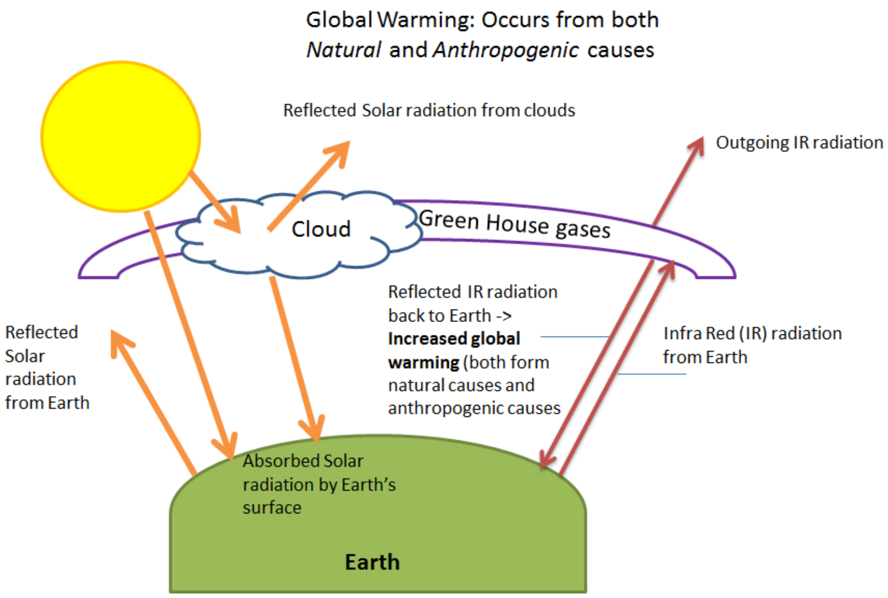

Figure 10: A simplified figure of Global warming. The radiation reflected back to Earth from GHG by IR radiation can occur at any height in the sphere and altitude.

For example release of *Black Carbon* can result in increased radiative forcing, by settling on white surface (ice, snow) the albedo ("whiteness" and possibility to reflect sunlight) will decrease. This will lead to less energy reflected back to atmosphere and a positive radiative forcing. The global warming is a natural process with an increasing global average temperature as a result. The issue concerns the acceleration of this increased global average temperature due to human-caused (anthropogenic) emissions. Within the last 25-50 years this rate has doubled compared to earlier measurements. More information and details can be found from the Intergovernmental Panel on Climate Change (IPCC) web page and especially in their report about the physical science basis on global warming, (IPCC Fourth Assessment Report (AR4), 2007).

Toxicity - Human and Aquatic: Toxicity is a way to explain the harmfulness of substances which cause effect on humans, animals and other organisms. Such substances can for example be oily compounds, chemicals, metals, particulate matters (PMs). These substances can be released by operational emissions and discharges, waste water release, oil spill and other acute or unplanned events. A severe incident can lead to losses in biodiversity and contamination of sea and land areas.

Eutrophication: Is caused by increased inflow of phosphorous and nitrogen from for example fertilizers, burning of fossil fuels and discharges of waste water. The increased inflow leads to increased growth of microorganisms and toxic algae species which affects the balance in the ecosystem.

Acidification: In water areas there is a risk for aquatic acidification which is a result of SO_x and NO_x emissions released from for example burning of fossil fuels, which are chemically transformed to sulphuric and nitric acids in the atmosphere and transported by rain down to the earth surface. The acids, with a lower pH than the area are then reacting and effecting ecosystem organisms in a negative way.

These environmental impacts are to large extent global issues. Requirements and guidelines have been developed both on a global level but also a national level in Norway. The Kyoto protocol, signed and ratified by Norway, has set targets for the GHG emissions, such as CO_2, CH_4, N_2O (nitrous oxide), HFCs (hydrofluorocarbons), PFCs (perfluorocarbons), SF_6 (sulphur hexafluoride), (United Nations Framework Convention on Climate Change, 2008). The OSPAR convention concerns Prevention and elimination of pollution from offshore sources (Annex III) and assessment, protection and conservation of the ecosystems and biological diversity of the marine environment (Annex IV and V), which has been signed and ratified by Norway. The OSPAR convention includes discharges to sea and the use of Best Available Technique and environmental practice for the environment, (OSPAR Commission, 2013). The Göteborg protocol treats and regulates emissions, SO_2, NO_x, NH_3 (ammonia) and NMVOC, which affect acidification, eutrophication and ozone depletion. Norway as well as most European countries and the U.S., have ratified the protocol and with a revised protocol in 2012, which includes targets for emissions until 2020 which also includes PM, (Miljøstatus , 2012-05-31).

3.3 Arctic challenges and conditions

The Arctic sea areas are covering the most northern part of the globe. For a long time this area has been undisturbed and untouched but the recent years of melting ice, make operations in the Arctic areas more easily accessible. The challenge to preserve the Arctic biodiversity and nature at the same time as increasing the activities is a significant issue for the Arctic states, (Barents Observer, 2012-11-23).

Figure 11: An overview map over the Arctic areas including Arctic boundaries and Sea ice extent (one randomly chosen month in summer season and one in winter season). Boundary according to AMAP (an Arctic Council working group), a regional extent based on a compromised among various definitions and essentially includes terrestrial and marine areas north of Arctic Circle (66°32ˈN) and north of 62° in Asia and 60° in North America, (source: http://www.amap.no/AboutAMAP/GeoCov.htm). Boundary according to EPPR (another Arctic Council working group) is based on their focus on emergency, prevention, preparedness and response, (source Arctic council and GRID-Arendal). The Sea ice extent boundaries are a way to show the Arctic areas which are ice-covered and non-ice-covered under certain seasons, (Source: Fetterer, F., K. Knowles, W. Meier, and M. Savoie. 2002, updated 2009. Sea Ice Index. Sea Ice Extent 2011. Boulder, Colorado USA: National Snow and Ice Data Center).

The international interest is high for the Arctic; one example is to use the Northern Sea Route for transportation all year around between Europe and Asia thanks to melting icecaps (Barents Observer, 2012-11-23).

The Norwegian part of the Arctic basically exists of the northern part of the Norwegian Sea, Greenland Sea and the Barents Sea which includes the land areas of Svalbard, Lofoten and the Jan Mayen Islands see Figure 1 in Chapter 1.2.

These areas consist of mostly untouched nature and unique biodiversity (Norwegian Polar Institute, 2013). The Arctic ice sea cover is decreasing rapidly. With increasing demand for energy in the world and increasing oil and gas prices, this opens up for more new offshore and marine activities. The Arctic paradox is when the melting ices opens up for more activities, such as oil and gas production, which emits GHGs and other pollutants that leads to even further ice melting, (DNV, 2012-09-24).

The Arctic areas can roughly be divided into the ice covered areas and the non-ice covered areas, see Figure 11. This can be permanent but also change during the time of the year. Most of the Norwegian part of the Arctic is non-ice covered areas. Since there is a large difference between different Arctic areas, there shall also be differentiated between the areas conditions and the risks of future environmental impacts. In this thesis, focus will be on the Arctic areas most easily accessed and which will probably be explored in the nearest future.

The Arctic's characteristics, which could impact future potential activities and also be a major challenge, are for example the low temperatures and the risk of icebergs. Icebergs can lead to severe misfortunes, due to collision with offshore assets. The most specific features and conditions for the Arctic area are:

- Extreme climate with low temperatures and snow,
- Ice and icebergs (seasonal ice calls, sea ice hydrology),
- Darkness under winter season (Lightness under summer season),
- Strong winds (Polar laws),
- Permafrost,
- Remoteness,
- Sensitive ecosystems and nature,
- Rapid changed conditions, e.g. fog and waves,
- Unique biological ecosystems involving fish, mammals, sponge, algae etc.

References: (Klima- og Forurensningsdirektoratet, 2013-01-10), (Arctic Council - EPPR, 2012).

These characteristics and conditions lead to some major challenges for offshore activities in the Arctic area.

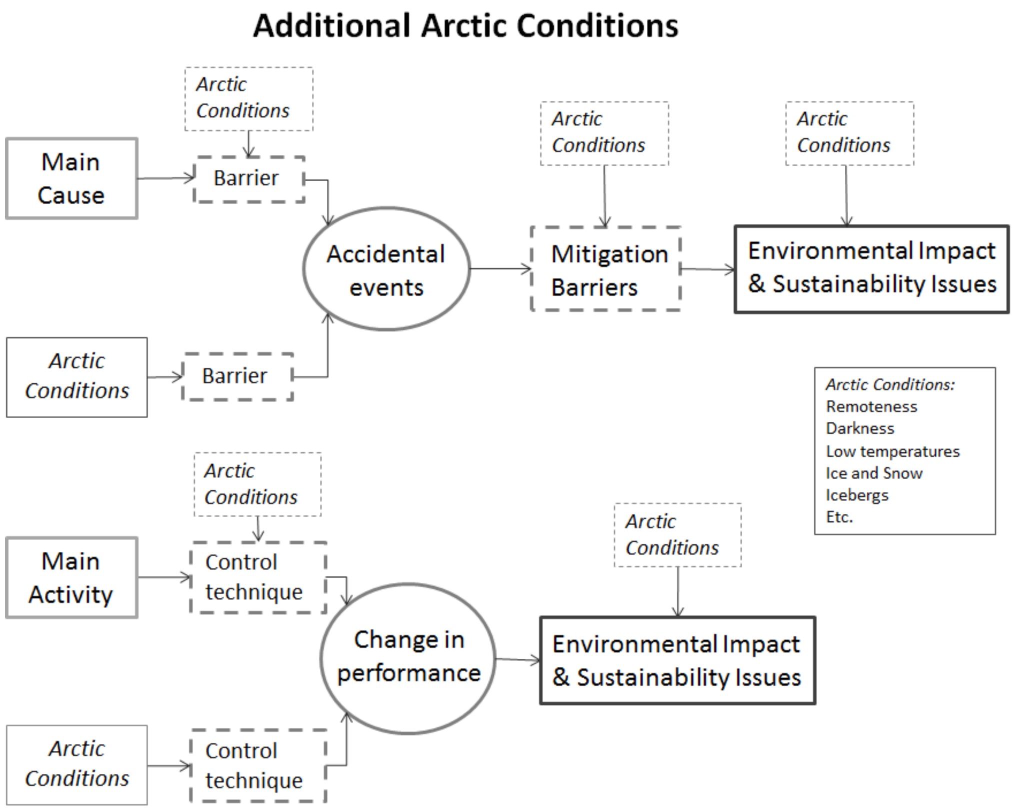

Figure 12: Arctic conditions' different on Environmental Impacts and Sustainability Issues.

All of these challenges should be assessed and evaluated in order to reduce the possible impact from offshore activities. In Figure 12, the different inputs from Arctic conditions are shown in connection to Environmental impacts and Sustainability issues. There is a division between *Accidental events* and *Change in performance.*

Accidental events, is, in this project, defined as unplanned and unintentional event/events caused undesirable harm to humans or to property or have negative effect on the environment, (Arctic Council - PAME, 2009-04-29). These accidental events are related to risk management and to minimize the risks of an activity. The Arctic conditions can both be a cause of the accidental event as well as affecting a barrier. Arctic conditions can also affect mitigation barriers which role is to minimize environmental impacts or issues. As an example, darkness (Arctic condition) can affect the visual detection (mitigation barrier) of an oil spill (accidental event), which can lead to increased environmental impact.

Change in performance, is, in this project, defined as deviations in operational performance which can have either a positive or negative effect on the environmental impacts or sustainability issues. This is not related to risk handling but instead treating the effects on continuing, regular operations. Arctic conditions can here be a component causing a change in performance or affecting any control technique causing change in performance. The Arctic conditions might also affect any existing environmental impacts or sustainability issue. An example is that the colder temperatures and icing can affect the performance of measuring instruments and require anti-icing equipment which might demand extra energy. This extra energy will then decrease the overall energy efficiency and also increased emissions from power generation.

The main challenges identified for offshore activities in the Arctic areas include:

- Low temperatures risks (e.g. icing, snow),
- Increased technology demand (e.g. material choice, structures),
- Increased risk of accidents and the severity of consequences (e.g. due to icebergs),
- Affecting factors on humans: darkness, remoteness, lack of access,
- Lack of infrastructure and support facilities,
- Increased preparedness for rapid changed conditions,
- Impacts from oil spills release,
- Impacts from discharges to sea,
- Impacts from emissions to air,
- Particular matter release (e.g. Black carbon and soot, also see Chapter 3.2).

References: (Klima- og Forurensningsdirektoratet, 2013-01-10) (Arctic Council - EPPR, 2012).

The Arctic conditions offer additional environmental effects, also see Chapter 3.2. There is still further research which can be performed assessing environmental impacts in Arctic areas, on for example oil spill effects on ice. There is lots of focus on risk assessment on accidental events, but environmental issues are also linked to impacts from operational performance activities such as emissions to air from power generation and flaring.

3.4 Best Available Techniques (BAT)

Best Available Techniques or BAT is mentioned in the European Union's Integrated Pollution Prevention and Control (IPPC) - directive (96/61/EC) from 1996 and later updated in 2008 (2008/1/EC), (European Parliament and Council of the European Union, 2008).

3.4.1 IPPC-directive on BAT

The purpose of the IPPC-directive is to minimise pollution from different industry sectors by controlling and preventing discharges and effluences. In Article 2 in the IPPC-directive (2008/1/EC), BAT is defined as:

"'*Best available techniques'* means the most effective and advanced stage in the development of activities and their methods of operating which indicate the practical suitability of particular techniques for providing in principle the basis of emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole", (European Parliament and Council of the European Union, 2008).

'Best' is defined with the meaning of being the most effective way to achieve a "high general level of protection of the environment as a whole", (European Parliament and Council of the European Union, 2008).

'Available' is defined as the techniques which are in that stage of development so that it is both economic and technical viable for the operator, (European Parliament and Council of the European Union, 2008).

'Techniques' is defined as both the technology being used as well as the design of the installation, its construction, maintenance, operation and decommissioning, (European Parliament and Council of the European Union, 2008).

To implement this, the European IPPC Bureau (EIPPCB) has published a series of BAT Reference Documents (BREF) to provide easier information exchange between nations, experts, industries and environmental organisations. Different BREFs are published for different industries or certain processes. There are at present no BREF concerning offshore oil and gas production. In this thesis project the BREF for Large Combustion Plants and Energy Efficiency will be considered (European IPPC Bureau, 2006).

3.4.2 BAT in Norway

The IPPC-directive was implemented in Norwegian legislation as a result from the EEA-agreement between EU-member states, Norway, Iceland and Lichtenstein, which were entered into force in 1994. The BAT is mentioned in the guidelines for the Pollution Control Act (Forurensningsloven) and the Activity Regulations (Aktivitetsforskriften) for the oil and gas industry. Besides this BAT is also being included in the standard NORSOK S-003 which considers the environmental concerns within the oil and gas industry (Petroleumstilsynet, 2012-12-20), (NORSOK S-003, 2005-12-03).

In practice, BAT is used for comparing and assessing different alternative techniques based on their environmental performance and including economical and technical availability, to be able to choose the alternative which reduces the overall impact on the environment as a whole.

3.4.3 DNV's BAT methodology

DNV has developed their own methodology to assess BAT for oil and gas industry activities through a master thesis. The methodology includes a tool and guidelines to compare different alternative, see Figure 13. In the oil and gas industry a BAT assessment can be performed during several stages and phases of a project. The main phases used for new development offshore project, as an example, are the conceptual phase, the pre-engineering (FEED) phase and the detailed engineering phase. BAT should be introduced and used as early as possible to avoid late changes and extra costs, (Karlsson & Westin, 2010).

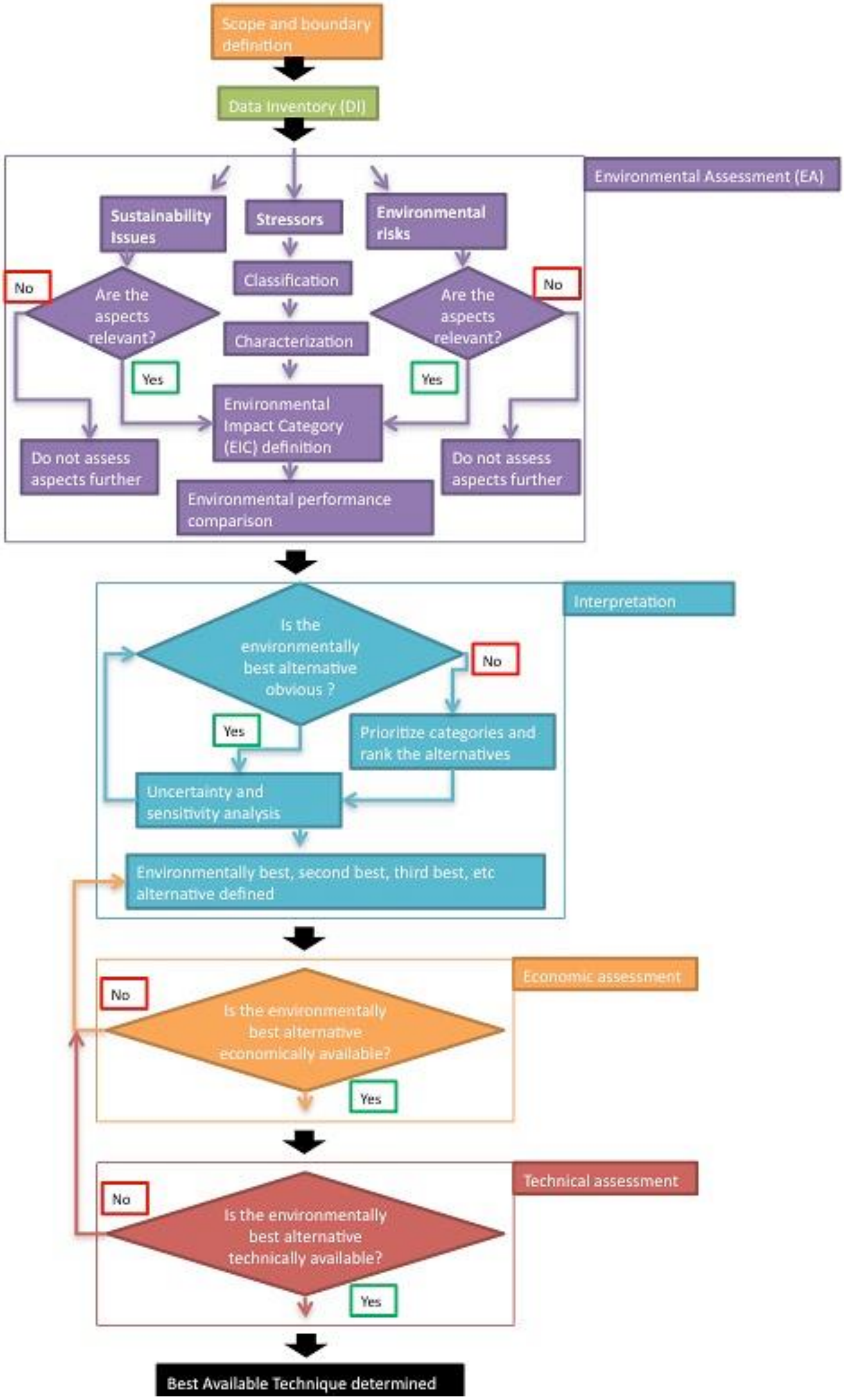

Figure 13: DNV's BAT structure of the guidelines, (Karlsson & Westin, 2010).

In this project the BAT methodology is applied to a more conceptual phase, both for a base case on the Norwegian Continental shelf and for a potential case in the Arctic area. This project will therefore use a modified variant for the DNV methodology guidelines, to a more applicable structure due to the conceptual level of the scope, see Figure 14.

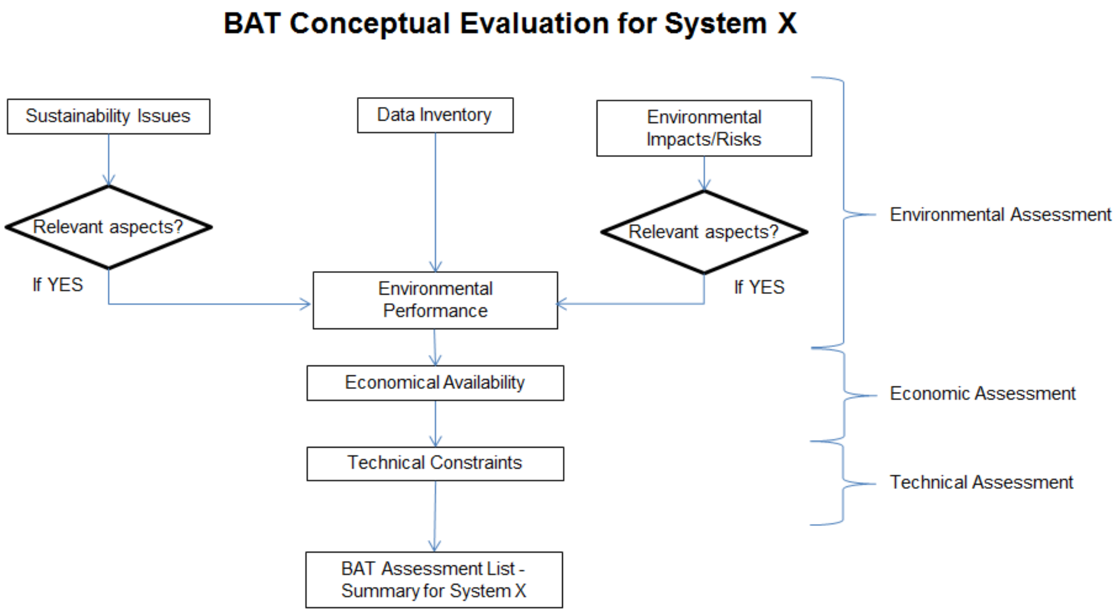

Figure 14: BAT-methodology for this project. Key aspects retrieved from (Karlsson & Westin, 2010).

3.5 Existing regulations and laws in Norway

In Norway there are several acts and regulations applicable to the oil and gas industry. Different agencies and directorates are responsible for different areas within the petroleum production and some of the most central for this project are presented here. In Appendix I, Norwegian regulations and acts are listed connected to environmental issues.

Klima- og Forurensningsdirektoratet, *Klif*, (The Climate and Pollution Agency) is responsible authority for making sure that pollution, waste and other harmful substances do not negatively affect health, well-being and production and reproduction of nature. Klif are also responsible for authorizing and controlling the industry for emitted substances like emissions to air, discharges to sea and chemical use. Klif administrate amongst other the Forurensningsloven (Pollution Act), Produktkontrolloven (Product Control act) and Klimakvoteloven (Trading Act) and the relating regulations. Klif and Direktoratet for Naturforvaltning (Directorate for Nature Management) are merging to become Miljødirektoratet (Environmental Directorate) from 1st of July 2013, (Klima- og Forurensningsdirektoratet, 2013).

Oljedirektoratet (Norwegian Petroleum Directorate) is responsible for setting frameworks and regulations for the oil and gas industry to create the greatest possible values for society by careful resource management based on safety, emergency preparedness and protection of the external environment. Oljedirektoratet is subordinate the Olje- og Energidepartementet (Norwegian Ministry of Petroleum and Energy) and responsible for a number of regulations and acts, including Petroleumsloven (Petroleum Act), (Oljedirektoratet, 2011-02-22).

Petroleumstilsynet (PTIL, Petroleum Safety Authority Norway (English abbreviation: PSA)) is the governmental supervisory authority. It is subordinate Olje- og Energidepartement, and is responsible authority for safety, emergency preparedness and working environment within the oil and gas industry in Norway. The regulatory responsibility covers all phases, from the planning and design phases to the construction, operation and potential disposal, (Petroleumstilsynet, 2013), (Klima- og Forurensningsdirektoratet, 2013).

Environmental Regulations in Norway in Petroleum industry	
Aktivitetsforskriften (The Activities Regulations)	*Regulations relating to conducting of petroleum activites - Emissions to external environment*
Innretningsforskriften (The Facilities Regulations)	*Regulations relating to Design and Outfitting of facilties etc in the Petroleum Activites*
Rammeforskriften (The Framework Regulations)	*Regulations relating to Heath, Safety and the Environment in the Petroleum Activities and at certain onshore facilities.* *Also called "Framwork HSE"*
Svalbardmiljøloven (Svalberd Environmental Protection Act)	*Relating to protection of the environment in Svalbard*
Miljøinformasjonsloven (Environmental Information Act)	*Regulation regarding informing the public*
Forurensningsloven (Pollution Control Act)	*Regulations concering Protection against Pollution and Concerning waste*
Forurensningsforskriften (Pollution Regulations)	*Regulations relating to pollution control*
Styringsforskriften (The Management Regulations)	*Management and the duty to provide information in the petroleum activities and at certain onshore facilities*
Petroleumsloven (Petroleum Act)	*Management of Norwegian petroleum resources*
IPPC Directive - BAT	*Integrated Pollution Prevention and Control - Ratified by Norway*
Kyoto protocol	*International agreement regarding GHG emissions - Ratified by Norway*
Gøteborg protocol	*International agreement regardin emissions to air leading to acidification, eutrophication and ground level ozone - Ratified by Norway*
OSPAR convention	*Ratified by Norway. Convention for the Protection of the Marine Environment in the North-East Atlantic*
Stortingsmelding (White papers)	*Norwegian Government (Regjeringen) support basis*

Figure 15: Overview of Environmental requirements for offshore production in Norway.

In Norway there are different acts which are applicable for the petroleum production, see overview in Figure 15.

Some of the most central to be mentioned are, (Petroleumstilsynet - Lover, 2013):

- Petroleum activities Act (PTIL/PSA),
- Pollution Control Act (Klif).

The most central regulations for offshore petroleum activities in Norway are set under the HMS-forskrifter (HSE-regulations: Health, Safety and Environment). The HMSregulations consists of five underlying regulations (forskrifter) which are applicable to offshore petroleum activities as well as certain onshore activities.

The five regulations are:

- The Framework Regulations (Rammeforskriften),
- The Management Regulations (Styringsforskriften),
- The Activities Regulations (Aktivitetsforskriften),
- The Facilities Regulations (Innretningsforskriften),
- The Technical and Operational Regulations (Teknisk og Operasjonell forskrift – applicable to onshore activities).

To each of the regulations, there are Recommendations/Guidelines (Veiledninger), which are not legally binding but shall be seen as guidelines for what the authorities want to achieve, (Petroleumstilsynet, 2013). In Appendix I, different regulations are listed which can refer to environmental issues, BAT and Arctic areas (mostly Barents Sea, Lofoten area and Svalbard) in Norway.

Some of the regulations and statements, from the Norwegian Government which can be specially mentioned, are:

- Oil content in discharged water may not exceed 30 mg/litre water (roughly 30 ppm), stated by the OSPAR Convention and ratified by Norway in 2002, (Olje- og Energidepartment, 2002-06-28). Even a lower concentration can be expected in future, about 10-20 ppm, due to availability of technical solutions and environmental effects observed at concentration lower than 30 ppm, (DNV, 2007).
- An aim from the Norwegian Government to have Zero discharges to sea of environmental harmful substances from the petroleum industry. For the Arctic areas there is a stricter requirement for Zero discharges to sea, though this is most certain to mean that there shall be Zero environmental damages or consequences from discharges to sea, (DNV, 2007), (Miljøverndepartement, 2011-03-11).
- In general emissions to air and discharges to sea should be avoided as much as possible. Norway has ratified the Kyoto-protocol and has a goal to reduce GHG-emissions in year 2020 with 30 % compared to the emissions in 1990. (Miljøverndepartement, 2007-06-22).
- BAT assessments should be performed to ensure that the best available technique for the environment as a whole, (Lovdata - Forurensningsforskriften, 2004-07-01). BAT shall be used for systems within the petroleum industry.

See Appendix I for further listing of the regulations and details.

3.6 Existing standards and guidelines

Within the petroleum industry there are different associations developing and managing standards and guidelines to follow. This project has concentrated on the most common standards and guidelines for environmental issues, which are applicable to the Norwegian Continental shelf and the associations are presented here. See Appendix II, for listing of some of the most relevant standards and guidelines.

Det Norske Veritas *(DNV)* is one of several classification societies, which has classification rules for floating production, storage and loading units. DNV also have certain standards when it comes to safety and environmental conditions for offshore activities.

European Integrated Pollution Prevention and Control Bureau (*EIPPCB),* is an action setup to provide organised information exchange between member states and the industry on the Best Available Techniques. The EIPPCB had produced several reference documents (BREFs) which can be used as guidance for governments and industry on BAT in different sectors and areas. For the petroleum production industry, the BREF on “Large Combustion Plants”, which refers to combustion installations with a rated thermal input over 50 MW, is the most interesting. The BREF on “Energy efficiency” is also of relevance for the offshore production industry. There are no specific BREFs for the oil and gas industry related to drilling, production or transportation, although there seems to be some future interest from the European Union to work with offshore platform safety, (European Union, 2012-01-19).

International Maritime Organization (IMO) is the United Nations specialized agency in control for the safety and security of ship transports and prevention of marine pollution. Since some petroleum production consists of floating drilling rigs and platforms, these standards and conventions are applicable to the oil and gas industry as well. The MARPOL, the International Convention for the Prevention of Pollution from Ships, is the main convention concerning pollution of the marine environment from emissions, waste and discharges.

NORSOK standards are developed by the Norwegian petroleum industry to “ensure adequate areas like safety, value-adding and cost effectiveness for developments and operations”, (Standard Online AS, 2013). The standards are to replace company specifications and to be used in regulatory qualifications, (Standard Online AS, 2013). Standards relating to Safety, Health and the Environment are listed with preface S and specially to be mentioned is the Standard S-003 – Environmental Care, which is stating the use of BAT, emissions to air and discharges to sea, (NORSOK S-003, 2005-12-03).

The International Electrotechnical Commission, *IEC*, is an organization who publishes international standards for the areas electrical, electronic and its related technologies. IEC is a sister organisation to ISO and are to complement each other, besides having collaboration, (IEC, 2013).

The International Organization for Standardization**,** ISO, is an international developer of standards within several areas and industries.

In Figure 16 a summary of the guidelines and standards often used for offshore production on the Norwegian Continental shelf. Also see Appendix II for further information of the standards and guidelines for environmental issues applicable on the Norwegian continental shelf.

Standards & Guidelines	
API	*API: 521,616*
DNV	*DNV: RP-C205, OS-A101, Class Rules*
EIPPCB - BAT and BREF	*BREF: Large Combustion Plants, Energy efficiency*
IACS	*Polar Class requirements*
IEC	*IEC: 60034,60079,60085,31892,61936*
IMO	*MARPOL: 73/78, SEEMP (FPSOs), MEPC circ. 406,* *Ballast water convention, Ship transportation Codes, MODU CODE, Guidelines, Polar Code*
International Finance Cooperation / World Bank Group	*Large Combustion Plants: Environmental, Health and Safety Guidelines: Offshore oil and gas development* *Environmental, Health and Safety Guidelines: Ambient Air Quality, Offshore Oil and Gas Development*
ISO	*ISO:10418,10436,10437,10439,13628,14001,14040,15138,15544,17776,19900,19902,19903,19904,19906,20815, 25457,31000,31010,3977,50001*
NORSOK	*E-001, S-001, S-003, Z-013*
PSA Guidelines	*PSA YA-711*

Figure 16: Overview over recommendations and standards for offshore production.

Some standards which could specially be mentioned are:

- NORSOK S-003 – Environmental care,
- ISO 14001 – Environmental management systems,
- ISO 19900 – Petroleum and natural gas industries - General requirements for offshore structures,
- ISO 19906 – Arctic offshore structures,
- ISO 50001 – Energy management.

3.7 Expected requirements and recommendations for Arctic

Potential and expected new regulations adapted to Arctic conditions are probably not going to be implemented the coming years. Norwegian authorities are more likely to make decisions from a case to case basis.

Klif has stated that there are more stringent requirements for activities in the Barents Sea, so activity applications will most likely have firmer demands to follow specific guidelines and objectives. For example the zero discharges to sea target is one of the requirements which might be harder followed in the Arctic. Klif will probably focus more on Black carbon emissions in the far northern parts, which previously generally not have been addressed offshore as an issue being more local. However, as previously mentioned, for each case an individual assessment has to be concluded for what alternative will have the least impact of the environment as a whole, (Klima- og Forurensningsdirektoratet, 2013-05-21), (Nesse, 2013-03-25).

In the Barents 2020 project (collaboration between Norway and Russia), report 3 discusses and lists standards and guidelines which are recommended to be updated to the Arctic conditions and challenges (Barents 2020 Project, 2010). Also the Arctic Council has several recommendations to future activities in the Arctic areas, especially when it comes to oil spill prevention, (Arctic Council - EPPR, 2012).

In general there are some expected guidelines and recommendations which would probably be applied for future Arctic offshore activities.

Discharges to Sea:

- Harder compliance with the requirement of Zero discharges to Sea, (Klima- og Forurensningsdirektoratet, 2013-05-21), (Miljøverndepartement, 2011-03-11), (DNV, 2007).
- Higher demand of substitution of hazardous substances and chemicals (Black and Red categories according to PLONOR) or chemicals which can lead to pollution of the environment if combined with another substance, (Miljøverndepartement, 2011-03-11) (Oljedirektoratet, 2010), (Klima- og Forurensningsdirektoratet, 2013-05-21).
- Lower requirement for oil concentration in water than present regulation of 30 ppm (about 30 mg/l), (Klima- og Forurensningsdirektoratet, 2013-05-21), (Eni Norge AS, 2008).
- A demand of 100 % re-injection of produced water under normal, continuous operation. A maximum of 5 % produced water can be discharged at operation disruptions and downtime for the re-injection system, if sufficient treated prior the discharge, (Oljedirektoratet, 2010) (Miljøverndepartement, 2011-03-11).

Emissions to Air:

- In general, the aim to reduce GHG emissions to air, especially emissions of CO_2, SO_2, NO_x, VOC and Black Carbon, (Miljøverndepartement, 2011-03-11), (Klima- og Forurensningsdirektoratet, 2013-05-21).
- Flaring shall be minimized and recirculated as much as possible and shall basically only be performed due to safety reasons. Flaring in Arctic can lead to soot pollution and higher GHG emissions, (Klima- og Forurensningsdirektoratet, 2013-05-21), (Miljøverndepartement, 2011-03-11).
- Increased energy efficiency shall be an aim, (Miljøverndepartement, 2011-03-11).

- For the power generation, electrification should be considered if possible. Also the design shall be as efficient as possible and the BAT shall be used, (Klima- og Forurensningsdirektoratet, 2013-05-21), (Miljøverndepartement, 2011-03-11).
- Waste heat recovery shall be used as much as possible. Due to Arctic conditions there might be an increase in heat demand, (Miljøverndepartement, 2011-03-11), (Klima- og Forurensningsdirektoratet, 2013-05-21).

Ecosystem

- Petroleum activities shall not harmfully affect flora and fauna. Areas with possible effect shall be mapped before any activities, (Miljøverndepartement, 2011-03-11).
- Due to biodiversity in Barents Sea and Lofoten: "The areas shall be managed so the diversity of ecosystems, habitats, species and genes are conserved and the productivity of the ecosystem is maintained. Human activities shall not damage the ecosystem function, structure, productivity and dynamics." (Miljøverndepartement, 2011-03-11).

Recommended standards and recommendations to be used:

- ISO 19906 – Arctic offshore structures,
- NORSOK S-003 – Environmental care,
- BAT assessments are recommended to be used, not only for power plants, but also for other systems to be evaluated, (Arctic Council - EPPR, 2012).

4 Findings of existing BAT and changes due to Arctic conditions

Conceptual assessments on BAT alternatives, for three technical systems, have been performed with the existing regulations and guidelines applicable on the Norwegian Continental shelf. These alternatives have then been assessed with addition to Arctic conditions and challenges. The alternatives are assessed according to the methodology described earlier; see Chapter 2.3, Figure 2. In this following chapter, the findings from these assessments are presented.

BAT for the Norwegian Continental shelf

This project investigation has first looked at a base case on the Norwegian Continental shelf and what a BAT assessment and its alternatives could look like. The base case is a petroleum production facility at a typical location in e.g. the central North Sea, producing both oil and gas. Since this investigation only is at a conceptual level, more location specific information such as production profile and local environmental status are not possible to include at a detailed level.

For each system studied, there is a reference alternative used, to be able to compared the environmental performance between alternatives. The most common type of technology used at present is chosen as the reference alternative.

Changes to BAT due to Arctic conditions

The changes that Arctic conditions might contribute to the BAT alternatives are here investigated and presented. These additions are evaluated both from the physical settings of the Arctic region as well as the expected requirements and guidelines applicable to the Arctic areas.

4.1 Power and Heat generation and Energy efficiency

The power and heat generation system are closely connected with the energy efficiency of a platform and therefore these two aspects are treated in the same chapter.

Scope:

The system boundaries have been limited to look at only the power generation on the platform itself and the operational production. Environmental aspect of designing, manufacturing, transportation and building of the different systems are not taken into account.

The main purpose of the power and heat generation is to provide sufficient, secure and safe power to the platform to meet the power and heat demand.

In Norway, the requirement to use BAT for large combustion plants (over 50 MW) are applicable to power and heat generation systems offshore. There is also the available reference document (BREF) for Large Combustion Plants, (Petroleumstilsynet, 2012-12-20) (European IPPC Bureau, 2006).

4.1.1 Power and Heat generation

The power and heat supply on an offshore production facility have several requirements, especially when it comes to safety and secure energy supply. The power supply needs to be stable and reliable to avoid possible accidents and sudden production stops. The power and heat production must also be applicable to the offshore conditions. The power demand is closely connected with the production profile of the site. The power production is generally designed according to the maximum production value, although this production value lasts for only a limited time compared to the lifetime of the field.

The most common power generation today for new installations is gas turbines with waste heat recovery system. The largest part of the CO_2 emissions from the petroleum activities in Norway comes from the turbines, see Figure 17.

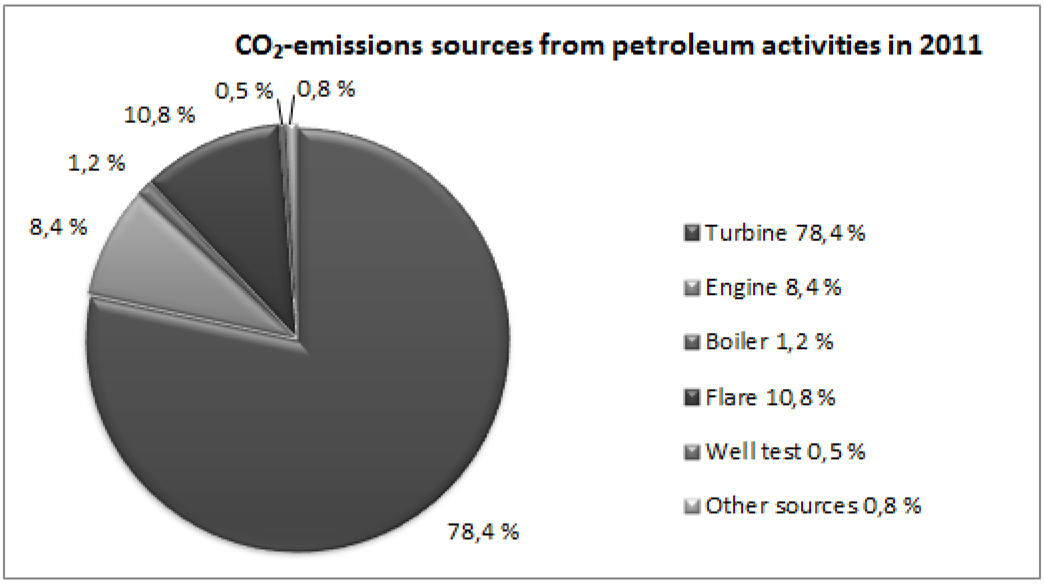

Figure 17: CO_2 emissions from Norwegian petroleum activities in 2011, numbers from Oljedirektoratet, (Olje- og Energidepartementet & Oljedirektoratet, 2013).

Normally the power demand for an offshore production facility can be between 20-80 MW, but varies depending on the site and facility. The biggest power users are gas compressors, oil export/booster pumps, water injection pumps to mention some. The heat demand for a facility is normally around half of the power supply, but this also differs depending on location and the activity. Some of the heat users are process systems and cargo heating, (Vandenbussche, Introduction to power and heat generation, 2013-02-18).

Some of the environmental issues regarding power and heat generation are the emissions released to air, mainly CO_2, NO_x and SO_x. This is depending on type of fuel, the consumption and the thermal energy efficiency used in the power and heat generation system, (Vandenbussche, Introduction to power and heat generation, 2013-02-18).

In general, the energy demand on Norwegian Continental shelf is increasing as a result of the increasing amount of mature fields. Mature fields most of the times demand more energy due to e.g. increased amount of produced water in the reservoirs as well as reduced pressure in the wells. The overall increased demand also depends on development for more natural gas production than oil production, which in general are more energy demanding, (SINTEF - Teknologi og samfunn, 2008).

4.1.2 Energy efficiency

There are two ways to look at energy efficiency on a platform. A first approach is to view the energy efficiency at separate systems and operations. Another way to view the energy efficiency is to look at the overall efficiency, where measuring the produced amount of oil and/or gas per unit of total energy input.

Some of the main areas where energy efficiency has the most potential are the design of the power generation system and the waste heat recovery system. However the venting and flaring activities on a platform can have a large impact on the overall energy efficiency. For higher overall efficiency, the fuel gas can be recovered instead of being flared and vented.

Increasing the energy efficiency means both economical savings and less environmental impact, in particular when looking at the whole life cycle and long-term use. Energy efficiency is a central discussion point within the industry and improvement requires both new technology development and operational management and control.

4.1.3 BAT for Power and Heat generation

To demonstrate some of the different alternatives and the BAT for power and heat generation, an assessment was carried out by using the methodology in Chapter 3.4.3, Figure 14.

The assessment considers some of the different subsystems for the heat and power generation system, as following:

- Power generation,
- Heat production,
- NO_x reduction techniques.

These are the key subsystems within the power and heat production on a platform and combined with energy efficiency measures these systems can be optimized to have the least environmental impact with technical feasibility and economic availability. For each subsystem, a base case alternative has been chosen to be able to compare the different alternatives.

Environmental Aspects, Stressors and Performance

The identified key environmental stressors and performance relevant for the existing Power and Heat generation system are:

- CO_2,
- CO,
- SO_x,
- NO_x,
- Energy use,
- Energy efficiency (thermal).

The impacts and sustainability issues from these are presented in Chapter 3.2. In Appendix IV the different subsystems are shown with additional information and their BAT evaluation.

Power generation

For the power generation subsystem, the following alternatives have been assessed, see Appendix IV:

- *Gas turbines* (single cycle) – Base case alternative: Often two to three turbines and one spare turbine on platforms in Norway. Generally dual fuel (gas or diesel) is used on turbines and uses gas from e.g. the platform's own gas production. The overall energy efficiency depends on load and turbine configuration.
- *Gas turbines – Combined cycle* (including Heat Recovery Steam Generation, HRSG): Combination of a gas turbine and a steam turbine and is generally run with duel fuel (gas or diesel) in Norway. Uses the excess heat for extra electricity production which increases the energy efficiency up to 50%. Drawbacks for offshore are space demanding (more compacts exists), more weight and more complex than single cycle gas turbines (the base case alternative).
- *Power from shore* (Electrification): Electrification by cables from shore, AC (for shorter distances) or DC (for longer distances). Applicability depends on closeness to shore. This will create larger electricity demand in Norway might need supply from non-renewable sources from the Nordic mix including e.g. some coal which would influence the total emissions accounting. This alternative also demands extending and possible modification of the grid and power and long distance subsea cables which could result in other impacts.
- *Centralised Power generation* (combined gas turbines): A "hub" between platforms to supply power by cables to each platform. Demands closeness between the platforms and the hub can have different alternatives for electricity production, here is combined gas turbines considered. The centralised power supply will increase overall energy efficiency and decreases the total emissions. Other electricity sources might also be considered, such as electricity from shore to a platform hub.
- *Engines*: Can be designed for different types of fuel; gas or diesel, dual fuel or multi fuel (also including oil). Can reach quite high thermal energy efficiency, but have heavy weight. Often diesel engines are used as a back-up system on platforms.

The techniques which are considered to have the least overall environmental impact and considered the Best Available Technique are presented in Appendix IV and summarized as:

- *Combined cycle* (HRSG): Due to the increasing the thermal energy efficiency and the use of waste heat, which also mean less emissions to air.
- *Electrification from shore:* Considered to have low emissions due to main electricity source in Norway comes from the renewable hydropower.
- *Centralised power generation* (platform hub): Increases the overall energy efficiency between the platforms and decreases the total emissions.

The alternative considered BAT for a specific site depends on the specifications and location which needs to be included when performing a full BAT assessment.

Heat generation

For the heat production subsystem, following alternatives has been assessed, see Appendix IV:

- *Waste Heat Recovery Unit system* (WHRU) – Base case alternative: In combinations with turbines (engines also a possibility) and use the excess waste heat transferred through heat exchangers to transfer the heating medium to various heat users on the platform. Increases the overall energy efficiency.
- *Electricity*: Either from platform production or onshore electrification. Will increase the overall energy use and so also the overall energy efficiency.
- *Boiler and Burner:* With oil or gas fuel which provides the heating system with sufficient heat for the platform.

The technique which is considered to have the least overall environmental impact and considered the Best Available Technique are presented in Appendix IV and identified here as:

- *Waste Heat Recovery Unit system* (WHRU): The use waste heat increases the overall efficiency and using waste energy means less total energy is needed. The waste heat recovery may also be used in combination with other power generation solution.

NO_x reduction

For the NO_x reduction techniques a couple of different alternatives was evaluated. NO_x reduction techniques are used for power generation from gas turbines (and possible also for engines), which is now a standard procedure in Norway, (European IPPC Bureau, 2006).

Following alternatives have been compared, also see Appendix IV:

- *No NO_x reduction* – Base case alternative: No reduction of the NO_x gases from the gas turbines at all.
- *Direct Steam injection:* Injection of steam which lowers the temperature and decreases the creation of NO_x. Have some drawback for offshore application regarding weight, space, complexity and need of feed water with certain qualities.
- *Direct water injection:* Injection of water which lowers the temperature and decreases creation of NO_x. Offshore constraints with weight, space, complexity and need of feed water with certain qualities.
- *Dry Low NO_x* – Combustion chamber (DLN): Mixing of air and fuel before combustion which leads to a homogeneous temperature distribution, lower flame temperature and as a result lower NO_x emissions.
- *Selective catalytic reduction* (SCR): Using ammonia as a cross media effect. Offshore constraints with space, weight, health issues from ammonia storage and handling.

The technique which is considered to have the least overall environmental impact and considered the Best Available Technique is presented in Appendix IV identified as:

- *Dry Low NO_x* (DLN): This alternative has the highest reduction level and at the same time available for offshore installations (weight, space and complexity constraints) compared to the other alternatives.

4.1.4 Changes to BAT for Power and Heat generation with Arctic conditions

There are increased general concerns for the environment and potential risk with offshore activities in the Arctic areas, this will affect the power and heat generation system. This together with the additional Arctic properties can change the BAT for the different subsystems.

Additional Environmental Aspects, Stressors and Performance

- Low temperatures
- Remoteness
- Darkness
- Black carbon (soot/particulate matters)
- Noise

There are also some other essential additions for higher requirements when it comes to:

- Decrease emissions to air
- Zero discharges to sea compliance
- Increased energy efficiency

The impacts and sustainability issues from these are presented in Chapter 3.2. In Appendix V, the different subsystems are shown with additional information and their BAT evaluation.

Power generation

For the power generation, there are probably going to be increased expectations regarding decreased emissions to air and the zero-discharges to sea target. The Arctic conditions which can be considered the most relevant to the power generation system are the low temperature, remoteness and darkness, black carbon and other particulate matter effects and noise disturbances due to local environmental effects. This also sets and increased demand for energy efficiency, both through the amount used and the means of use, i.e. more efficiency use, for an overall higher efficiency.

There are some special considerations regarding power generation in Arctic climate. One of them is the concern with low temperatures. This might be an issue for some of the power alternatives but for alternatives with gas turbines, this will probably not be the case since gas turbines get an increased effect in cold climate due to compressed air having a higher density which is the input air (with a slight increase the thermal efficiency of the turbine), (Utengen, 2013-04-09).

There will probably be increased interests for electrification from shore or/and from other nearby production units. The first oil production unit in Barents Sea is going to be Goliat, with planned production start in 2014. In the impact assessment report for Goliat there are different alternatives assessed for power generation, and the chosen solution was electrification from shore combined with one gas turbine with WHRU, (Eni Norge AS, 2008). This alternative might therefore also be higher considered for potential future production units in the Arctic areas.

Some alternatives which might be applicable in the future are, see Appendix V:

- *Electrification* from Wind energy (in combination of other renewable energy sources e.g. wave): Have operational and intermittency issues.

- *Electrification* from Solar energy (in combination of other renewable energy sources e.g. wave): Have operational and intermittency issues and might not be applicable for the seasonal dark Arctic areas.
- *Nuclear energy:* Currently used in Russian Arctic ships. Have other waste, safety and public acceptance issues (nuclear radioactive waste).
- *Fuel cells:* Still in developing stage.

In general, there are difficulties with deciding which power generation alternative is BAT for the Arctic area due to need of site specifications, though what can be seen is a trend towards electrification from shore (from mostly hydropower) and/or combinations between different other alternatives. What is not yet available, and thus BAT, are combinations with renewable energy sources such as wind energy, wave energy, solar energy and fuel cells have been mentioned as a potential BAT alternative in the future. Combinations with CCS (Carbon Capture and Storage) are also considered as potential alternative in the future which would decrease emissions but demands energy which will affect the overall energy efficiency. This is tested at present on the Norwegian Continental shelf at the Sleipner field where CO_2 is removed from the natural gas (not from the fuel gas), (Oljedirektoratet, 2010) (SINTEF - Teknologi og samfunn, 2008) (SINTEF Energy Research, 2011).

Heat production

With Arctic conditions, lower temperature, snow, ice and risk of icing will most likely lead to higher demand of heating. Increased heating is needed to avoid human injuries, equipment damages, material failure, and reduced performance. Same general expectations regarding decreasing emissions to air and zero-discharges to sea target are applicable for the heat generation. The alternative Waste heat recovery will probably be future BAT as well for Arctic, due to easy access of excess heat, see Appendix V. With increased heat demand there is a need to evaluate if the waste heat available on the platform is sufficient and secure due to the Arctic conditions. If not, other heat solutions or combinations are required like heat pump alternatives might be a solution using other sources for operation. Another aspect is when waste heat is unavailable due to e.g. power generation selection of power from shore, then electricity heating will probably be used which would decrease the overall energy efficiency on the platform.

NO_x reduction techniques

There is more or less an industry requirement to use NO_x reduction techniques existing on the Norwegian Continental shelf today. With Arctic conditions this is probably going to be even more reinforced. The BAT alternative already identified, Dry Low NO_x, will probably be suitable for Arctic conditions. Other alternatives which are now under the developing stage might be available with evaluation of the Arctic conditions, see Appendix V.

For the NO_x reduction techniques, the Cheng Steam injection cycle might be a future possible BAT alternative which can be included in the evaluation for future use. This alternative could provide a higher overall energy efficiency compared to other alternatives. Overall, there is no concrete evidence of that the Arctic conditions and constraints will affect the present BAT for NO_x reduction techniques when looking at a conceptual level.

4.2 Flare system

The flaring system is closely connected to many different systems on a platform and it is used in order to release gaseous forms of hydrocarbons involved in the process. This release is either out of safety reasons or out of continuous removal of unwanted gas.

Scope:

The scope for the flare system has been to look at some of the subsystems working under an operational situation. The safety issue with ability to vent and flare under emergency situations are of course essential, but this study does not include a risk assessment. The focus has been on operational flaring system. Environmental aspects of designing, manufacturing, transportation and building of the different systems are not taken into account due to time and information limitations.

4.2.1 The Flare system

The flaring and venting system is a way to release hydrocarbon gases (natural gas) and vapours on oil and gas platforms, see Figure 18. Venting is when excess gas is directly released to the surrounding air, without being burnt. Flaring is when the excess gas is released to the surroundings by first being burnt, so that dangerous (very reactive) gas compound is transformed into another less dangerous gas compound (e.g. with lower global warming potential), both for safety and environmental reasons, (Haukebø & Vandenbussche, 2013-02-21).

The flaring can be divided into two separate types of activities; continuous flaring and the non-continuous flaring. The continuous flaring mostly exists at platforms where there is no economic gain or technical possibility in using the excess natural gas or re-injection to the reservoir; this does not apply normally in Norway today. The non-continuous flaring is mainly results from testing, servicing, start and shut-downs and maintenance. The flaring is also a key safety system for the offshore platform, (Clearstone Engineering Ltd., 2008-09-18). On offshore platforms the flaring is located to a flare tower, (Argo Flare Service Ltd, 2013).

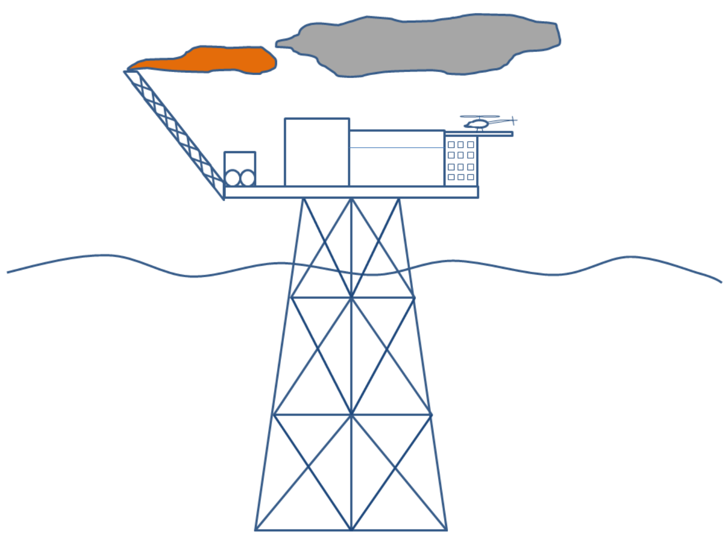

Figure 18: Schematic illustration of an offshore platform with flaring. Provision is taken against improper detailed content and dimensions.

There is a lot of global flaring which contributes to GHG and other emissions to the air. Estimations of natural gas flaring is approximately 150 billion cubic meters and stands for about 1.2% of the global CO_2 emissions. For some oil producing countries the flaring itself can stand for up to a third of the country's CO_2 emissions. There is a large volume of the non-renewable source of natural gas which is flared instead of being recovered, sold or used. The World Bank has started a partnership program to reduce worldwide flaring. Reducing flaring both contributes to higher energy efficiency as well as performs mitigating measures in climate change. At the same time reduced flaring as a result of recovering the natural gas creates revenues and increased available energy, (The World Bank, 2012-07-03) (The World Bank, 2011).

In Norway the flaring has reduced the last decades due to mainly regulatory measures as policies and taxes, especially the Carbon tax introduction in 1990. Today about 10% of the CO_2 emissions from petroleum production comes from flaring, see Figure 17, (Olje- og Energidepartementet & Oljedirektoratet, 2012).

There are no specific regulation regarding limits of flaring in Norway, but flaring is restricted and only permitted for safety reasons, (The World Bank - GGFR). The CO_2 emissions from flaring are together with energy production from petroleum production, within the quota accounting in Norway, (Oljedirektoratet, 2010). Instead excess natural gas shall be either sold, which needs infrastructure and transportation, or re-injected to the reservoir, (Norwegian Petroleum Directorate, 2008-08-25).

4.2.2 BAT for Flare system

The different alternatives considered BAT today are alternatives reducing the amount of flaring. The other parts of the flare gas system are working towards a more reliable flare system which would result in less flare gas volume. The flare system has been divided into three parts treated in this project, which are following:

- Flare design,
- Ignition system,
- Flare management.

The only one mentioned in the SINTEF report is flare gas recovery, (SINTEF - Teknologi og samfunn, 2008).

Environmental Aspects, Stressors and Performance

The identified key environmental aspects relevant for the existing flare system are:

- Volume of Flared Gas,
- CO_2,
- NO_x.

The impacts and sustainability issues from these are presented in Chapter 3.2. In Appendix VI the different subsystems for the flare system are shown, with additional information and BAT evaluations.

Flare design: The flare design part includes Low Pressure (LP) and High Pressure (HP) flaring and the recovery of these systems. Also the design of the flare tip can be included in the design part, though not considered in this project. (Argo Flare Service Ltd, 2013). Following flare design alternatives have been assessed, also see Appendix VI:

- *Open flare system (both LP and HP system)* – Base case alternative: Both low and high pressure gases are flared and no recovery is implemented. The open flare system needs a pilot flame system.
- *Closed flare system: LP recovery, HP open:* The low pressure gas is recovered
- *Closed flare system: LP recovery, HP recovery*

The techniques considered BAT are the two closed systems, see Appendix VI:

- Closed flare system: LP recovery, HP open, due to availability and often HP is less used. This alternative reduces the volume of flaring and therefor also the amount of emissions compared to the base case alternative.
- Closed flare system: LP recovery, HP recovery, probably more technological challenging but still possible. This alternative reduces the volume of flaring and therefor also the amount of emissions compared to the base case alternative.

Since the high pressure (HP) system is normally used for unplanned operations, the alternative Closed flare system with only low pressure (LP) recovery can be considered well enough for some sites.

Ignition system:

Historically it has been less common with a combined system ignition system and pilot system. In this project the ignition system and the pilot system is differentiated into two separate systems. The pilot's function is to maintain a stable flaring and re-igniting the flare if needed. In Norway where flare recovery is common, the pilot system has sometimes been removed or is not installed. The ignition system purpose is to light the flare gas, either the flare directly or the pilot, (Argo Engironmental Engineering - Jonathan Miles, 2004).

The flaring system is mainly considered a safety system for offshore facilities. In Norway there is an aim for no flaring operations, where a pilot is not necessary. This project is not looking into the pilot system, only ignition system where it is mentioned if pilot or not is necessary.

The ignition system includes different alternatives. Either a pilot flame is used to ignite the gas or, for non-pilot systems, a pellet driven ignition or a direct spark ignition system can be used, (Argo Flare Service Ltd, 2013).

The following ignition alternatives have been evaluated:

- *Flame front generator with Pilot based system* – Base case alternative: Compressed air and fuel gas are metered through control valves into a mixing chamber. Further downstream of the mixing chamber there is a sparking device to initiate the flame front (fire ball) which travels to the pilot where it ignites the pilot.
- *Pellet based ignition with Ballistic based system:* Ignition pellet is launched through a guide pipe and ignites when the pellet emerge from the guide pipe. Different types of pellets exists which has a relatively high reliability.
- *Electric spark ignition with/without Pilot based system*: Two basic forms of electronic ignition system; high energy and high voltage. Possible both with and without pilot.

The techniques which can be considered BAT are all three alternatives; further assessments are needed depending on the site specifications, see Appendix VI:

- *Flame front generator with Pilot based system;* depending on site specifications.
- *Pellet based ignition with Ballistic based system;* depending on site specifications.
- *Electric spark ignition with/without Pilot based system;* depending on site specifications.

The latest development has been towards designing pilot-free systems. The pilot has traditionally been the most common system due to the high reliability.

Flare management: Also to be mention is the Flare management, which are mainly different kinds of operational routines and procedures of the production. By planning and managing planned shut downs the flaring volume can be reduced, (Oljedirektoratet, 2010). The flare management part has not really been evaluated according to BAT, since it is more of a management approach than a specific technique. Since there seems to be significant emission reduction possibilities with flare management this has been brought up for attention in this thesis report.

4.2.3 Changes to BAT for Flare system with Arctic conditions

No particulate technical change in performance for the considered BATs with Arctic conditions has been discovered. However, there might be a higher focused on the local environment and impacts on ice covered areas from emissions like soot (black carbon).

Additional Environmental Aspects, Stressors and Performance

- Black carbon (soot/particulate matters),
- Fire and smoke impact (possible impact on birds),
- Light spills from flare (possible light pollution in the partly very dark Arctic area, which could affect certain species).

The impacts and sustainability issues from these are presented in Chapter 3.2.

The main solution to minimize the impacts in Arctic areas is to reduce the overall flaring. The no-flaring technique by recovery decreases the emissions from flaring. The flaring today cannot be totally avoided, but only allowed due to safety and emergency reasons. Since the no-flaring exists already on the Norwegian Continental shelf, is this probably something which is going to be even more required.

The direct changes in BAT alternative for the flare systems are difficult to assess though increasing expectations of reduced flaring will probably enhance the alternatives with gas recovery and no-pilot flame. These techniques also need to be evaluated further due to Arctic conditions as e.g. risk of icing, see more details in Appendix VII.

According to some investigations, Black Carbon (BC) emissions in the Arctic area are very small part compared to the total global emissions today. Flaring from shipping and other production as oil and gas, seems to have a large impact on low-altitude BC concentrations in the Arctic. With increasing activities this will probably increase if no measures are taken. BC emissions from flaring are estimated to 12% in year 2000 from the Arctic Council nations (high contribution from Russia), (Arctic Council - AMAP, 2011).

4.5 Produced water system

The produced water system is related to the separation process, which separates oil, natural gas and produced water from the reservoir on the platform.

Scope:

The system boundary for the produced water system is to only look at the handling of produced water from the oil and gas extraction. No other sources of waste water production are included in this thesis, as this is normally a separate system. The produced water system has been divided into re sub-systems. Environmental aspect of designing, manufacturing, transportation and building of the different systems are not taken into account.

4.5.1 Produced water system

The produced water is extracted together in a mixture of oil and natural gas from the reservoir, mostly from oil production and less with gas production. The volume of produced water from the well increases with the age of the well. When the well age increases so does also the amount of energy needed to handle the produced water, both for treatment and potential reinjection, (Miljøverndepartement, 2011-03-11).

In addition to water, the produced water also contains:

- Solid particles, like sand, in different sizes which can bond with oil particles in different ways, affecting the oil density in the produced water.
- Dispersed oil; oil droplets in different sizes and types. The small the droplets are the more difficult it is to separate them from the produced water.
- Natural occurring dissolved organic compounds, like PAH.
- Natural occurring dissolved inorganic compounds, for example heavy metals like barium and strontium and radioactive substances.
- Treatment chemicals which are added during drilling and extraction processes.

The separation process which separates oil, natural gas and the produced water from each other is divided into several steps as shown in Figure 6. After the main separation, the produced water continues for treatment. In the treatment process different techniques can be used to reduce the concentration of oil droplets and other substances (see bullet point list above). When the water has been treated to required concentrations it can either be discharged to the sea or re-injected to the reservoir again.

As a result of the re-injection, recovery from the well can be enhanced in addition to disposal of the produced water. The re-injection of the produced water can either be to the same well or to a pressure well (a drilled well nearby to increase the well pressure). This is especially welcome since the reservoir pressure declines over time and there is a need for increased pressure to continue production. It is important for the re-injected water to undergo treatment prior to the re-injection. This mainly reduces the re-injection problems compared to non-treated water and decreases the amount of solid particles, (Oljedirektoratet, 2010).

In Norway, the limit for oil concentration in discharged produced water is 30 mg/l, (Olje- og Energidepartement, 2002). The average oil concentration in discharges produced water was 11,5 ppm, in 2011, which is substantially below the required 30 ppm, (Norsk Olje & Gass, 2012). For the Barents Sea there it is expected to have 95% re-injection of the produced water volume, under operation. This takes into account 5% of planned and un-planned shutdown of the injection system. The produced water still needs to undergo treatment, (Miljøverndepartement, 2011-03-11).

4.5.2 BAT for Produced water system

The different subsystems considered in this project for the produced water system have been:

- Produced Water Treatment Technique; different treatment for reducing hazardous substances in the produced water mixture.
- Produced Water Reduction Technique (above sea level/top side); are different techniques to reduce the volume of produced water reaching the platform for treatment.
- Produced Water Disposal (also included Recycling) after Treatment; is the management of the treated water at either the platform or subsea treatment system.

The treatment techniques today are focused to reduce the oil content in the produced water. Though there are also other smaller concentrations of low radioactive material and metals which will be released if the produced water is discharged, which is not further discussed in this project report (DNV, 2007).

Environmental Aspects, Stressors and Performance

The identified key environmental aspects relevant for the existing Produced water system are:

- Oil concentration (after treatment)
- Oil content: PAH concentration
- Oil content: BTEX concentration
- Use of chemicals
- Production chemicals concentration
- Energy use
- Waste generation

The impacts and sustainability issues from these are presented in Chapter 3.2. In Appendix VIII, the different subsystems for the produced water system are shown, with additional information and BAT evaluations.

Produced water treatment

There are lots of different techniques to treat produced water for especially oil content. In this project about twenty different techniques have been identified, not all of them might be yet economical available. The different techniques is also treating different substances, this project have been focused on the BAT treating oil content. This means that a produced water treatment system can include several different treatment techniques to remove different substances. For more information and the different alternatives, see Appendix VIII.

For the produced water treatment, the following alternatives have been assessed:

- *Hydrocyclones* – Base case alternative: A physical method which separates solids from liquids based on density. The performance of the cyclones depends on the cone angle. This method can remove particles in range 5-15 μm and reduces dispersed oil concentration up to 75-80%.
- *C-tour:* Uses liquid condensate to extract dissolved components from the produced water. Reduces the dispersed oil content up to 60-70% and BTEX/PAH by 70-95%. This method needs condensate.

- *Compact Floatation Unit* (CFU): This is a modernized hydrocyclones method with an addition of injected gas to lift the oil droplets. Can reduce the dispersed oil content up to 70% and can also reduce other non-dissolved substances.
- *Macro Porous Polymer Extraction* (MPPE): A one step process to remove dissolved and dispersed oil by a liquid-liquid extraction technology. This alternative needs pre-treatment by e.g. hydrocyclones. Can achieve reduction of BTEX up to 99% and PAH up to 98%.
- *Membrane filtration:* Four different membrane separation processes, for example microfiltration and ultrafiltration. Can be combines with other treatment techniques.
- *Drop emerging technologies* (e.g. PECT-filter or Mares Tail): A fibre technology to merge oil droplets. Can be combined with hydrocyclones.

There are several other techniques to be used for produced water treatment of different substances; these are not assessed further in this thesis. Different techniques can either be supplementary or used separately. Some of the other alternatives which can be mentioned are Thermal technologies (distillation), Biological aerated filters, Gas floatation, Physical adsorption and Media filtration, see Appendix VIII for further details.

For the Produced water treatment techniques, the technologies considered BAT for the Norwegian Continental Shelf are summarized in following listing, for further details see Appendix VIII, (DNV, 2007):

- *C-tour:* Oil content is lower than base case and can come down to 1-5 ppm of dispersed oil substances after treatment. This alternative is today used on some installations on the Norwegian Continental shelf today.
- *Compact Floatation Unit* (CFU): Oil content after treatment is 10-15 ppm of dispersed oil, which is lower than base case. This alternative is probably the most commonly used alternative on the installations on the Norwegian Continental shelf today.
- *Macro Porous Polymer Extraction* (MPPE): Oil content after treatment is < 1 ppm of dispersed oil substances, which is lower than base case. This technique is presently tested on some installations today.

Amongst the other treatment techniques, not further assessed in this project, there are other potential BAT alternatives such as media filtration. These have been tested offshore, but are still not used significantly offshore, (National Petroleum Council, 2011-09-15). Depending on the individual specification of an installation, these other techniques can probably also be considered BAT.

Produced water reduction

Reduction techniques main function is to minimize the volume of produced water. This can be done both by shut-offs or reducing the volume to the topside platform by separation and re-injection of the produced water earlier in the process.

For the produced water reduction, the following alternatives have been assessed, also see Appendix VIII:

- *No Produced water reduction (topside)* – Base case alternative: This alternative includes no reduction measurements to reduce the volume of produced water transported to the platform.

- *Water shut-offs:* This includes a chemical or physical shut-off on different production zones in wells. Can have possible issues with finding non-hazardous and approved chemicals. Can reduce produced water volume up to 40% per well.
- *Subsea separation and Re-injection:* This alternative needs power supply and a subsea compression station. Can reduce the produced water volume up to 90%.
- *Downhole separation and Re-injection:* A special separator which divides the water from oil and gas in the well. Can reduce the produced water volume up to 90% and exists in both vertical and horizontal designs.

The alternative which can be considered BAT today for this subsystem is presented (see Appendix VIII):

- *Water Shut-offs:* Due to this is available today and reduces the produced water volume to the platform by up to 40% compared to the base case.

The alternatives, Subsea and Downhole separation techniques, which can reduce the volume of produced water up to 90 %, but these alternatives are today under development.

Produced water disposal

The two alternatives for disposal (or potential usage) of the treated produced water, is basically either to discharge or to re-inject it. Most of the produced water is discharged after treatment today but recently injection and re-injection have an increasing interest. This can be profitable both for the advantage of using the produce water for further oil and gas recovery and decreasing the discharges to sea.

For the produced water disposal, the following alternatives have been assessed, see Appendix VIII:

- *Discharges to Sea* – Base case alternative: The produced water is discharged to sea after treatment.
- *Produced water Re-Injection* (PWRI): The produced water is injected or here re-injected in the used wells or in a formation for storage or for enhanced oil and gas recovery. This alternative is energy intensive which will increase the energy demand for the installation and as a result also the emissions to air. Therefor there is a trade-off between discharges to sea and emissions to air with this alternative.

Both of the alternatives are considered available, (SINTEF - Teknologi og samfunn, 2008), see Appendix VIII:

- *Discharges to Sea:* After sufficient treatment this can be an alternative for some sites.
- *Produced Water Re-Injection* (PWRI): Injection or re-injection will minimize the volume of discharged produced water to sea. This alternative can also lead another value in enhanced oil and gas recovery.

In the future more focus will most likely be on injection and re-injection due to the aim for zero discharges to sea. There is a difference in cost between the alternatives, which can make the discharge option more attractive to operators if there is no regulatory instrument which can boost the technical development and to reduce the cost.

4.5.3 Changes to BAT for Produced water with Arctic conditions

For the produced water system in Arctic areas there will be more stringent requirements for zero discharges to sea. This means that there should be no discharges of produced water, and everything has to be handled through injections and disposal techniques or possible other re-use. In Appendix IX, the different subsystems and their alternatives have been evaluated due to some of the relevant Arctic conditions. The impacts and sustainability issues from these are presented in Chapter 3.2.

Additional Environmental Aspects, Stressors and Performance

- Zero discharges to sea
- Warm water release to sea
- Energy use

The produced water volume is expected to be minimized though this is defined as one type of waste, especially in the Arctic areas. This mean increasing interest in minimizing the produced water volume transported up to the platform. This can mainly be achieved by separation and reduction measures, (Arctic Council - PAME, 2009).

This mainly requires re-injection of all produced water in Arctic areas, according to governmental requirements of the zero discharges to sea target, (Miljøverndepartement, 2006-03-31) (Miljøverndepartement, 2011-03-11).

5 Technical and physical challenges

In general there are challenges with any activity in the Arctic area, since this is an area in an extreme environment which there is still limited knowledge about. There are large uncertainties both when it comes to the environmental impacts and the risks with increasing activities. This project has aimed at summarizing and getting an overview of different areas including regulations and expectations from the Norwegian government, Arctic physical environment and some offshore production systems. There are several of the areas which could be examined more into details. This report provides an overview of some of the challenges we stand in front of.

Power and Heat generation:

The largest part of emissions released from offshore production today come from the power and heat generation system, which for the Norwegian Continental shelf mostly is from gas turbines. It can be concluded that increased focus on mitigation measures and higher energy efficiency will be even more important for potential future activities in the Arctic. New alternative technology for heat and power generation have been developed the last years and will probably continue in the future as a result to policy instruments as carbon tax and due to the constraints existing in the Arctic. The increasing energy demand for the production operation means that there shall be more focus on the total energy efficiency for each platform and possible energy re-use.

The coming BAT technologies for Arctic areas are of course not sure but will most likely be alternatives which increase the energy efficiency and decreases emissions to air. At the same time it is necessary to remember constraints as weigh, size and possible maintenance limitations existing on offshore facilities. Future alternatives such as electrification, combined gas cycle with heat recovery system and possible also some renewable energy sources in combination with Carbon capture and Storage (CCS) are highly possible in the future.

Flare system:

As discussed earlier, continuous flaring is not performed on a regular basis on the Norwegian Continental shelf. Since the flaring is not only a way of releasing unwanted gas, flaring is also a safety system. In the future, focus will most likely be more intensified for reducing the amount of continuous flaring and avoid flaring for emergency reasons. This can be achieved by including flare management and also by gas recovery, where the gas is re-circulated, in the flare system and operation. One challenge is to avoid operational shutdowns or emergency situations to minimize flaring, through management measures and new technology.

Produced Water Treatment:

The Zero discharges to sea requirement which is mentioned in the management plan for Barents Sea and Lofoten will mean increasing re-use or handling the produced water without discharge it to the sea. Although there will probably be some discharges from operational deviations and these discharges will need to be treated beyond compliance of concentration limits.

BAT challenges:

What is considered BAT in general, highly depends on the site and location specifications. Although BAT assessment is also a continuing process during different phases of a production project, there are new technologies coming up and what is considered BAT might change over time. The techniques demonstrated in this project might not be the only alternatives, but can be seen as a listing of the most common alternatives on the NCS.

The Arctic conditions, both physical and technical, which can affect and challenge the production facility and the operations, should be taken into consideration when assessing future BAT. There is also a question regarding whether or not BAT, best available technique, is good enough for the Arctic areas.

There is also a time perspective which should be accounted for, BAT is something that changes over time and continuously developing, so preparing for the future is something which should be considered.

6. Conclusion

The scope of project has been performed with a broad perspective, looking into different aspects within the petroleum activity in Norway as well as future activities. Different aspects have been included such as regulation, guidelines and expectations, environmental conditions and impacts but also technological aspects.

To performing any activities which would have social and economic benefits and at the same time trying to preserve ecosystems in the world is a challenge which might not have a complete solution.

To reconnect to the research questions stated in the beginning, following summarizations are made.

- Environmental regulations and requirements in Norway are mostly performance based when it comes to petroleum activities, but instead Klif has high demands on activity applications and assessing on individual case level. There is in general an aim for zero discharges to sea and for Norway to become carbon neutral in 2050, set by the Norwegian Government. For further listing of regulations, guidelines and standards see Appendix IAppendix II, and Appendix III.

- When it comes to BAT (Best Available Technique) practices in Norway is this mentioned as something which should be used in the petroleum sector. The BAT concept has not been further defined form the IPPC-directive in Norway and interpretations about what is “available” economically and technically, can be discussed further.

- For the three different technical systems studied; power and heat generation, flare system and produced water system, the alternatives considered BAT have been assessed on a conceptual level. Due to assessing BAT on a complete level requires site specific consideration for each individual case, this project can only give an indication towards alternatives to be considered, see Appendix IV, Appendix VAppendix VI, Appendix VII, Appendix VIII and Appendix IX.

- Any future activities in the Arctic areas will impact the environment, to what degree is yet to be answered. Stronger requirements for the areas can be expected. Though Arctic activities could affect several nations and environment impacts, not just within one country’s boarder but also other Arctic nations. There is global interest for international collaboration when it comes to the Arctic areas between the Arctic states, and this can only be positive for the area in achieving sustainable development.

- Any changes in applying existing BAT in Norway’s Arctic areas is concerning zero discharges to sea requirement and minimizing emissions to air. This affects the power and heat generation with more focus on electrification and waste heat recovery system compared to the traditionally use of gas turbines. Though a question from where this electricity comes from and the capacity of providing enough, secure electricity in the future are areas which needs further investigation, technology development and discussions. There are plans for developing and expanding the Norwegian grid, which also includes possible electrification from onshore to offshore installations in the future. When it comes to the flare system, an increased expectation for no-flaring techniques is high on the agenda. Though there is still an issue with flaring for safety reasons. Techniques to reduced continuous flaring by recovery are today available; this can hopefully be further developed and used globally. For the produced water system, the zero discharges to sea requirements for Barents Sea (and probably for the rest of Arctic areas in Norway as well) will prevent any discharges to sea during normal operation. The focus lies on developing technology for reducing the volume and re-injection of the produced water rather than treatment though this is still necessary. There are available technologies today, but these can be further developed to gain even more competiveness towards the discharge alternative.

7. Discussion and future recommendations

This thesis has been performed on a conceptual level which also means that there have been lots of different areas to cover and to get an overview of, from regulations to environmental and science and from the oil and gas industry to technology systems. There seems to be deepened natural scientific articles and technical reports written in some areas but few which connect both the Arctic conditions and environmental in addition to offshore activities. This is something which might be further assessed in order not to miss the whole picture and to avoid unnecessary area conflicts.

In general, there are reports and articles about some physical scientific, detailed area, but very little information about the connection science-environment-technology on a conceptual level. Of course there should always be topic-deep reports and knowledge, but if there is no overview or any area connecting science and technology there might be some things we could oversee.

There are both ethical and moral issues regarding any future petroleum activities in the Arctic. The society today is depending on oil as an energy source and since this is a non-renewal and finite source which also have high emission levels this is not sustainable in the future. The benefits and advantages of especially oil as a transport energy source are today superior and there is no full substitution for this energy source. In other industries, e.g. automotive industry, there is often a lifetime perspective (e.g. performing Life-cycle assessments) for a product and its processes; this might be an interesting view to apply for the oil and natural gas extraction and production activities.

For the future development in the oil and gas industry there seems to be focus on more subsea solutions such as extraction, separation and production processes. This demands less energy and can provide enhanced recovery as well as providing unmanned solutions. Carbon Capture and Storage (CCS) are another area of interest and future potential of handling and storage emissions form oil and natural gas extraction and production.

When it comes to the largest source of air emissions at petroleum production facilities, the power generation system, there is an increased interest in electrification. This can be provided from onshore but also in the long-term future include offshore renewable sources like wind or solar energy, in locations with suitable conditions. To electrify future production facilities also demands a grid system able to provide the electricity as well as increased supply of electricity and infrastructure.

For the Arctic there are still uncertainties about the impacts any activities will have on the environment. What can be said is that the global impact on Arctic is still going to be constant and as an effect have increased temperature and melting of ices, independently of any petroleum activities. The importance of evaluating the base line in the Arctic areas is significant for any future evaluation of impacts and possible mitigation measures. This is in order to assess any negative effects from petroleum activities which is mostly a local issue while there are also continuous global issues, such as global warming, affecting the Arctic environment. It is hard to say that the possible impacts and its consequences are from the petroleum industry and therefore it is also very important to continue with research and studies including different scenarios and aspects. Any decision making should include facts and include a sustainability view and the initiations to start petroleum activities would probably be most profitable to the environment if it is performed and evaluated on a step to step basis.

Since this project has involved several different areas of interest with lots of material there has been a challenge to navigate between the information and how deep into the details I should investigate. To be able to evaluate on a more detailed level is something more common to use, but in this case the challenge was mainly to concentrate on a higher level during a certain time period and trying to get an overview rather than a detailed picture.

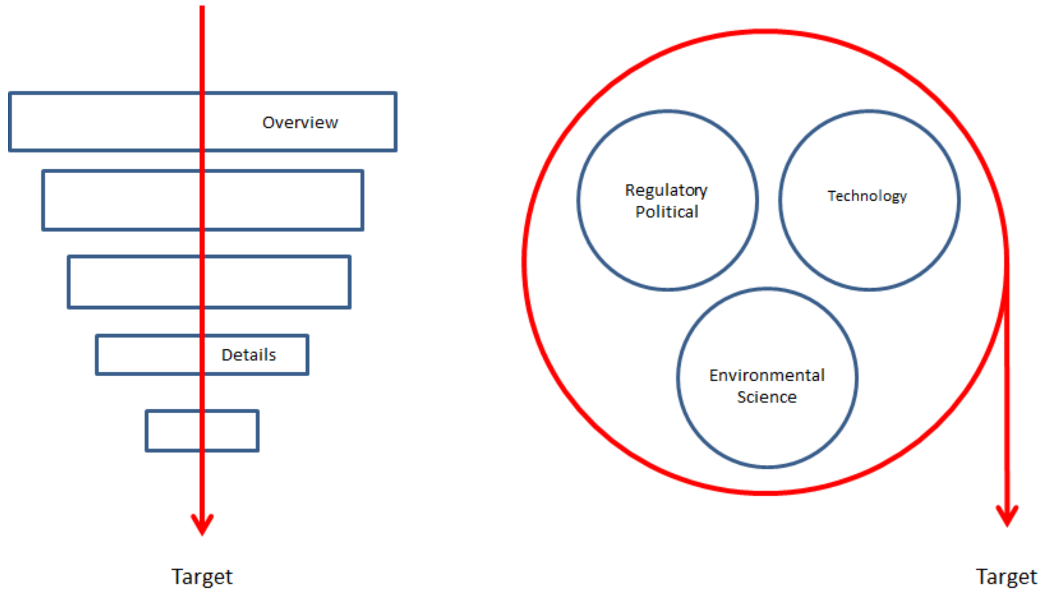

Figure 19: To the left, a top-down approach getting into detailed studies to reach a final target. To the right, a more circular approach, this connects different areas of interest to reach the final target. The approach on the right hand side has been more used in this thesis project.

The Arctic continent, potential oil and gas exploration and technologies and how to manage these are definitely an area to look more into; the combination of politics, economy, natural science and technology have too few connecting synergies and often parallel investigations and a full view including all these aspects are rarely found.

Norway has the chance to take a lead when it comes to developing policy instruments regulating emissions and discharges from petroleum production and to take a lead within environmental technologies, especially for the Arctic areas. Collaboration between nations instead of competing is something which could be beneficial and increase the speed of technology development to find sustainable solutions.

One can have arguments both for and against any further explorations and activities in the Arctic areas. This is not an easy statement to make when considering all aspects and having a global view. What can be stated is that any decisions shall be performed with sufficient information and facts as well as discussions. The concept of continuous improvement and minimize the environmental impact should be integrated in any decisions as well as the environment around us. This is not a static but a dynamic process.

8. References

Arctic Council - AMAP. (2011). *AMAP Technical Report Nr. 4 - The Impact of Black Carbon on Arctic Climate.* Denmark: Narayana Press.

Arctic Council - EPPR. (2012). *EPPR RP3 Report - Recommended Practices for Arctic Oil spill preventation.* Emergency Prevention Preparedness and Response RP3 Project - DNV.

Arctic Council - PAME. (2009). *Protection of the Arctic Marine Environment Working Group - Arctic Offshore Oil and Gas Guidelines.*

Arctic Council - PAME. (2009-04-29). *Protection of the Arctic Marine Environment Working group - Arctic Offshore Oil and Gas Guidelines.* Retrieved 2013-05-06, from http://www.pame.is/amsa-home/questions-and-answers/77-arctic-ocean-review-project

Arctic Council. (2013). *Maps: Arctic council*. Retrieved 2013-03-19, from Arctic Council website: http://www.arctic-council.org/index.php/en/about/maps

Argo Engironmental Engineering - Jonathan Miles. (2004). *Business Briefing Exploration & Production: The Oil & Gas Review - Environmental and Maintenance Challenge in Flare Ignition and Combustion.* Retrieved 2013-04-24, from Argo Flare Service Web site: http://www.touchbriefings.com/pdf/951/miles.pdf

Argo Flare Service Ltd. (2013). *Argo Flares Research - Introduction*. Retrieved 2013-04-20, from Argo Flare Service Web site: http://www.argoflares.com/research/introduction/

Barents 2020 Project. (2010). *Barents 2020: Assessment of International standards for safe exploration, production and transportation of Oil and Gas in the Barents Sea. Report 3.* Norway: Erik Tanche Nilssen AS.

Barents Observer. (2012-11-23). *Arctic - 46 vessles through Northern Sea Route*. Retrieved 2013-03-19, from http://barentsobserver.com/en/arctic/2012/11/46-vessels-through-northern-sea-route-23-11

Clearstone Engineering Ltd. (2008-09-18). *Technical report - Guidelines on Flare and Vent Measurements - Prepared for The Global Gas Flaring Reduction partnership (GGFR) and the World Bank.* Retrieved 2013-04-24, from http://siteresources.worldbank.org/INTGGFR/Resources/Guidelines_Flare_Vent_Measurement.pdf

DNV. (2007). *Teknisk Rapport - TEKNA - Miljøteknologi for Oljeutvinning i Nordområdene - Rapport Nr. 2007-0433.* Retrieved 2013-04-30, from http://www.tekna.no/ikbViewer/Content/776315/milj%F8teknologi%20tekna%20fra%20DNV.pdf

DNV. (2012-09-24). *Det Norske Veritas: Arctic Update - Arctic resource development: Risks and responsible management, Executive summary*. Retrieved 2013-05-07, from http://www.dnv.com/industry/oil_gas/publications/updates/arctic_update/2012/01_2012/Arcticresourcedevelopment.asp

Eni Norge AS. (2008). *Goliat - Plan for utbygging og drift av Goliat - Del 2 Konsekvensutredning.*

European IPPC Bureau. (2006). *Joint research Centre - Institute for Prospective Technological Studies (IPTS) - Reference Documents - Large Combustion Plants*. Retrieved 2013-03-20, from http://eippcb.jrc.es/

European Parliament and Council of the European Union. (2008). *Directive 2008/1/EC concerning Integrating Pollution Prevention and Control.* Avaliable at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:024:0008:0029:EN:PDF: Official Journal of the European Union.

European Union. (2006, July). *European IPPC Bureau - Reference documents - Large combustion plants - Reference document on Best Avaialbe Technique.* Retrieved 2013-02-26, from http://eippcb.jrc.es/reference/lcp.html

European Union. (2012-01-19). *Official Journal of the European Union - Commission Decision on setting up for the European Union Offshore Oil and Gas Authorities Group.* Retrieved 2013-03-25, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2012:018:0008:0010:EN:PDF

Giampaolo, T. (2006). *Gas Turbine Handbook: Principles and Practices, Third edition.* United States of America: The Fairmont Press.

Haukebø, S., & Vandenbussche, V. (2013-02-21). Introduction to Flare System. (E. Thylander K., Interviewer)

IEC. (2013). *International Electrotechnical Commission*. Retrieved 2013-03-25, from About us: http://www.iec.ch/about/?ref=menu

International Institute for Sustainable Development. (2010, September). Sustainabile Development: from Brundtland to Rio 2012 - Background Paper prepared for consideration by the High Level Panel on Global Sustainability at its first meeting, 19 Spetember 2010. United Nations Headquarters, New York.

International Orgianization for Standardsization. (1996). *ISO 14001:1996(E) Environmental management systems - Specification with guidance for use.*

IPCC Fourth Assessment Report (AR4). (2007). *Climate Change 2007: The Physical Science Basis - Contribution of Working Group I to the Fourt Assessment Report of the IPCC.* Camebridge, United Kingdom and New York, NY, USA: Camebridge Univeristy Press.

Karlsson, E., & Westin, M. (2010). *Best Available Techniques – Guideline proposal for Det Norske Veritas.* Institutionen för Energivetenskaper. Lund: Lunds Tekniska Högskola.

Klima- of Forurensningsdirektoratet. (2001-02-15). *Regelverk - EU-/EØS-regelverk - IPPC*. Retrieved 2013-03-20, from http://www.klif.no/Regelverk/EU-EOS-regelverk/EU-direktiver/IPPC-Direktiv-om-integrert-forebygging-og-begrensning-av-forurensning/

Klima- og Forurensningsdirektoratet. (2013). *Om oss: Klif*. Retrieved 2013-03-20, from http://www.klif.no/no/Om-oss/

Klima- og Forurensningsdirektoratet. (2013-01-10). *Aktuellt: Nyheter: Januar 2013 - Advarer mot hastverk i Barentshavet*. Retrieved 2013-02-06, from http://www.klif.no/no/Aktuelt/Nyheter/2013/Januar-2013/Klif-advarer-mot-hastverk-i-Barentshavet/

Klima- og Forurensningsdirektoratet. (2013-05-21). *Kommentarer till forslag til program for konsekvensutredning for PL 532 Johan Castberg, tidigare Skrugrad, Statoil ASA.* Retrieved 2013-05-28, from Aktuelt - Nyheter - Mai 2013 - Må utrede miljøkonsekvenser ved flere utbyggingsalternativer: http://www.klif.no/nyheter/dokumenter/Brev_Statoil_johan_castberg.pdf

Lovdata - Forurensningsforskriften. (2004-07-01). *Lovdata - Forskrift om begrensning av forurensning (Forurensningsforskriften) - Vedlegg II. Beste tilgjengelige teknikker.* Retrieved 2013-04-20, from http://www.lovdata.no/cgi-wift/ldles?doc=/sf/sf/sf-20040601-0931.html

Miljødepartement. (2010). *Melding til Stortinget 10 (2010-2011) - Oppdatering av forvaltningsplanen for det marine miljø i Barentshavet og havområdene utenfor Lofoten.* Retrieved 04 29, 2013, from http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011.html?id=635591

Miljøstatus . (2012-05-31). *Gøteborgprotokollen: Luftforurensning*. Retrieved 2013-04-19, from Miljøstatus Web site: http://www.miljostatus.no/Tema/Luftforurensning/Goteborgprotokollen/

Miljøverndepartement. (2006-03-31). *Regjeringen - Melding til Stortinget (2005-2006) - Helhetlig forvaltning av det marine miljø i Barentshavet og havområdene utenfor Lofoten (forvaltningsplan).* Retrieved 2013-04-15, from http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/20052006/stmeld-nr-8-2005-2006-.html?id=199809

Miljøverndepartement. (2007-06-22). *Regjeringen - Stortingsmelding Nr 34 (2006-2007) - Norsk klimapolitikk pp. 36-56.* Retrieved 2013-05-04, from http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2006-2007/Stmeld-nr-34-2006-2007-.html?id=473411

Miljøverndepartement. (2011-03-11). *Regjeringen - Melding til Stortinget (2010-2011) - Oppdatering av forvaltningsplanen for det marine miljø i Barentshavet og havområdene utenfor Lofoten.* Retrieved 2013-04-05, from http://www.regjeringen.no/pages/16007995/PDFS/STM201020110010000DDDPDFS.pdf

National Petroleum Council. (2011-09-15). *Prudent Development - Realizing the Potential of North America's Abundant Natural Gas and Oil Resources - Technology Subgroups Topic Papers - Paper #2-17 Management of Produced Water from Oil and Gas Wells.* Retrieved 2013-05-06, from http://www.npc.org/PD_topic_papers.html

Nesse, S. (2013-03-25). Potential recommendations and regulations for Arctic in Norway - Email. (E. Thylander K., Interviewer)

Norsk Olje & Gass. (2012). *Miljørapport 2012 - Oljeindustrins Landsforening (OLF) - Olje- og gassindustrins miljøarbeid - Fakta og utviklingstrekk.* Retrieved 2013-04-30, from http://www.norskoljeoggass.no/Documents/Milj%c3%b8rapport%202012/Milj%c3%b8rapport%202012.pdf

NORSOK S-003. (2005-12-03). *Sectors: Petroleum: S-Safety(SHE): S-003.* Retrieved 2013-02-20, from Standards Norway: http://www.standard.no/PageFiles/1054/S-003.pdf

Norwegian Petroleum Directorate. (2008-08-25). *Publications - Norwegian Continental Shelf - No to Flaring*. Retrieved 2013-04-24, from http://www.npd.no/en/Publications/Norwegian-Continental-Shelf/No2-2008/No-to-flaring/

Norwegian Polar Institute. (2013). *Home: The Arctic*. Retrieved 2013-03-19, from Norwegian Polar Institute Web site: http://www.npolar.no/en/the-arctic/

Ocean Explorer. (2005). *NOAA*. Retrieved 2013-03-18, from Ocean Explorer - National Oceanic and Atmosperic Administration Web site: http://oceanexplorer.noaa.gov/explorations/06mexico/background/oil/media/types_600.html

Offshore magazine. (2011). *Regulatory demands raising the bar for accurate flare gas measurements - Offshore magazine, Volume 71, Issue 10.* Retrieved 2013-04-24, from http://www.offshore-mag.com/articles/print/volume-71/issue-10/production-operations/regulatory-demands-raising-the-bar-for-accurate-flare-gas-measurement.html

Olje- og Energidepartement. (2002). *Stortingsmelding nr 38 (2001-2002) - Om olje- og gassvirksamheten.* Retrieved 2013-04-29, from http://www.regjeringen.no/Rpub/STM/20012002/038/PDFA/STM200120020038000DDDPDFA.pdf

Olje- og Energidepartementet & Oljedirektoratet. (2012). *Rejeringen - Olje- & Energidepartementet - Fakta 2012 - Norsk petroleumsvirksomhet.* Retrieved 2013-02-17, from http://www.regjeringen.no/nb/dep/oed/aktuelt/nyheter/2012/fakta-2012---norsk-petroleumsvirksomhet.html?id=678126

Olje- og Energidepartementet & Oljedirektoratet. (2013). *Rejeringen - Olje- & Energidepartementet - Fakta 2013 - Norsk Petroleumsverksemd.* Retrieved 2013-05-01, from http://www.npd.no/Global/Norsk/3-Publikasjoner/Faktahefter/Fakta2013/FAKTA_2013.pdf

Olje- og Energidepartment. (2002-06-28). *Regjeringen - Stortingsmelding Nr 38 (2001-2002) - Om olje- og gassvirksomhet.* Retrieved 2013-05-03, from http://www.regjeringen.no/Rpub/STM/20012002/038/PDFA/STM200120020038000DDDPDFA.pdf

Oljedirektoratet. (2010). *Beskrivelse av miljøteknologi - Delutredning til sektorutredning Petroleum og energi, Helhetlig forvaltningsplan for Barentshavet - oppdatering 2010, Kartlegging av tilgjengelig miljøteknologi.*

Oljedirektoratet. (2011-02-22). *About OD: Oljedirektoratet*. Retrieved 2013-03-20, from http://www.npd.no/no/Om-OD/

OSPAR Commission. (2013). *OSPAR Convention - Protecting and Serving the North-East Atlantic and its resources*. Retrieved 2013-04-19, from http://www.ospar.org/content/content.asp?menu=01481200000000_000000_000000

Petroleumstilsynet - Forskrifter. (2013). *Regelverk - Om Regelverket på Petroleumstilsynets myndighetsområder - HSM-foreskriftene*. Retrieved 2013-04-30, from http://www.ptil.no/regelverk/om-regelverket-paa-petroleums-tilsynets-myndighetsomraader-article9020-21.html

Petroleumstilsynet - Lover. (2013). *Regelverk - Lover*. Retrieved 2013-04-30, from http://www.ptil.no/lover/category213.html

Petroleumstilsynet. (2012-12-20). *Regelverk - Veiledning - Aktivitetsforskriften.* Retrieved 2013-03-15, from http://www.ptil.no/aktivitetsforskriften/category383.html#_Toc345589351

Petroleumstilsynet. (2012-12-20). *Veiledning til Aktivitetsforskriften.* Retrieved 2013-03-14, from Petroleumstilsynet Regelverket: http://www.ptil.no/getfile.php/Regelverket/Aktivitetsforskriften_veiledning_n.pdf

Petroleumstilsynet. (2013). *Om oss: Petroleumstilsynet*. Retrieved 2013-03-20, from http://www.ptil.no/om-oss/category23.html?lang=no_NO

Petroleumstilsynet. (2013). *Regelverk - Om Regelverket på Petroleumstilsynets myndighetsområder - HSM-foreskriftene*. Retrieved 2013-04-30, from http://www.ptil.no/regelverk/om-regelverket-paa-petroleums-tilsynets-myndighetsomraader-article9020-21.html

Regjeringen - Europaportalen. (2013). *Europaportalen - EØS - EØS-avtalen*. Retrieved 2013-03-20, from http://www.regjeringen.no/nb/sub/europaportalen/eos/eos-avtalen.html?id=516157

SINTEF - Teknologi og samfunn. (2008). *Bruk av BAT (Beste Tilgjengelige Teknikker) - princippet for miljøsikkerhet.* Norway: SINTEF A4531.

SINTEF Energy Research. (2011). *E.Øyskebø/M.Korpås - Electrification of offshore petroleum installations with offshore wind integration.* Retrieved 2013-03-25, from http://www.sintef.no/project/NorthSeaGrids/paper_EWEA_2011_Oyslebo.pdf

Standard Online AS. (2013). *NORSOK - Sector: Petroleum: S-Safety (SHE)*. Retrieved 2013-03-25, from http://www.standard.no/en/Sectors/Petroleum/NORSOK-Standard-Categories/S-Safety-SHE/

Statistics Norway. (2013-02-07). *Statisktisk sentralbyrå - Uslipp av klimagaser, 1990-2011, endelige tall*. Retrieved 2013-03-19, from http://www.ssb.no/natur-og-miljo/statistikker/klimagassn

The World Bank - GGFR. (n.d.). *Global Gas Flaring Reduction - Regulation of Associated Gas Flaring and Venting - A Global Overview and lessons from International Experience.* Retrieved 2013-04-24, from http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2004/07/16/000012009_20040716133951/Rendered/PDF/295540Regulati1aring0no10301public1.pdf

The World Bank. (2011). *Global Gas Flaring Reduction Partnership (GGFR) - Improving Energy Efficiency & Mitigating Impact on Climate Change.* Retrieved 2013-04-24, from http://siteresources.worldbank.org/INTGGFR/Resources/GGFR_NewBrochure(Oct2011).pdf

The World Bank. (2012-07-03). *The World Bank Web site - News*. Retrieved 2013-04-21, from http://www.worldbank.org/en/news/press-release/2012/07/03/world-bank-sees-warning-sign-gas-flaring-increase

United Nations Framework Convention on Climate Change. (2008). *Kyoto Protocol - Reference Manual On Accounting of Emissions and Assigned amount*. Retrieved

2013-04-19, from http://unfccc.int/resource/docs/publications/08_unfccc_kp_ref_manual.pdf

Utengen, T. (2013-04-09). Principla engineer - Rotating Machinery, DNV. (E. K. Thylander, Interviewer)

Vandenbussche, V. (2013-02-06). Introduction to the offshore Oil and Gas industry. (E. K. Thylander, Interviewer)

Vandenbussche, V. (2013-02-18). Introduction to power and heat generation. (E. K. Thylander, Interviewer)

9. Bibliography

A list of other reference sources which are not directly referred to in this report.

AMAP, 2010. Assessment 2007: Oil and Gas Activities in the Arctic – Effects and Potential Effects. Volume I. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. Vii + 423 pp.

AMAP, 2011. Arctic Pollution 2011. Arctic Monitoring and Assessment Programme (AMAP), Oslo. Vi + 38pp. ISBN: 13 978-993-7971-066-0

AMAP, 2011. The Impact of Black Carbon on Arctic Climate (2011). By: P.K. Quinn, A. Stohl, A. Arneth, T. Berntsen, J. F. Burkhart, J. Christensen, M. Flanner, K. Kupiainen, H. Lihavainen, M. Shepherd, V. Shevchenko, H. Skov, and V. Vestreng. Arctic Monitoring and Assessment Programme (AMAP), Oslo. 72 pp. ISBN – 978-82-7971-069-1

AMAP, 2011.Climate Change in the Arctic – A Hot Topic 2011. SWIPA. Arctic Monitoring and Assessment Programme (AMAP). ISBN: 978-82-7971-072-1

Aunan, K., 2001. Climate measures in Norway. Potential reductions in offshore emissions. Cicerone 2/2001.

Bader, A., Baukal C.E. Jr., Bussman W., 2011. Selecting the proper flare systems. Back to basics. American Institute of Chemical Engineers (AIChE). 2001.

Barents 2020 Project. (2010). Barents 2020: Assessment of International standards for safe exploration, production and transportation of Oil and Gas in the Barents Sea. Report 3. Norway. Erik Tanche Nilssen AS.

Barents 2020 Project. (2012). Barents 2020: Assessment of International standards for safe exploration, production and transportation of Oil and Gas in the Barents Sea. Report 4. Norway. Erik Tanche Nilssen AS.

Bolland, O., Nord, L.O., 2012. Steam bottoming cycles offshore – challenges and possibilities. Journal of Power technologies 92 (3) p. 201-207, 2012.

CIMAC, 2012. Background information on Black carbon emissions from large marine and stationary diesel engines – Definition, measurement methods, emission factors and abatement technologies. The International Council on Combustion Engines 2012.

Dalsøren, S.B. et al., 2012. Environmental impacts of shipping in 2030. Copernicus Publications on behalf of the European Geosciences Union.

EPPR, 2012. Recommended Practices for Arctic Oil spill Prevention. EPPR RP3 Report Rev -03.1. 31 August 2012. Report No./DNV Reg No.: /1-53JREN

Fidler, C., Noble, B., 2011. Advancing strategic environmental assessment in the offshore oil and gas sector: Lessons from Norway, Canada and the United Kingdom. Environmental Impact Assessment Review 34 (2012) 12 (21)

IFC, 2007. Environmental, Health and Safety Guidelines for Offshore Oil and Gas Development. International Finance Corporation (IFC). World bank Group. 2007

James D.N. McEwen & Matthew R. Johnson, 2012. Black carbon particulate matter emission factors for buoyancy-driven associated gas flares, Journal of the Air & Waste Management Association, 62:3, 307-321.

Kloster, P., 1999. Energy optimisation on offshore installations with emphasis on offshore combined cycle plants. Society of Petroleum Engineers Inc. (SPE 56964) 1999.

Kloster, P., 2000. Reduction of emissions to air through energy optimisation on offshore installation. Society of Petroleum Engineers Inc. (SPE 61651) 2000.

Leirgulen, S.I., 2012. Standardising Arctic challenges. *Oil & Gas Journal.* Jun 4, 2012. 110. 6 p. B14.

Masterson, D.M. 2012. The Arctic Islands Adventure and Panarctic Oils Ltd. Cold regions Science and Technology 85 (2013) 1-14.

Paulin, M., 2010. Arctic conditions challenge offshore projects. *Offshore;* Aug. 2010. 70 (8).

Porta, L. and Bankes, N. 2011. Becoming Arctic-Ready: Policy Recommendations for Reforming Canada's Approach to Licensing and Regulating Offshore Oil and Gas in the Arctic.

Snow, N. 2012. Norway's Arctic approach. *Oil & Gas Journal.* Dec 3, 2012. 110. 12 p. 48.

The Economist. The melting north, Special report, The Arctic, 2012-06-16

Appendix Content

[Empty]

Appendix I. Existing offshore regulations in Norway

Existing Regulation in Norway
Focus on Offshore Petroleum Production regarding Environmental aspects

Theme	Area	Regulation source	Content	Sites/Sources
Emissions to Air	**General**	Forurensningsloven (Pollution Control Act) Aktivitetsforskriften (The Activities Regulations) Norwegian Government (Regjeringen): Stortingsmelding nr 34 (2006-2007) Kyoto protocol (ratified by Norway) Gøteborg protocol (ratified by Norway)	Forurensningsloven: General regulations regaring Pollution in Norway. Regarding exploration for and production and utilisation of subsea natural resources on the continental shelf in accordance with Section 4 in Pollution Act. Aktivitetsforskriften: Operator must have permission according to Forurensningsloven Chapter 3 Stortingsmelding nr 34 (2006-2007): Short term: Reduced GHG-emissions from 2006 to 2020 by 3-5 million CO2-equivalent Long term goal: Norway shall be Carbon Neutral in 2050	Forurensningsloven: http://www.regjeringen.no/nb/dok/lover_regler/lover/forurensningsloven.html?id=171893 Lovdata: http://www.lovdata.no/all/hl-19810313-006.html PTIL: http://www.ptil.no/framework-hse/category408.html http://www.regjeringen.no/nb/dep/md/dok/rapporter_planer/rapporter/2007/naringslivets-miljoansvar/-5/-3/-2.html?id=477932 Aktivitetsforskriften: http://www.ptil.no/getfile.php/Regelverket/Aktivitetsforskriften_n.pdf Guidelines: http://www.ptil.no/aktivitetsforskriften/category383.html SINTEF report A4531, 2008
	CO2	Kyoto protocol (ratified by Norway 2002) Norwegian Government (Regjeringen)	Carbon tax for the petroleum industry on the Norwegian Continental Shelf. Tax: 410 NOK/tonne CO2 emitted, from 1st January 2013. Quota-based	http://www.regjeringen.no/en/dep/fin/Documents-and-publications/official-norwegian-reports-/2012/nou-2012-16-2/10/3/1.html?id=713589 http://www.regjeringen.no/en/dep/md/press-centre/Press-releases/2012/the-government-is-following-up-on-the-cl.html?id=704137 Kyoto: http://www.regjeringen.no/en/archive/Bondeviks-2nd-Government/ministry-of-the-environment/Nyheter-og-pressemeldinger/2002/norway_ratified_the_kyoto_protocol.html?id=247482
	CH4	Kyoto protocol (ratified by Norway)	CH4 is converted into CO2-equivalents and a part of the total accounting for GHG.	http://www.regjeringen.no/en/dep/fin/Documents-and-publications/official-norwegian-reports-/2012/nou-2012-16-2/10/3/1.html?id=713589
	NOx	Gøteborg-protocol, ratified by Norway, Stortinget 2002 (also see Stortingmelding nr 88 (2000-2001) MARPOL Norwegian Government(Regjeringen) - Norwegian Pollution Control Authority: Nox-Fee	Fee: 17,01 NOK/kg emitted NOx (from 2013-01-01)see Costums (toll.no) For manufactoring industries, transport comprising of ships, fishing vessels, air traffic and railways as well as engines, boilers, turbines in manufactoring industries. Large units are applicable for the tax system (boilers > 10MW) (Propulsion engines >750kW). NOx also imposed on flaring offshore and on oil and gas installations onshore. Norway is obliged through the Gøteborgsprotokollen to limit the emissions of NOx to maximum 156 000 tonne per year from year 2010 (Regjeringen).	http://www.regjeringen.no/nb/dep/fin/tema/skatter_og_avgifter/nox-avgiften.html?id=481419 http://www.stortinget.no/Global/pdf/Innstillinger/Stortinget/2000-2001/inns-200001-088.pdf http://www.ekh.unep.org/files/GP-6.pdf http://www.lovdata.no/for/sf/sv/td-20061128-1342-022.html http://www.lovdata.no/for/sf/sv/td-20121127-1217-019.html http://www.toll.no/upload/aarsrundskriv/2013_NOx.pdf
	nmVOC	Gøteborg-protocol, ratified by Norway, Stortinget 2002 (also see Stortingmelding nr 88 (2000-2001) MARPOL	Norway is obliged through the Gøteborgsprotokollen to limit the emissions of nmVOCo maximum 195 000 tonne per year from year 2010 (Regjeringen).	Regjeringen: http://www.stortinget.no/Global/pdf/Innstillinger/Stortinget/2000-2001/inns-200001-088.pdf http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2006-2007/Stmeld-nr-34-2006-2007-.html?id=473411 Miljøteknologi - Karlegging av tilgjenglig miljøteknologi for petroleumindustien på norsk sokkel, 2011
	SO2	Gøteborg-protocol, ratified by Norway, Stortinget 2002 (also see Stortingmelding nr 88 (2000-2001) Sox- MARPOL	Norway is obliged through the Gøteborgsprotokollen to limit the emissions of SO2 to maximum 22 000 tonne per year from year 2010 (Regjeringen). SO2 from petroelumindustry is limited, mainly related to transition to fuels with low sulfur content.	Regjeringen: http://www.stortinget.no/Global/pdf/Innstillinger/Stortinget/2000-2001/inns-200001-088.pdf http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2006-2007/Stmeld-nr-34-2006-2007-.html?id=473411

Theme	Area	Regulation source	Content	Sites/Sources
Discharges to Sea	**General**	OSPAR convention (ratified by Norway)	OSPAR: The Convention for the Protection of the marine Environment of the North-East Atlantic Includes the Arctic waters (Region I). Contained within the OSPAR Convention are a series of Annexes which deal with the following specific areas: -Annex I: Prevention and elimination of pollution from land-based sources; -Annex II: Prevention and elimination of pollution by dumping or incineration; -Annex III: Prevention and elimination of pollution from offshore sources; and -Annex IV: Assessment of the quality of the marine environment.	Areas: http://www.ospar.org/content/regions.asp?menu=00020200000000_000000_000000 Convention: http://www.ospar.org/html_documents/ospar/html/ospar_convention_e_updated_text_2007.pdf
	Oil concentration in water	OSPAR convention Aktivitetsforskriften (The Activities Regulations)	Maximum 30 ppm oil content (OSPAR 2007). Long term goal (by 2020): -Parties shall achieve a reduction of oil in pw dishcarged ito a level which ensures no harm to marine environment -A continous reduction og Hazardous Substances via pw, by achieve concentration near values for naturally occuring substances and close to zero for man-made syntetic substances. (DNV-TEKNA) Aktivitetsforskriften: -Oil in water shall be cleaned before emitted to sea (not displacement water) with optimal effect (comparing added chemicals). -Oil in water emitted to sea should be as low as possible. -Oil content in water may not exceed: Max 30 mg oil/litre water (ppm, average for one month). Expectations on beyond complance more towards 10-20 ppm at least.	DNV- Teknisk rapport TEKNA 2007 Aktivitetsforskriften: http://www.ptil.no/getfile.php/Regelverket/Aktivitetsforskriften_n.pdf Guidelines: http://www.ptil.no/aktivitetsforskriften/category383.html Oil in water: http://www.regjeringen.no/nb/dep/oed/dok/regpubl/prop/2011-2012/prop-85-s-20112012/9.html?id=677387 OSPAR convention 2001/1: http://www.regjeringen.no/Rpub/STM/20012002/038/PDFA/STM200120020038000DDDPDFA.pdf http://www.ospar.org/content/content.asp?menu=00120000000059_000000_000000 See more at: Rammeforskriften kapittel II, Styringsforskriften § 7 og § 8, Forurensningsloven kapittel 3. In Aktivitetsforskriften - Guidelines: Refers to lots of Standards ISO, NORSOK, NS, IMO. http://www.ptil.no/aktivitetsforskriften/category383.html
	Chemicals	Aktivitetsforskriften (The Activities Regulations) Forurensningsloven Norwegian Government(Regjeringen) - Stortingsmelding nr 58 (1996-1997)	Only use green and yellow chemicals as target. Aktivitetsforskriften: -Directives regarding categories: Black, Red, Yellow, Green -Black and Red chemicals should only be used if necessary for technical and safety reasons, shall be prioritiSubstituted Forurensningsloven: -Operators must have permission according to Forurensningsloven kapittel 3, for use and emissions of chemicals as well as injection of chemicals and chemicals in water. Use of chemicals has to be reduced as much as possible. Operators must use chemicals with least contamination as possible. -Un-used chemicals are not allowed to be emitted to sea or dumped elsewhere (Forurensningsforskriften kapittel 22).	Aktivitetsforskriften: http://www.ptil.no/getfile.php/Regelverket/Aktivitetsforskriften_n.pdf Guidelines: http://www.ptil.no/aktivitetsforskriften/category383.html Stortingsmelding nr 58 SINTEF report A4531, 2008

Existing Regulation in Norway
Focus on Offshore Petroleum Production regarding Environmental aspects

Theme	Area	Regulation source	Content	Sites/Sources
Barents and Lofoten Areas	**Produced water dishcarge**	Rammeforeskriften (The Framework Regulations) Forvaltningsplan Barents & Lofoten, St.melding nr 8 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10	Rammeforskriften: -Rammevilkårene for operations in Barents sea states that at least 95% of produced water should be re-injected. Forvaltningsplan: -Maxmium 5% dischage of produced water (treated) at operational deviations -100% re-injection or injection (or other satisfactory methods) to handle produced water without any discharge, at normal operation	Forvaltningsplan Barents & Lofoten, St.melding nr 8: http://www.regjeringen.no/nb/dep/md/tema/hav--og-vannforvaltning/havforvaltning/forvaltningsplan-barentshavet.html?id=87148 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10: http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011.html?id=635591
	Cuttings and Drilling mud	Forvaltningsplan Barents & Lofoten, St.melding nr8 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10	Shall be no discharges to sea of cuttings and drilling mud.	Forvaltningsplan Barents & Lofoten, St.melding nr 8: http://www.regjeringen.no/nb/dep/md/tema/hav--og-vannforvaltning/havforvaltning/forvaltningsplan-barentshavet.html?id=87148 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10: http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011.html?id=635591
	Zero Discharges to Sea	Forvaltningsplan Barents & Lofoten, St.melding nr8 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10	Zero emission discharge in Barents and Lofoten, as mentioned in the target from Stortingsmelding nr 58.	Forvaltningsplan Barents & Lofoten, St.melding nr 8: http://www.regjeringen.no/nb/dep/md/tema/hav--og-vannforvaltning/havforvaltning/forvaltningsplan-barentshavet.html?id=87148 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10: http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011.html?id=635591
	Flora and Fauna	Forvaltningsplan Barents & Lofoten, St.melding nr 8 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10	No harm to flora or fauna from petroelum activities.	Forvaltningsplan Barents & Lofoten, St.melding nr 8: http://www.regjeringen.no/nb/dep/md/tema/hav--og-vannforvaltning/havforvaltning/forvaltningsplan-barentshavet.html?id=87148 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10: http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011.html?id=635591
	Acute Pollution	Forvaltningsplan Barents & Lofoten, St.melding nr 8 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10	Forvaltningsplan: Shall be same standby at least, as the rest on the Norwegian Continental shelf. Lots of directions from PTIL	Forvaltningsplan Barents & Lofoten, St.melding nr 8: http://www.regjeringen.no/nb/dep/md/tema/hav--og-vannforvaltning/havforvaltning/forvaltningsplan-barentshavet.html?id=87148 Oppdatering Forvaltningsplan Barents & Lofoten, St.melding nr 10: http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011.html?id=635591
	Svalbard Protection	Svalbardmiljøloven (Svalbard Environmental Protection Act)	-Relating to protection of the environment in Svalbard -Also see this Forskrift for regulating for affecting nature on Savalbard and Jan Mayen: see Lovdata	http://www.klif.no/artikkel____31249.aspx http://www.regjeringen.no/en/doc/laws/Acts/svalbard-environmental-protection-act.html?id=173945 http://www.lovdata.no/cgi-wift/wiftldles?doc=/app/gratis/www/docroot/for/sf/md/td-19710528-8617-0.html&emne=forurensning*&&

Existing Regulation in Norway
Focus on Offshore Petroleum Production regarding Environmental aspects

Theme	Area	Regulation source	Content	Sites/Sources
BAT	**Best Available Techniques**	Forurensningsloven Forurensningsforskriften (Pollution Regulations) Rammeforskriften - Guidelines Aktivitetsforskriften - Guidelines EU, IPPC, EIPP Norweigan Government (Regjeringen): Stortingsmelding 8 (2005-2006), 14 (2006-2007), 26 (2006-2007), 34 (2006-2007), 38 (2003-2004)	"To use the best avaialbel techniques for the Environment as a whole" Forurensningsloven: IPPC and BAT is mentioned in the Statement/Intrepretations to the Act, Statement/interpretation, 22.09.1998, Forurensingsloven §§ 1 og 16. Forurensningsforskriften: BAT should be used as stated in the IPPC-directive and it's the plant owners responsibility. Aktivitetsforskriften - Guidelines: For those energy generation facilities on more than 50 MW, the EU Directive 96/61/EF on pollution prevention (IPPC-directive) on shall also be applicable. Energy production facilites are mentioned in BREFs, techniques which are considered BAT. The Directive is through then EU-agreement committed by Norway and as well implemented in Norwagian legislation (see more info in the Guidelines). EU - IPPC: BREFs (BAT Refernce Documents) Also see Refering to BAT at Regjeringen.no	Forurensningsloven, IPPC-directive: http://www.regjeringen.no/en/dep/jd/agenda/tolkningsuttalelser/naturressurs--og-miljorett/tolkningsuttalelser-om-forurensningslove/-1-og-16---sporsmal-om-endringer-i-forur.html?id=455022 Forurensningsforskriften: http://www.lovdata.no/cgi-wift/ldles?doc=/sf/sf/sf-20040601-0931.html BAT: http://www.regjeringen.no/nb/dep/md/dok/rapporter_planer/rapporter/2007/naringslivets-miljoansvar/-5/-3/-2.html?id=477932 Aktivitetsforskriften: http://www.ptil.no/getfile.php/Regelverket/Aktivitetsforskriften_n.pdf Guidelines: http://www.ptil.no/aktivitetsforskriften/category383.html EU - IPPC: http://eippcb.jrc.es/reference/ Stortingsmelding: http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld.html?id=701
Oil & Gas Activities	**Directions for production facilities**	Inretningsforskriften (The Facilities Regulations) after 2013-01-01	Inretningsforskriften: Should be constructed so that chemical- and energy-use is reduced and the external environment is contaminated as little as possible. A facility to clean produced water shall be developed so the oil content in each discharge is as low as possible (Aktivitetsforskriften §60). The discharge point should be located where the least harm is done to the marine environment. In Guidelines: States to use the Code for the construction and equipment of mobile offshore drilling units (2009 MODU Code), Lots of different NORSOK and ISO but not any regarding environment.	Inretningsforskriften (The Facilities Regulations) after 2013-01-01: http://www.ptil.no/getfile.php/Regelverket/Innretningsforskriften_n.pdf PTIL: http://www.ptil.no/facilities/category400.html?lang=en_US Guidelines: http://www.ptil.no/innretningsforskriften/category385.html http://www.ptil.no/acts/category214.html?lang=en_US
	Regulations relating to Heath, Safety and the Environment in the Petroleum Activities and at certain onshore facilities. (General + Guidelines) Rammeforskriften (The Framework Regulations) also called "Framework HSE"	Rammeforskriften (The Framework Regulations)	Rammeforskriften: -Regulations regarding Petroleum activities and other activities onshore. Kapittel VI, VII, VIII is only for Petroleum activities offshore. These regulations are not for Svalbard. -Section 17: "Duty to establish, follow up and futher develop a management system which applies to: Working Environemntal Act, Pollution Control Act, Petroleum Act, Product Control Act, Fire and Explosion Protection Act. See more info at supplementary Management Regulations. For mobile facilities (floating) in offshore petroleum activities, the IMO resolution A.741 International Safety Management Code (ISM Code) can be used as a basis for the management system which applies to m,aritime operating conditions." -Section 24: "Use of recognised standards: If using recommended standards in the Guidelines (regarding HSE), then it can be assumed that regulatory requirements are fulfilled. Combinations of parts of standards shall be avoided." -Section 3: "Application of maritime regulations in the offhsore petroleum activities - Offshore floating facilities: Should follow Norwegian Maritime Directorate's regulations for mobile facilities (the Red Book), with suplement classification rules provided by DNV or International flag state rules."	PTIL: http://www.ptil.no/rammeforskriften/category386.html http://www.ptil.no/getfile.php/Regelverket/Rammeforskriften_n.pdf Lovdata: http://www.lovdata.no/cgi-wift/ldles?doc=/sf/sf/sf-20100212-0158.html Interpretations: http://www.ptil.no/rammeforskriften/category391.html http://www.ptil.no/rammeforskriften/til-3-anvendelse-av-forskrifter-om-helse-miljoe-og-sikkerhet-hms-regelverket-paa-flyttbare-innretninger-bruk-av-maritimt-regelverk-normer-article3981-391.html HSE: http://www.ptil.no/framework-hse/category403.html Guidelines: http://www.ptil.no/framework-hse/category408.html General: http://www.ptil.no/framework-hse/category408.html Management Regulations: http://www.ptil.no/framework-hse/category408.html#_Toc280608959 Eni Norge: http://www.eninorge.com/en/Field-development/Goliat/Development-solution/ Guidelines: -Should use standards: NORSOK and API, CEN, CENELEC, ISO, IEC is normative. Mention NORSOK R-003N

Existing Regulation in Norway
Focus on Offshore Petroleum Production regarding Environmental aspects

Theme	Area	Regulation source	Content	Sites/Sources
Oil & Gas Activities	Regulations regarding mangement of Norwegian petroleum resources	Petroleumsloven (Petroleum Act) Oljedirektoratet (Norwegian Petroleum Directorate)	Petroleumsloven: -Chapter 7 - Laibility for Pollution damage: General information about Petroleum activity in Norway and about Pollution (air and sea). -Chapter 3: Production licence etc - Section 3-1: Opening of new areas: An evaluation needs to be made, prior to opening new areas and its production, where an assessment regarding the impact of the petroleum activities on trade, industry and the environment. Also if possible risks of pollution, economical and social effects resulting from petroleum activities.	NPD: http://www.npd.no/en/Regulations/Acts/Petroleum-activities-act/ http://www.npd.no/en/Regulations/Acts/Petroleum-activities-act/#Section 1-5
	Energy effieciency	Rammeforeskriften (The Framework Regulations)/ Also called "Framwork HSE"	The most energy efficient use as possible (HSM-foreskrifterna). As much as possible utilization of excess energy as internal re-use.	
	Management Regulations for Petroleum activities	Styringsforskriften (The Management Regulations)	Management and the duty to provide information in the petroleum activities and at certain onshore land facilities	Styringsforskriften: http://www.ptil.no/styringsforskriften/category382.html?lang=no_NO
	Technical and Operational issues for Petroleum activities	Teknisk og Operasjonell forskrift (Technical and Operational Regulations), after 2013-01-01	Relating to technical and operational matters at onshore applications	Teknisk og operasjonell forskrift: http://www.ptil.no/getfile.php/Regelverket/Teknisk_og_operasjonell_forskrift_n.pdf http://www.ptil.no/regulations/category216.html
	Management and provide information for the petroleum activities	Styringsforeskriften (The Management Regulations) after 2013-01-01	Styriingforeskriften - Guidelines: NORSOK Z-003, N-003, S-002N, Z-001, D-010, N-006, can be used. ISO: NS-EN ISO 17776:2002 Petroleum and natural gas industries – Offshore production installations – Guidelines on tools and techniques for hazard identification and risk assessment, NS-ISO 31000:2009 Risk management - Principles and guidelines. Norsk olje og gass 070 - Norsk olje og gass' Guidelines for the application of IEC 61508 and IEC 61511 in the Norwegian petroleum industry, revision no. 02, 29 October 2004.	PTIL: http://www.ptil.no/getfile.php/Regelverket/Styringsforskriften_n.pdf Guidelines: http://www.ptil.no/styringsforskriften/category387.html
Other Relevant Acts	Management and governance on Svalbard	Svalbardloven (Svalbard Act)		JD (Justis- og beredskapsdepartementet)
	General regulation regarding fire and explosion	Brann- og eksplosjonsvernloven (Fire and Explosion Protection Act)	In Chapter 4: regarding industry/company duties.	http://www.lovdata.no/all/hl-19250717-011.html
Environment in General	Regulation regarding informaion to public	Miljøinformasjonsloven (Environmental Information Act)	-Environmental law gives all citizents the right to get information from both public authorities and provate companies on matters which affect the environment.	http://www.klif.no/artikkel____31248.aspx http://www.regjeringen.no/en/doc/laws/Acts/environmental-information-act.html?id=173247

Appendix II. Existing Standards and Guidelines

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
ISO	ISO 14001	Environmental Management systems	ISO 14001 specifies requirements for an environmental management system to enable an organization to develop and implement a policy and objectives which take into account legal requirements and other requirements to which the organization subscribes, and information about significant environmental aspects. It applies to those environmental aspects that the organization identifies as those which it can control and those which it can influence. Notes Barents 2020: Nominated by RN07	Barents 2020 report no 3 2010 page 115 (http://www.dnv.com/binaries/barents_2020_report_%20phase_3_tcm4-519577.pdf) Responsible: ISO/TC207/SC1
	ISO 10418	Petroleum and natrual gas industries - Offshore production installations - Analysis, design, installation and testing of Basic surface process safety systems	ISO 10418:2003 provides objectives, functional requirements and guidelines for techniques for the analysis, design and testing of surface process safety systems for offshore installations for the recovery of hydrocarbon resources. The basic concepts associated with the analysis and design of a process safety system for an offshore oil and gas production facility are described, together with examples of the application to typical (simple) process components. These examples are contained in the annexes of ISO 10418:2003. ISO 10418:2003 is applicable to fixed offshore structures, floating production, storage and off-take systems for the petroleum and natural gas industries. ISO 10418:2003 is not applicable to mobile offshore units and subsea installations, although many of the principles contained in it may be used as guidance. Notes: Nominated by RN03 On TC23 GOST-ISO development program.	Barents 2020 report no 3 2010, http://www.dnv.com/binaries/barents_2020_report_%20phase_3_tcm4-519577.pdf ISO: http://www.iso.org/iso/catalogue_detail.htm?csnumber=38067
	ISO 10436 and 10437	Petroleum, petrochemical and natural gas industries - Steam turbines - Special-purpose applications	ISO 10437:2003 specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing and preparation for shipment of special-purpose steam turbines. It also covers the related lube-oil systems, instrumentation, control systems and auxiliary equipment. It is not applicable to general purpose steam turbines, which are covered in ISO 10436.	Barents report 2020 no 3 2010, p 121. Responsible: ISO/TC67/SC6
	ISO 10439	Petroleum, chemical and gas service industries - Centrifugal compressors	ISO 10439 specifies requirements and gives recommendations for the design, materials, fabrication, inspection, testing and preparation for shipment of centrifugal compressors for use in the petroleum, chemical and gas service industries. It is not applicable to machines that develop less than 35 kPa above atmospheric pressure, nor is it applicable to packaged, integrally geared centrifugal air compressors, which are covered in ISO 10442. Also check ISO 10440 and 10442 for other compressor standards. Also 13631, 13707.	Barents 2020 report no 3 2010, page 122 Responsible: ISO/TC118/SC1
	ISO 13628	Design and operation of subsea production systems - Part 1: General requirements and recommendations	ISO 13628-1:2005 provides general requirements and overall recommendations for development of complete subsea production systems, from the design phase to decommissioning and abandonment. ISO 13628- 1:2005 is intended as an umbrella document to govern other parts of ISO 13628 dealing with more detailed requirements for the subsystems which typically form part of a subsea production system. The complete subsea production system comprises several subsystems necessary to produce hydrocarbons from one or more subsea wells and transfer them to a given processing facility located offshore (fixed, floating or subsea) or onshore, or to inject water/gas through subsea wells. Notes Barents 2020: On TC23 GOST-ISO development program. Also see also ISO 13628-4,5,6,7,8,9,10,11,15.	Barents 2020 report no 3 2010, page 131-132

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
ISO	ISO 14040	Environmental management - Life cycle assessment - Principles and framework	Principles and framework. Might be applicable to petroleum sector.	Barents 2020 report no 3 2010, page 120 Responsible: SO/TC207/SC5 http://www.iso.org/iso/catalogue_detail.htm?csnumber=37456
	ISO 15138	Petroleum and natural gas industries - Offshore production - Heating, ventilation and air-conditioning	ISO 15138:2007 specifies requirements and provides guidance for design, testing, installation and commissioning of heating, ventilation, air-conditioning and pressurization systems and equipment on all offshore production installations for the petroleum and natural gas industries that are new or existing, normally occupied by personnel, or not normally occupied by personnel; or fixed or floating but registered as an offshore production installation. For installations that can be subject to "Class" or "IMO/MODU Codes & Resolutions", the user is referred to HVAC requirements under these rules and resolutions. When these requirements are less stringent than those being considered for a fixed installation, then it is necessary that ISO 15138:2007, i.e. requirements for fixed installations, be utilized. Also check ISO 15547, 16812 for heat exchanger standards.	Barents 2020 report no 3 2010 page 123 Responsible: ISO/TC67/SC6
	ISO 15544	Offshore production installations - Requirements and guidelines for emergency response	Objectives, functional requirements and guidelines for emergency response measures on installations used in development of offshore hydrocarbon resources. Barents 2020: Nominated by RN04 On TC23 GOST-ISO development program	Barents 2020 report no 3 2010, page 118 Responsible: ISO/TC67/SC6
	ISO 17776	Offshore production installations - Guidelines on tools and techniques for hazard identification and risk assessment	Identification and assessment of hazards associated with offshore oil and gas exploration and production activities, including seismic and topographical surveys, drilling and well operations, field development, operations, decommissioning and disposal. Applicable to fixed offshore structures; floating production, storage and off-take systems.	Barents 2020 report no 3 2010, page 129 Responsible: ISO/TC67/SC6
	ISO 19900	Petroleum and natural gas industries - General requirements for offshore structures	Specifies general principles for the design and assessment of structures subjected to known or foreseeable types of actions. These general principles are applicable worldwide to all types of offshore structures including bottom-founded structures as well as floating structures and to all types of materials used including steel, concrete and aluminium. Applicable to the design of complete structures including substructures, topsides structures, vessel hulls, foundations and mooring systems. Notes form Barents 2020: On TC23 GOST-ISO development program.	Barents 2020 report no 3 2010, page 116 Responsible: ISO/TC67/SC7

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
ISO	ISO 19901	Specific requirements for offshore structures - Part 1 to Part 6	Part 3: Topside structures, Part 4: Geotechnical and foundation design, Part5: Weight control during engineering Part6: Marine operations. Requirements and guidance for the planning and engineering of marine operations, encompassing the design and analysis of the components, systems, equipment and procedures required to perform marine operations. . This part of ISO 19901 is applicable to marine operations for offshore structures, including steel and concrete gravity-base structures (GBS); piled steel structures and compliant towers; tension leg platforms (TLP); deep-draught floaters (DDF), including spars or deep-draught caisson vessels (DDCV); floating production semi-submersibles (FPSS); floating production, storage and offloading vessels (FPSO); other types of floating production systems (FPS); mobile offshore units (MOU). Also topsides and components of any of the above; subsea templates and similar structures; gravity, piled, drag-embedded and suction or other anchors; tendon foundations; and associated mooring systems. This document is also applicable to modifications of existing structures, e.g. installation of additional topsides modules.	Barents 2020 report no 3 2010, page 124 Responsible: ISO/TC67/SC7 ISO: http://www.iso.org/iso/home/store/catalogue_tc/catalogue_tc_browse.htm?commid=49622
	ISO 19902, 19903, 19904, 19905	Petroleum and natural gas - Offshore structures (different)	Different kinds of requirements depending on structure: Fixed steel structure, Fixed concrete structure, Monohulls, Semi-submersible, Spars, Jack-ups etc.	Barents 2020 report no 3 2010, page 126 Responsible: ISO/TC67/SC7
	ISO 19906	Arctic offshore structures	Specifies requirements and provides guidance for the design, construction, transportation, installation, and decommissioning of offshore structures, related to the activities of the petroleum and natural gas industries, in arctic and cold regions environments. Objective to ensure that arctic and cold regions offshore structures provide an appropriate level of reliability with respect to personal safety, environmental protection and asset value to the owner, to the industry and to society in general. ISO 19906 does not contain specific requirements for the operation, maintenance, service life inspection or repair of arctic offshore structures. Does not apply specifically to mobile offshore drilling units (see ISO 19905-1), the procedures relating to ice actions and ice management contained herein may be applicable to the assessment of such units. Mechanical, process and electrical equipment and any specialized process equipment associated with arctic or offshore operations are not covered except insofar as the structure needs to sustain safely the loads imposed by the installation, housing, and operation of such equipment. Notes: Nominated by RN02, RN04	EPPR report, page 19 Barents report no 3 2010, page 112 Responsible: ISO/TC67/SC7
	ISO 20815	Petroleum, petrochemical and natural gas industries - Production assurance and reliability management	ISO 20815:2008 introduces the concept of production assurance within the systems and operations associated with exploration drilling, exploitation, processing and transport of petroleum, petrochemical and natural gas resources. ISO 20815:2008 covers upstream (including subsea), midstream and downstream facilities and activities. ISO 20815:2008 provides processes and activities, requirements and guidelines for systematic management, effective planning, execution and use of production assurance and reliability technology. This is to achieve cost-effective solutions over the life cycle of an asset-development project structured around the following main elements: production-assurance management for optimum economy of the facility through all of its life-cycle phases, while also considering constraints arising from health, safety, environment, quality and human factors; planning, execution and implementation of reliability technology. Notes form Barents 2020: On TC23 GOST-ISO development program.	Barents report no 3 2010 page 124-125 Responsible: ISO/TC67

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
ISO	ISO 25457	Petroleum, petrochemical and natural gas industries - Flare details for general refinery and petrochemical service	ISO 25457:2008 specifies requirements and provides guidance for the selection, design, specification, operation and maintenance of flares and related combustion and mechanical components used in pressure relieving and vapour-depressurizing systems for petroleum, petrochemical and natural gas industries	Barents report no 3 2010 page 128
	ISO 31000	Risk management - principles and guidelines	ISO 31000:2009 provides principles and generic guidelines on risk management. Not specific to any industry or sector and can be lead throughout the life of an organization, and to a wide range of activities, including strategies and decisions, operations, processes, functions, projects, products, services and assets. Can be applied to any type of risk, whether having positive or negative consequences. The design and implementation of risk management plans and frameworks will need to take into account the varying needs of a specific organization. It provides a common approach in support of standards dealing with specific risks and/or sectors, and does not replace those standards. Notes Barents 2020: Nominated by RN03.	Barents report no 3 2010 page 129 Responsible: ISO/TMB
	ISO 31010	Risk management - risk assessment techniques (to support 31000)	Guidance on selection and application of systematic techniques for risk assessment. A generic risk management standard.	EPPR report, page 13
	ISO 3977	Gas turbines - procurement	Design and procurement of gas turbine system applications.	Barents report no 3 2010 page 121 Responsible. ISO/TC192
	ISO 50001	Energy management	Organizations to use energy more efficient through an energy management system (EnMS). ISO 50001:2011 provides a framework of requirements for organizations to: -Develop a policy for more efficient use of energy -Fix targets and objectives to meet the policy -Use data to better understand and make decisions about energy use -Measure the results -Review how well the policy works, and -Continually improve energy management.	Standard: http://www.iso.org/iso/home/standards/management-standards/iso50001.htm

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
IEC	IEC 60034	Rotating electrical machines	Applicable to all rotating electrical machines	Barents report no 3 2010 page 114
	IEC 60079	Explosive atmospheres	Specifies the general requirements for construction, testing and marking of electrical apparatus and Ex components intended for use in explosive gas atmospheres. Electrical apparatus complying with this standard is intended for use in hazardous areas in which explosive gas atmospheres, caused by mixtures of air and gases, vapours or mists, exist under normal atmospheric conditions. Notes: Nominated by RN03	Barents report no 3 2010 page 129 Responsible: IEC/TC31
	IEC 60085	Electrical insulation - Thermal evaluation and designation	IEC 60085:2007 now distinguishes between thermal classes for electrical insulation systems and electrical insulating materials. It establishes the criteria for evaluating the thermal endurance of either electrical insulating materials (EIM) or electrical insulation systems (EIS). It also establishes the procedure for assigning thermal classes. This standard is applicable where the thermal factor is the dominant ageing factor. The major technical changes with regard to the previous edition concern the fact that this edition is an amalgamation of the third edition of this standard together with IEC 62114:2001. It has the status of a horizontal standard in accordance with IEC Guide 108.	Barents report no 3 2010 page 114 Responsible: IEC/TC65
	IEC 61892	Fixed and Mobile offshore units - Electrical installations	Contains provisions for electrical installations in mobile and fixed units used in the offshore petroleum industry for drilling, production, processing and for storage purposes including pipeline, pumping or 'pigging' stations, compressor stations and exposed location single buoy moorings. It applies to all installations, whether permanent, temporary, transportable or hand-held, to AC. installations up to and including 35 000 V and DC installations up to and including 1 500 V. This standard does not apply either to fixed equipment for medical purposes or to the electrical installations of tankers.	Barents report no 3 2010 page 115 Barents 2020 2009, p96: for Arctic: needs additional low temperature consideration
	IEC 61936	Power installations exceeding 1 kV AC.	Provides, in a convenient form, common rules for the design and the erection of electrical power installations in systems with nominal voltages above 1 kV AC. and nominal frequency up to and including 60 Hz, so as to provide safety and proper functioning for the use intended. This standard applies to all high voltage installations except as stated otherwise in some cases specified in other parts of IEC 61936.	Barents report no 3 2010 page 115 Responsible: IEC/TC99

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
NORSOK	Standard E-001	Electrical system	This NORSOK standard contains provisions for electrical installations at all voltages to provide safety in the design of electrical systems, selection, and use of electrical equipment for generation, storage, distribution and utilization of electrical energy for all purposes in offshore units which are being used for the purpose of exploration or exploitation of petroleum resources. Each clause in this NORSOK standard refers to the equivalent clause in the IEC 61892, Edition 1, series of standards.	http://www.standard.no/en/Sectors/Petroleum/NORSOK-Standard-Categories/E-Electrical/E-0012/
	Standard S-001	Technical safety	This NORSOK standard describes the principles and requirements for the development of the safety design of offshore installations for production of oil and gas. Where applicable, this NORSOK standard may also be used for mobile offshore drilling units. This standard, together with ISO 13702, also defines the required standard for implementation of technologies and emergency preparedness to establish and maintain an adequate level of safety for personnel, environment and material assets. Notes: Nominated by RN03, RN04	Barents report no 3 2010 page 130 http://www.standard.no/PageFiles/1054/S-003.pdf Responsible: SN/PET
	Standard S-003	Environmental care (including BAT)	States that BAT should be used. Includes guiding principles: general, framework conditions, decision process, project phases. Emissions to Air: general, energy management, Nox, Flaring, Oil storage etc. Discharges to Sea: general, produced water etc., Waste: general etc., Annex A: BAT determining factors This NORSOK standard includes criteria and methods for establishing limitations for emissions to air, discharges to sea, for selection and handling of chemicals and for waste management. Citation: Some examples on functional requirements given by the NORSOK S-003 standard are cited below: NOX control on turbines: -New gas turbines should be of low-NOx type to achieve an emission level of 25 ppmv (dry off gas, 15 % O2) or better. Steam or water injection to achieve a similar level may be considered when this technology is proven for offshore application. -The reasons for not achieving a low NOx emission level shall be clearly documented. Flaring: -Should include, but not be limited to, consideration of the following measures: recycling of gas from high pressure relief systems during normal operation; -Recycling of low pressure relief systems during normal operation (subject to cost-benefit evaluation); -Process design that minimizes risk of tripping of compressors etc.; control and condition monitoring systems to reduce the number of trips, planning of start-up activities to reduce flaring.	Standard: http://www.standard.no/PageFiles/1054/S-003.pdf Barents 2020 report no 3 2010 page 116, http://www.standard.no/PageFiles/1054/S-003.pdf
	Standard Z-013	Risk and emergency preparedness analysis	This NORSOK standard presents requirements to planning, execution and use of risk and EPA, with an emphasis on providing insight into the process and concise definitions. This NORSOK standard is structured around the following main elements: • Establishment of risk acceptance criteria prior to execution of the risk analysis. • The relation between the risk and EPA, especially the integration of the two types of analysis into one overall analysis process. • Planning and execution of analyses. • Further requirements to use of risk and EPA for different activities and life cycle phases. • Establishment of requirements based on risk and EPA. Notes: Nominated by RN03, RN04	Barents 2020 report no 3 2010 page 130

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
EIPPCB - BAT and BREF	Reference Document on Best Available Techniques for Large Combustion Plants	Regarding Power and Heat generation offshore: Turbines, Engines, Nox reducing techniques etc. For Power installations with thermal input of 50 MW or more.	See chapter 3 for specific technologies (page 92,102,120-,134,155,160,167,170,185,194) , chapter 7 for Offshore technologies (page 494-499, 512-513, 521-522), (also potentially chapter 6: page 385-389,395, 424,432,447-488,451,460,469-472)	BREF BAT- large combustion plants 2009 , http://eippcb.jrc.es/reference/
	Reference Document on Best Available Techniques for Energy efficiency	Guidance and conclusions on techniques for energy efficiency that are considered to be compatible with BAT in a generic sense for all installations covered by the IPPC Directive.	Page 154 and forward explains some techniques to consider to achieve energy efficiency in energy-using: 3.1 Combustion: Reduction of the flue-gas temperature (p154), Installing an air or water preheater (p 155), Recuperative and regenerative burners (p 158), Reducing the mass flow of the flue-gases by reducing the excess air (p 160), Burner regulation and control (p 161) e.g. reducing NOx, Fuel choice (p 162), Oxy-firing (oxyfuel), reducing heat losses by insulation (p 164), Reducing losses through furnace openings (p 165). 3.2 Steam systems: page 170 and lots of alternatives e.g. Pre-heating water, Heat exchangers, Heat pumps (electricity -> heat, COP factor, 3.3 Heat recovery and cooling (p195), 3.4 Cogeneration (p 208), Electrical power supply (p 222), 3.6 Electric motor driven sub-systems, 3.7 Compressed air systems (p238), 3.8 Pumping systems (p 260), 3.9 Heating, ventilation and air conditioning (HVAC) (p 267), 3.10 Lighting (p 278), 3.11 Drying, separation and concentration processes (p 282)	BREF BAT Energy efficiency, http://eippcb.jrc.es/reference/
	Best Available Techniques for different areas		"In the international context, the European information exchange on best available techniques is considered to be an EU contribution to the global process initiated in 2002 at the World Summit on Sustainable Development so that non-EU countries can also reap the benefits of this ambitious work."	NORSOK S-003, BAT report etc. EIPPCB. http://eippcb.jrc.es/index.html
International Finance Corporation / World Bank Group	Large Combustion Plants	Environmental, Health and Safety Guidelines: Offshore oil and gas development	Regarding industry-specific impacts and management, Performance indicators and monitoring etc. Full report on: (http://www1.ifc.org/wps/wcm/connect/9e3b4c004e7bd26497a8bffce4951bf6/2013+Working+Doc_Offshore+Oil+and+Gas+Development.pdf?MOD=AJPERES)	Barents 2020 report no 3 2010 www.ifc.org
	Environment, Health and safety	Environmental, Health and Safety Guidelines (EHS Guidelines)	1. Environmental: Air Emissions and Ambient Air Quality, Energy Conservation, Wastewater and Ambient Water Quality, Hazardous Materials Management, Waste Management, Noise etc. IFC'c Sustainability Framework: Performance standards and guidance notes 2012: managing environmental and social risks. (http://www1.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/IFC+Sustainability/Sustainability+Framework/Sustainability+Framework+-+2012/Performance+Standards+and+Guidance+Notes+2012/)	Barents 2020 report no 3 2010, http://www1.ifc.org/wps/wcm/connect/554e8d80488658e4b76af76a6515bb18/Final%2B-%2BGeneral%2BEHS%2BGuidelines.pdf?MOD=AJPERE

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
IMO	MARPOL 73/78	Annexes with amendments.	The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years. Notes: Nominated by RN07. Annex VI: Regulations for the prevention for Air pollution from ships (+fixed and floating drilling rigs and other platforms). Regulates e.g. NOx, SOx, PMs from engines (diesel) for FPSOs and other floating structures.	Barents 2020 report no 3 2010, page 116 UK: http://www.ukooaenvironmentallegislation.co.uk/contents/topic_files/offshore/power_generation.htm
	MARPOL SEEMP (Ship Energy Efficiency Management Plan) (Regarding FPSOs)	Mandatory for all vessels after 1e Jan 2013. FPSOs certified for international trade are required to have a SEEMP, but is dependant on the flag.	The SEEMP is a part of MARPOL Annex VI (not all flags have ratified this). A general rule: If the vessel has an International Air Pollution Certificate (IAPP) it also needs an International Energy Efficiency Certificate (IEEC) which includes SEEMP. IMO - MEPC.1/683 Guidance for the Development of a SEEMP recognizes that operational efficiencies will make an invaluable contribution to reducing global carbon emissions. Its main purpose is to establish a mechanism for a company and/or a ship to improve the energy efficiency of a ship's operation that is preferably linked to a broader corporate energy management policy.	www.imo.org , The SEEMP - ship energy efficiency management plan (http://www.dnv.com/SEEMP)
	MARPOL MEPC/ Circ.406	For FPSO and FPU	See document: IMO GUIDELINES FOR APPLICATION OF MARPOL ANNEX I REQUIREMENTS TO FPSOs AND FSUs	
	Ballast water Convention	For ships	Regarding FPSOs. International Convention for the Control and Management of Ships' Ballast Water and Sediments Notes: Nominated by RN07	Barents report no 3 2010, page 116
	Ship Transport-ation Codes	If a floating offshore unit or for assistant vessels	Regarding FPSOs.	
	IMO MODU CODE	Code for the construction and equipment of mobile offshore drilling units	The code for the Construction and Equipment of Mobile Offshore Drilling Units	EPPR report, page 131 and http://www.imo.org/publications/documents/newsletters%20and%20mailers/mailers/i810e.pdf
	IMO - Guideline	Guidelines for ships operating in Arctic Ice Covered waters (MPEC/Circ.1056)	Regarding FPSOs.	Barents 2020 report no 3 2010, page 131
	IMO Polar Code	International Code of Safety for Ships in Polar Waters *(IMO doc. DE41/10)	Regarding FPSOs.	http://www.imo.org/mediacentre/hottopics/polar/Pages/default.aspx and EPPR

Existing Standards & Guidelines
Focus on Offshore Petroleum Production regarding Environmental aspects

Association	Standard/ Guideline	Description	Text	Sites/Source
DNV	DNV RP-C205	Environmental conditions and Environmental loads		Barents 2020 report no 3 2010, page 26
	DNV-OS-A101	Safety Principles and Arrangement	Provides general safety and arrangement principles for offshore units and installations. The standard is applicable to overall safety and integrity aspects of all types of floating offshore units and fixed installations	
CLASS RULES	DNV	Classification	Rules for Classification of: — Offshore Drilling and Support Units — Floating Production, Storage and Loading Units — Ships, Part 5, Chapter 1: Ships for navigation in ice	Barents 2020 report no 3 2010, page 131 etc.
	Different Classification Societies	Relevant classification rules/standards for floating offshore units	Rules and standards from class society which has recognized and relevant competence and experience with offshore petroleum activities, and has established rules, standards and procedures for classification of floating offshore units. MORE STANDARDS CAN BE ADDED IF THIS IS USED (FLOATING UNIT).	Barents 2020 report no 3 2010, Appendices Responsible: Relevant Class Society
PSA Guidelines	PSA YA-711	Principles for Alarm system design	Norwegian Petroleum Safety Authority guideline describing a set of established principles for well-functioning alarm systems. The purpose of this document is to help those involved in the design, procurement, maintenance and operation of alarm systems. It is intended to help both in improving existing systems as well as during development of new systems and modifications. This document gives guidance on alarm generation, structuring, prioritisation, presentation and alarm handling. The requirements are based on the latest international recognised requirements on alarm systems available at the time of writing, with focus on realistic solutions based on research and best practice from different process industries.	Barents 2020 report no 3 2010, page 119
IACS	IACS - Guideline	International Association of Classification Societies (IACS): Requirements concerning Polar Class	Relates to ships	Barents 2020 report no 3 2010, page 131

Used Sources:

Barents 2020 report no 3 2010, available at http://www.dnv.com/binaries/barents_2020_report_%20phase_3_tcm4-519577.pdf

EPPR RP3 Report - Recommended practices for Arctic Oil psill prevention 2012, available at http://www.arctic-council.org/eppr/wp-content/uploads/2012/08/EPPR-RP3-Best-Practices-report-v3.1-31aug121.pdf

Appendix III. Expected requirements and guidelines for Arctic areas

Expected New Requirements and Guidelines for Arctic areas
Focus on Offshore Petroleum Production regarding Environmental aspects

Area	Description	Text	Sites/Sources
Discharges to Sea	General	Requirements from Norwegian government: -Zero discharges to sea target (under normal operation and production) for Norwegian continentl shelf shall be harder practiced in the Barents and Lofoten sea -Avoid and prevent oil spill during cargo/fuel oil transfer (PAME TROOP) -EPPR Report states highest priority in offshore activities should be to prevent oil spill int he ice-infested waters (EPPR Report, Forvaltningsplan Barents & Lofoten p. 61, 126): Demand of no discharges from cuttings or produced water (zero emissions) represents a stricter requirement in relation to the requirements applied to other parts on NCS -All discharges planned in the Barents Sea needs to be permitted by Klif -Operational discharges from activities in the area shall not cause damage to the environment or contribute to increased levels of oil or other hazardous substances over time.	Konsekvensutredning Goliat (EIA) - Plan før utbyggning og drift Del 2 - 2008; http://eni.offshorefilm.com/web/GOLIAT_Konsekvensutredning.pdf PAME Guidelines for Transpfer of Refined Oil and Oil products in Arctic waters (TROOP) 2004 (EPPR Report p 23) EPPR Report page 24 and page 30 AMAP- Arctic Oil and Gas Report 2007, page 30-31 Barents 2020 report 4, Forvaltningsplan Barents and Lofoten 2010-2011
	Chemicals	-Target is to increase use of PLONOR substances and focus on Substitution and reduction of hazardous chemicals. -No discharges of hazardous substances of chemicals (discribed as regulated compound or SFT's Black and Red category) -No discharges of "more friendy" chemicals (SFT's Yellow and Green categories) which can lead to damage from other harzards. -Chemicals shall be chosen with regards to have the least possible pollution -Chemicals: Zero-discharges target applicable here for environmental hazardous chemicals and substances (labelled red and black). Substituation of chemicals (Stortingsmelding 26 (2006-2007): to reduce all red and black chemicals.	Miljøteknologi 2010 Stortingsmelding 26 (2006-2007)
	Oil concentration	-Avoid any discharges with oil content zero discharges to sea target) -Oil concentration: Expected less than regulated today (30 ppm OSPAR), Probably more towards 10 ppm (Konsekvensbeskrivning Goliat)	Konsekvensutredning (EIA) Goliat - Plan før utbyggning og drift Del 2 - 2008; http://eni.offshorefilm.com/web/GOLIAT_Konsekvensutredning.pdf
	Produced water	Zero-discharge to Sea target shall be used here, (Stortingsmelding, Forvaltningsplan) -Requirement of 95% (earlier 85%) re-injection of produced water (100% under normal operation) and possible 5% discharged of treated produced water under stops and operation disruptions. Possible use of parallell treatment technical systems and techniques for reduced produced water (Forvaltningsplan, Miljøteknologi 2002,2010). Treatment of produced water shall be as effective as possible (to seperate oil and water), several technolgies exists. This also reduced heat demand. (Konsekvensbeskrvning Goliat). -Aim is to have 100% re-injection of produced water at 95% of the time. -Produced water demand for Barents sea (From Stortingsmeldning nr 38, 2003-2004): For produced water will the general zero-emission target be applicable (for physical zero-emission). For activities in Barents sea and Lofoten is further demand: for the activities will injection or potential other technolgy which hinder discharges of produced water be added. Maximun 5% of the produced water can be discharged under un-normal circomstances (stops). More exact treatment demands will be stated by the Konsesjonsmyndighetene for a certain activity.	Konsekvensutredning Goliat - Plan før utbyggning og drift Del 2-2008; http://eni.offshorefilm.com/web/GOLIAT_Konsekvensutredning.pdf Miljøteknologi Barents and Lofoten; http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011/10.html?id=637992 http://www.regjeringen.no/upload/kilde/oed/rap/2003/0004/ddd/pdfv/186155-miljoteknologi2.pdf AMAP- Arctic Oil and Gas Report 2007, page 30-31 Stortingsmeldning - Forvaltningsplan Barents and Lofoten 2010-2011

Expected New Requirements and Guidelines for Arctic areas
Focus on Offshore Petroleum Production regarding Environmental aspects

Area	Description	Text	Sites/Sources
Emissions to Air	**General**	Aim to minimize emissions to air and include seasonal and ice conditions to ensure "no significant change" in colour and chemical composition of ice cover. (Barents 2020 report 4) Norweigan Gov. has the following general objectives as basis for efforts to prevent and limit pollution of Barents Sea-Lofoten: Emissions and dishcarges of pollutants into that area shall not cause injury or damage to nature's capacity for self-renewal. Activites in Barents sea-Lofoten area will not contribute to elevated levels of pollutants, (Oppdaterad Forvaltningsplan Barents & Lofoten 2010-2011, p 125).	Barents 2020 report 4: Assessment of international standrads for safe exploration, production and transportation of oil and gas in the Barents sea Oppdatering Forvaltningsplan Barents & Lofoten, 2010-2011, http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-20102011.html?id=682050
	CO2	Target for emission reduction of CO2 for Barents and Lofoten: 20% reduction. (Miljøteknologi 2002) Future: CO2- capture and storage (EU directive on CCS-geological storage of CO2, 2009)	Miljøteknologi Barents and Lofoten; http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011/10.html?id=637992 http://www.regjeringen.no/upload/kilde/oed/rap/2003/0004/ddd/pdfv/186155-miljoteknologi2.pdf
	Nox	Target for emission reduction of Nox for Barents and Lofoten: 85% reduction when full load (Miljøteknologi 2002) NORSOK S-003: Some examples on functional requirements given by the NORSOK S-003 standard are cited below: NOX control on turbines: –"New gas turbines should be of low-NOx type to achieve an emission level of 25 ppmv (dry offgas, 15 % O2) or better. Steam or water injection to achieve a similar level may be considered when this technology is proven for offshore application. –The reasons for not achieving a low NOx emission level shall be clearly documented." Nox can be reduced by Low Nox technolgies: Low Nox Single or Dual fuel, SCR, Energy efficiency, Energy management.	-Miljøteknologi Barents and Lofoten; http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011/10.html?id=637992 http://www.regjeringen.no/upload/kilde/oed/rap/2003/0004/ddd/pdfv/186155-miljoteknologi2.pdf
	Others (SO2, VOC etc)	-Target for emission reduction of VOC for Barents and Lofoten: 95% reduction if evaporation goes through recycling technology. (Miljøteknologi 2002)	-Miljøteknologi Barents and Lofoten; http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011/10.html?id=637992 http://www.regjeringen.no/upload/kilde/oed/rap/2003/0004/ddd/pdfv/186155-miljoteknologi2.pdf
	Black carbon/PM	Black carbon (BC) can lead to impacts like radioactive forcing, albedo impacts, cloud impacts whcih can lead to a climate response in Increase temperature. BC has a strong absorption of solar radiation, insolubility in water, stable at high emperatures (unique). BC is a product from combustion of hydrocarbon-based fuel when not enough oxygen is present for complete conversion. BC in Arctic: BC can undergo transformation as they are trasported to Arctic areas, (AMSA 89439)	-AMSA Report 89439- Black carbon: http://amap.no/ http://www.imo.org/ourwork/environment/pollutionprevention/airpollution/documents/air%20pollution/report%20imo%20black%20carbon%20final%20report%2020%20november%202012.pdf

Expected New Requirements and Guidelines for Arctic areas
Focus on Offshore Petroleum Production regarding Environmental aspects

Area	Description	Text	Sites/Sources
Emissions to Air	**Flaring system**	HP and LP gas flare shall be recirculted, no continueling pilot flame but an automatic ignition system for critical situations which demands high safety preparedness. Considering alternatives which creates as low as possible concentrations of PAH and soot. (Konsekvensbeskrivning Goliat) Minimize flaring accoring to BAT. Flaring in Arctic can be an unwanted soource of soot pollution and GHG emissions.(Barents 2020 report 4) NORSOK S-003: Flaring: Should include, but not be limited to, consideration of the following measures: -recycling of gas from high pressure relief systems during normal operation; -recycling of low pressure relief systems during normal operation (subject to cost-benefit evaluation); -process design that minimizes risk of tripping of compressors etc.; -control and condition monitoring systems to reduce the number of trips; -planning of start-up activities to reduce flaring." (barents 2020 report 3) Minimize flaring by: Recycle gas (HP and LP), Design and control of unplanned shut-downs, Planning start-ups.	Konsekvensutredning Goliat - Plan før utbyggning og drift Del 2-2008; http://eni.offshorefilm.com/web/GOLIAT_Konsekvensutredning.pdf NORSOK S-003 Barents 2020 report 4 Barents 2020 report 3
	Energy efficiency	Increased Energy efficiency will reduce GHG and other emissions to air Increase Energy efficiency by: Energy management, Design power and heat production by analysing lifetime demand of platform to reduce the demand, inrease efficiency, potential use of Renewables (Barents 2020 report 4)	-Barents 2020 report 4: Assessment of international standrads for safe exploration, production adn transportation of oil and gas in the Barents sea
	Power generation	Consider Electrification from shore (Norwegian government, Forvaltningsplan, Miljøteknologi) AMAP states that it is important to assess Electrification from shore. (AMAP Report) Power generation: To chose smaller and higher amount of gas turbines (instead of larger) creates a higher efficiency during all stages of the production. (PAME- Guidelines, page 41) Design the energy production (eg gas turbine configuration, shared energy, power from shore) (Barents 2020 report 4) BAT shall be used when selecting Gas turbines, engines, boilers (Barents 2020-report 4, IPPC) In Barents Sea will probably natural gas be available as a fuel source for the production phase. Gas turbines are in general chosen for energy and heat production and are also the main contributor to emissions fo CO_2, NO_x and SO_2 etc. (Barents 2020 -report 4) If Gas turbines are considered: Guidelines (from IFC guidelines for ambient air quality and for thermal power production) if Larger than 15 MWh: NO_x-levels should be lower than 25 ppm and recommendations for smaller and increase quantity turbines for higher effieciency.	Konsekvensutredning Goliat - Plan før utbyggning og drift Del 2-2008; http://eni.offshorefilm.com/web/GOLIAT_Konsekvensutredning.pdf Utbyggning og drift av Goliatfeltet - Konklusjoner og villkor, Regjeringen 2008-2009; http://www.regjeringen.no/nb/dep/oed/dok/regpubl/stprp/2008-2009/stprp-nr-64-2008-2009-/5.html?id=560094 AMAP- Arctic Oil and Gas Report 2007, page 30-31 Barents 2020 report 4: Assessment of international standrads for safe exploration, production adn transportation of oil and gas in the Barents sea Arctic Council - PAME- Arctic offshore oil and gas guideliens
	Heat generation	Use waste heat (Barents 2020 report 4), WHRU mostly common and is better environemtally than boilers or heaters. (Barents 2020 -report 4) Can be hard to combine with Electrification from shore Low temperatures can cause an additional need for heating and mechanical ventilation. This issue can be relevant to safety barriers and critical for certain functions.	Barents 2020 report 4: Assessment of international standrads for safe exploration, production adn transportation of oil and gas in the Barents sea Barents 2020 report 3: Assessment of international standards for safe exploration, production and transportation of oil and gas in the Barents Sea

Expected New Requirements and Guidelines for Arctic areas
Focus on Offshore Petroleum Production regarding Environmental aspects

Area	Description	Text	Sites/Sources
Ecosystem		Oppdatering Forvaltningsplan Barents & Lofoten 2010-2011 p 124: Petroleum activities shall not damage the fragile flora and fauna. There is requirement that areas that may be affected will be surveyed prior to any activites. The Norwegian Gov has the following general objectives as basis for biodiversity in Barents-Lofoten area: Barents Sea -Lofoten area should be managed so that the diversity of ecosystems, habitats, species and genes are conserved and ecosystem productivity is maintained. Human activity in the area shall not hurt ecosystem function, structure, productivity and dynamism.	Stortingsmeldning - Forvaltningsplan Barents and Lofoten 2010-2011 Miljøteknologi TEKNA fra DNV: http://www.tekna.no/ikbViewer/Content/776315/milj%F8teknologi%20tekna%20fra%20DNV.pdf
BAT	**Use of BAT in Arctic**	BAT is mentioned in eg Forurensingsloven and shall be used for the whole Norwegian Continental shelf. Aim is to encourage the highest standrads available by BAT and BEP. 9 guidelines with goal to assisst regulators to develop standards and to encourage highest standrads currently available by defining recommended practices in Arctic offshore oil and gas production. (PAME- Guidelines) EPPR Report states that significant impacts from oil and gas activities in the Arctic can be prevented to a large extent by using BAT.	Arctic Council - PAME: Arctic Offshore Oil and Gas Guidelines EPPR Report-Recommended practices for Arctic Oil spill prevention, 2012, page 30
Applicable Standards	**Possible updates and recommendations for existing Standards to Arctic environment**	Barents 2020 Report 3 and 4: ISO 19906:2010 Petroelum and natural gas industries - Arcitic offshore structure: Should be adopted as a common standard in Arctic,gives an overarching design principles for winterization of topsides and drilling systems, but need some adjustments regarding adding: Add some definitions (eg for floating structures, term ice event). Add some requirements and guidelines for ice management, clauses which can be more relevant for Floating structures. Recommended Key HSE Standards: NORSOK S-003 - Environmental Care (2005): BAT to be used in design and engineering phases. Aspects covered here: Emissions to air; energy management, NOx control, flaring, emission control and motitoring, Discharges to sea; produced water, drain system, chemicals, cooling water, waste managment, decommissioning, drill cuttings etc. ISO 13702 - Control and mitigation of fires and explosions on offshore production installations, ISO 10418 - Basic surface safety systems, ISO 17776 - Offshore production installations - Guidelines and techniques for hazard identification and risk assessment: The standard is generic and can be used for the Barents Sea, but in the project documents the environmental conditions need to be stated, NORSOK Z-013 (risk and emergency preparedness analysis): Can be used in Barents Sea, but in the project documents the environmental conditions need to be stated. ISO 13702 (Control and mitigation of fires and explosions on offshore production installations) updated to cold climate, ISO 10418(Offshore production installations – Basic surface process safety systems), IEC 61508, IEC 61511, ISO 15138 (offshore production installatiosn - heating, ventilation and air conditioning), IEC 60079, IEC 61892-7, NORSOK S-001 (technical safety), NORSOK D-010 (well integrity in drilling and well operations). In general it can be said that the standards that give general principles of design and basic functional requirements (ISO 3100, ISO 19906, ISO 13702, ISO 17776, IEC 61508, IEC 615011, NORSOK S-001, NORSOK Z-013, NORSOK D-010) can be used as they are, but that the informative parts of the standard needs to be updated to give sufficient guidance on design and risk assessment for the Barents Sea but should be updated to refer to each other, especially from ISO 19906. Standards which need to be updated with more specific requirements a to reflect Barnets sea conditions are IEC 60079, 80079, 61892-7. (Barents 2020 report 3)	Barents 2020 report 3: Assessment of international standards for safe exploration, production and transportation of oil and gas in the Barents Sea Barents 2020 report 4: Assessment of international standards for safe exploration, production and transportation of oil and gas in the Barents Sea

Expected New Requirements and Guidelines for Arctic areas
Focus on Offshore Petroleum Production regarding Environmental aspects

Area	Description	Text	Sites/Sources
EU	**Offshore platform safety group**	For furutre: European union offshore oil and gas authority's group ?	Email contact with Pascal Barthe, European IPPC Bureau Document: Official journal of the European Union,Commission decsion, 19 January 2012 on setting up of the European Inion Offshore Oil and Gas Authorities Group (2012/C 18/07), http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2012:018:0008:0010:EN:PDF

Sources:

Barents 2020 report 4: Assessment of international standrads for safe exploration, production adn transportation of oil and gas in the Barents sea, avaliable at http://issuu.com/dnv.com/docs/barents_2020_report_phase_4?mode=embed&layout=http%3A%2F%2Fskin.issuu.com%2Fv%2Flight%2Flayout.xml&showFlipBtn=true&proShowMenu=true

Barents 2020 report no 3 2010, available at http://www.dnv.com/binaries/barents_2020_report_%20phase_3_tcm4-519577.pdf

EPPR RP3 Report - Recommended practices for Arctic Oil psill prevention 2012, available at http://www.arctic-council.org/eppr/wp-content/uploads/2012/08/EPPR-RP3-Best-Practices-report-v3.1-31aug121.pdf

Arctic portal, available at http://library.arcticportal.org/

Appendix IV. BAT for Power and Heat generation

BAT for Power and Heat Generation

BAT Assessment - Power & Heat Generation		
	Regulations	**Guidelines & Standards**
Require-ments	In Norway: IPPC-directive for BAT shall be used. Emission targets: Zero-target for discharges to Sea, decrease emissions to air. Minimize emissions of CO_2 and Nox. Discharge permit based on BAT CO_2-tax: 410 NOK/tonne CO_2 (from 2013) NOx-fee: 17,01 NOK/kg NOx (from 2013)	**BAT EU**-directive guidelines regarding Large combustion plants, BREF LCP. **IMO - MARPOL 73/78**: Regulation 13 to Annex VI is about emissions of NOx from diesel Engines. **NORSOK S-003:** Minimize emissions of CO_2 and NOx, New gas turbines should be of low- NOx type (25 ppmv NOx),Efficient energy generation. Possible use: Gas turbine cycle enhancement, Integrated or shared power, generation with other installation, Optimum size, number and type of turbines according to demand profile, Power from shore.
Technology Screening Results	Technical screening: different technologies for heat and power generation will be considered, but they should all be existing technologies. Information form different suppliers might be different, but will not be further discussed since this is on a conceptual level. Divided into following subsystems: Power generation, Heat generation, NOx-reduction techniques. Sources: BAT BREF - Large combustion plants 2006, SINTEF report A4531, Suppliers lists: http://www.offshore-technology.com/	

BAT- Assessment

	Alternative	Description	Environmental Performance/Stressors: CO2	CO	SOx	NOx	Energy use (fuel)	Energy efficiency (thermal)	Technical Constraints	Economical Availability (cost, fuel cost, taxes etc.)	Additional information
Technique - Power generation	Base level: Gas turbine: Conventional Cycle ("simple cycle")	Input: Gas from e.g. the platform's own gas production Output: Electricity	Base level	Base level (about 35 ppmv under simplified,normal conditions	Base level Not generally a concern (BREF p 460)	Base level Nox: 25 ppmv (under simplified and normal conditions, DNV BAT example)	Base level Natural gas	Base level up to 35-37 % (depending on load)	Energy efficiency depending on the load and turbine configuration. Generally: Dual-fuel (gas + diesel) in Norway Common in Norway: 2-3 turbines per platform	Economical Available	Suppliers: Titan (n=35%), Rolls-Royce, Siemens, Alstom, ABB, Ansaldo Smaller (12-15 MW): Solar, Siemens Larger (20-30 MW): GM LM2500, Rolls Royce RB211 See more suppliers at: http://www.offshore-technology.com/contractors/power/ Sources: DNV - Mini-workshop, Interview Tore Utengen DNV
	Gas turbine: Combined Gas Cycle (CC, CHP) (including HRSG)	Combination of a gas turbine process and a steam turbine process. Can cover heat demands and have an efficiency up to 47-80%. No heat production, uses excess heat for electricity production. Generally: Dual-fuel in Norway	Lower (reduced by 20-30 %, SINTEF)	Lower (about 25 ppmv under simplified and normal conditions, DNV BAT report example)	NA Not generally a concern (BREF p 460)	Lower (reduced by 20-30 %, SINTEF)	Lower Natural gas and Steam	Higher efficiency: up to about 50%	From DNV: Takes more space(25-50% extra), has more weight (almost 50% more), and is more complex (inc. maintenance) CC and CHP plants are flexible, CHP efficiency from 47-80% due to heat demand, CHP can be maximized regardless of load level or heat demand, BREF p 459. CC and CHP can be placed on top of gas turbines and solve space problem. CC involves ultra-pure water in closed circuit. Requires seawater for cooling at about 2000 m3/h. From Article (Steam bottoming cycles offshore): Challenges are space and weight (can be made more compact), harsh external conditions offshore (other building-material selection), need of fresh water for steam cycle.	Seawater system might be integrated with other seawater systems and decrease investment cost.	**Available, Possible BAT** (SINTEF report A4531 p 48-49) Examples of installations: Snorre B, Oseberg, Eldfisk (but operational and maintenance problems..?) Supplier: ABB Sources: Mini-workshop, BAT BREF ex on p 459, Steam bottoming cycles offshore-challenges and possibilities http://www.offshore-mag.com/articles/print/volume-60/issue-4/technology/combined-cycle-plant-to-power-snorre-production-platforms.html http://eccc.uno.edu/pdf/Hill-Inozu-Wang-Bergeron-OTC-14289.pdf SINTEF: http://www.sintef.no/Teknologi-og-samfunn/Sikkerhet/Rapporter--Reports/Bruk-av-BAT-Beste-Tilgjengelige-Teknikker--prinsippet-for-miljosikkerhet/
	Electrification - Power from shore (PFS)	Electrification by cables (DC or AC) from shore. Here assume for Norwegian conditions, i.e. Hydropower.	Lower (depending of primary energy source, Norway: 98% hydro)	Lower	Lower	Lower	Not applicable Mixture of electricity production sources	Probably higher, depending on source	Additional material as cables and the installation on seabed (possible environmental impacts), DC to AC converter (heavy and large). Reduced emissions, better safety, increased energy efficiency, higher uptime (ABB). Reduced risk of diesel and gas leakage on platform, reduced CO2 and NOx, CO2-emissions by use of gas-fired boilers (back-up), only potential emission reductions (SINTEF).	Lower maintenance costs. Higher investment costs. Lower operations and modification costs, more gas for sale (when also gas prod.) (ABB)	**Available, Possible BAT** (SINTEF A4531 report p 48-49) Power from shore increases the overall demand for electricity, marginal/average emission accounting. Tested on: Troll A (DC), Valhall (DC), Gjøa (AC), Goliat, partly (AC) Suppliers: ABB, http://www02.abb.com/global/abbzh/abbzh250.nsf/0/ac9261708c75466cc1257a20004c71d3/$file/Electrification+-+H%C3%A5vard+Devold.pdf Sources: SINTEF A3158 report,http://www.worldenergy.org/documents/congresspapers/53.pdf

BAT- Assessment											
	Alternative	Description	Environmental Performance/Stressors						Technical Constraints	Economical Availability (cost, fuel cost, taxes etc.)	Additional information
			CO2	CO	SOx	NOx	Energy use (fuel)	Energy efficiency (thermal)			
Technique - Power generation	Centralized power generation (combined gas turbines)	A hub platform supplying power to several nearby platforms by underwater cable.	Lower	Lower	Lower	Lower	Lower Natural gas and Steam Since reduced power consumption (better use)	Higher overall energy efficiency	Depends very much on specific location of platform and field, needs to be geographical close. Transmission loss should be taken into account when calculating environ benefits, mostly marginal. Emission reduction can be more significant if power generation is based on combined cycle and/or low Nox turbines, BREF p455. Existing retrofitting installations are under evaluation (unlikely to be cost-effective), BREF p 455. Cost saving have been reported.	Major capital investment, so only suitable in specific situations: newly manned or unmanned platforms.	**Available, Possibel BAT**, demands geographical closeness (SINTEF A4531 report p 48-49). Examples: Marathon Brae offshore platform and East Brae. Sources: BAT BREF p 455, SINTEF report A4531, OPERA concept: http://www.dnv.com/resources/publications/dnv_forum/2012/forum_03_2012/opera_an_innovative_concept_for_efficient_offshore_power_generation.asp http://www.hse.gov.uk/research/rrhtm/rr430.htm
	Engines (Diesel and/or Gas)	Engines running on different fuels Power from 0,8 -16 MW / engine	Higher with diesel Lower/Same with gas (increase efficiency)	Higher with diesel Lower with gas	Higher (SO2 from engines about 72% of total SO2-emissions from offshore)	Higher with diesel	Either combination: Diesel, Gas, Dual fuel (diesel and gas), Multi fuel (diesel, gas, oil etc.)	Different Dual fuel: High, about 49% thermal fro dual fuel (Wärtsilä) Diesel: Up to 40% (thermal)	Possible with Dual fuel or Multi-fuel (gas, diesel or oil) see link. Weight: Heavy (almost x2 as turbines). Combined with steam and heat cycle for electricity production up to 70% efficiency (Brazil, Petrobras, Wärtsilä). Sometimes Diesel engines are used for backup system/emergency generators for utilities and planned maintenance stops, continously tested in intervals.	Cost for fuel (diesel)	Suppliers: Wärtsilä Sources: http://www.tu.no/industri/2013/01/11/vil-erstatte-turbiner-med-gassmotorer http://www.wartsila.com/en/references/Petrojarl-I Mini-workshop,SINTEF report A4531, Multi-fuel: http://www.offshore-technology.com/contractors/power/pgs-power-generation-solutions/
Technique - Heat generation	Base level: Waste heat recovery unit system (WHRU) (heating medium system)	In combination with Gas turbines, Electrification(onshore) /Gas turbine back-up Re-using the excess heat produced, through a heating medium transferred to heat users.	Base level	Base level	Base level	Base level	Base level	Base level Gas turbines combination: up to 90% overall efficiency (energy equivalents)	Often lots of waste heat on-board, good for overall energy efficiency to use WHRU, when large heat demand. Usually heat exchanger with Exhaust (about 500 degree C) to water system. Combined with Gas turbines, but also possible with Diesel engines: but less and colder exhaust to use (low temp 70-90 degree C). Demands more tubing, possible thermal losses.	Economical Available	**Available. Considered BAT,** if large heat demand. Examples: Goliat and many more... Sources: DNV internal, (ref. Article C105 Total combined cycle study, page 5) Klif: Statoil application: www.klif.no/nyheter/arkiv/statoil_29.doc Interview Tore Utengen
	Electricity	Heat from produced electricity on platform or other source.	Similar or lower depending on source	Similar or lower depending on source	Similar or lower depending on source	Similar or lower depending on source	NA	Possible lower, total system efficiency.	E.g. from electrification from shore, nuclear reactors offshore etc. Energy efficiency: Depend on electricity source (gas turbines n=app 27%, DNV).	Economical Available	
	Boiler/Burner with oil/gas		Higher?	Higher?	Higher?	Higher?	Higher?	Same, Thermal efficiency = up to 90% (DNV)	Increased accidental risks. Large emissions	Economical Available	BAT BREF page 385 DNV

BAT- Assessment

	Alternative	Description	Environmental Performance/Stressors: CO2	CO	SOx	NOx	Energy use (fuel)	Energy efficiency (thermal)	Technical Constraints	Economical Availability (cost, fuel cost, taxes etc.)	Additional information
Technique - NOx reduction (Mainly for Gas turbine)	Base level: No NOx reduction measures	Probably not likely due to other issues	Base level	Base level	Base level	Base level 100-180 ppmv NOx (at 15% O2)	Base level	Base level	No measures to reduce the NOx.	Have to pay NOx-fee.	
	Direct steam injection	Steam injection lowers the temperature -> lower Nox creation	Lower Reduced CO2 by 3-10% (SINTEF)	NA	NA	Lower Reduction by 50-90% (SINTEF)	NA	NA	Offshore issues with weight, space, complexity. Water and steam injections are available for a range of gas turbines. Requires modifying the fuel jets or separate water injection manifold. Water must be of at least 'high pressure boiler feed-water' quality, which are not usually available offshore. There is a modest increase in power output but a slight decrease in the turbine efficiency.	NA	NOT considered BAT according to BREF p 483 Available on onshore facilities, need to be qualified for offshore (SINTEF) Sources: SINTEF report p49 Possible more info at: Nox-master thesis
	Direct water-injection	Water injection lowers the temperature -> lower Nox creation	NA no significant impact	NA	NA No significant impact	Lower Reduction by 50-90% (SINTEF) < 25 ppmv	NA	NA	Offshore issues with weight, space, complexity. Conventional steam injection in gas fired turbines, where 40 to 60 % NOX emission reduction can be achieved with no significant increase in CO emission. Need water processing.	NA	NOT considered BAT according to BREF p 483 Available on onshore facilities, need to be qualified for offshore (SINTEF) Sources: SINTEF report p49 Possible more info at: Nox-master thesis
	Dry Low NOx combustion chamber (DLN)	Mixing of air and fuel before combustion which leads to a homogeneous temperature distribution and a lower flame temperature -> lower Nox emissions.	Possible higher If part-load, decrease in thermal efficiency, higher CO2 emissions	NA	NA No significant impact	Lower Reduction by 50-85% from base level. < 25 ppmv (15% O2)	NA	Possible lower. Part-load: possible decrease in thermal efficiency(loss up to 13% -> increase CO2 up to 13%)	Often large gas turbines (over 20MWe), used offshore, well established for gas turbines using natural gas, effective and reliable (BREF p363-364). Possible for both new and retrofitting turbines. Marginal environmental benefits for part-load operations with varying load, leads to frequent turbine trips and consequent flaring. No NOx reduction during start-up and part load operations and unplanned stops, due to low rates.	Economical Available	**Available, considered BAT** (SINTEF report p 48-49) Considered BAT according to BREF p 483 Suppliers: Siemens Sources: BREF p 463-464 (456-457)
	Selective catalytic reduction (SCR)		Possible higher CO2 emissions (SINTEF)	NA	NA	Lower, reduction by 80-90% from base level	NA	NA	Cross media effects: Ammonia emissions! Needs more space and higher weight. Health and safety issues by storage and handling of ammonia offshore. Not good or viable of offshore installations at present time.	Economical available: plant specific.	Possible future Available, not considered BAT according to BREF p 483 Available on ships (SINTEF) Sources: BREF page 475, SINTEF report p 49

Appendix V. Changes to BAT for Power and Heat generation due to Arctic conditions

Changes to BAT for Power and Heat Generation for Arctic areas

	BAT Assessment - Power & Heat Generation	
	Regulations	**Guidelines & Standards**
Requirements	Arctic: Zero-target for discharges to Sea. Decrease emissions to air. CO2-tax: 410 NOK/tonne CO2 (from 2013) NOx-fee: 17,01 NOK/kg NOx (from 2013) Sources for regulations: -Forvaltningplanen Barents og Lofoten + Oppdatering Forvaltningsplan (Management plan for Barents and Lofoten) -Miljøteknologi 2010, Barents og Lofoten	To be applicable: ISO 19906 NORSOK S-003 Offshore conditions: needs to be Stable, Reliable and Safe. Arctic sources: Barents 2020 reports 3 and 4 EPPR report Arctic council
Technology Screening Results	No complete BAT assessment will be performed due to only on a conceptual level and no location specifications (i.e. Environmental status, Platform-type etc.) Possible higher energy requirement, both electricity and heat, due to colder climate and other safety systems. Technical screening: different technologies for heat and power generation will be considered, but they should all be existing technologies. Information form different suppliers might be different, but will not be further discussed since this is on a conceptual level. Divided into following subsystems: Power generation, Heat generation, NOx-reduction techniques. Cold climate for gas turbines: needs filter: http://www.rolls-royce.com/Images/er200na_tcm92-21095.pdf http://www.pneumafil.com/gasturbine/app/arctic.html	

BAT- Assessment - Arctic Changes

		Environmental Performance/Stressors - Arctic Additions						
	Alternatives	Noise	Low temperature effects	Remoteness and darkness	Discharges to Sea - Aim: Zero discharges to Sea	Black Carbon/Soot/ Particulate matter	Arctic Constraints and Possibilities (Technical, Economical, Environmental)	Additional information
Technique - Power generation	Base level: Gas turbine: Conventional Cycle ("simple cycle")	Turbines: 120-155 dB (inlet & exhaust), reduction is possible through different technologies (silencer systems, enclosures)	Probably no effect. Anti-ice tech. Possible higher effect (cold air have higher density)	Remoteness: No large impact, possible maintenance Darkness: No large impact	Base level No discharges to sea under normal operation.	Base level Not generally a concern (BREF p 460). About 5 mg/Nm3 (under simplified and normal conditions, DNV BAT example)	BAT BREF- Large combustion plants: 7.1.11 Control of noise emissions -High-efficiency, multi-stage systems are engineered to combat corrosion in offshore and coastal installations. In cold climates, icing and frost conditions are controlled using a pulse type filtered -Would in general work well in Arctic conditions, lots of same type of turbines used in aircrafts at high and cold altitudes. Material choices would probably not be needed to be evaluated.	**Possible changes due to Arctic conditions due to reduction/handling of Black carbon/Soot particles, aim to reduce emissions.** Sources: Gas turbine handbook 2006 http://www.hse.gov.uk/research/rrhtm/rr430.htm Interview with Tore Utengen Rolls Royce: http://www.rolls-royce.com/Images/er200na_tcm92-21095.pdf
	Gas turbine: Combined Gas Cycle (CC) (including HRSG)	Probably the same as base case	Probably no effect. Anti-ice tech. Possible higher effect (cold air have higher density)	Remoteness: No large possible impact, probably maintenance Darkness: no large impact	No discharges to sea under normal operation.	Same as base case	Extra weight and need damp/steam system	**Available, BAT** (SINTEF report p 48-49) **Possible changes due to Arctic conditions due to reduction/handling of Black carbon/Soot particles, aim to reduce emissions.**
	Electrification - Power from shore (PFS)	Probably lower	Maybe a problem? Isolation?	Remoteness: Depending on distance, this might be an issue (mostly economical). Darkness: No possible impact	No discharges. Cable in sea, possible other effects?	NA Not applicable, no local discharges (possible form electricity mix)	Issue with remoteness and far to shore. Demands development of grid system onshore for the supply. Increased demand of offshore electrification also demands increased supply from preferable renewable sources, to meet the demand. Otherwise supply might come from non-renewable sources like coal-fire plants etc.	**Available, BAT** (SINTEF report p 48-49) **Possible changes due to Arctic conditions due to remoteness, low temperature effects.**
	Centralized power generation (combined gas turbines) - Hub shared between platforms	Probably the same/potentially more locally if more turbines	Probably no effect. Anti-ice tech. Possible higher effect (cold air have higher density) if gas turbines are used.	Remoteness: Depending on site and other possible platform closely. If long distances this can be an issue. Darkness: no large impact	NA No discharges to sea under normal operation.	Same as base case	Do not exist today on the Norwegian continental shelf shelf. Can be very site-specific, lots of close-by platforms - long distances not preferable. A hub can reach higher overall efficiency and also be combined conventional and combined cycle.	**Available, possible BAT,** demands geographical closeness (SINTEF report p 48-49). **Possible changes due to Arctic conditions due to remoteness, aim for reducing emissions, reduction/handling of Black carbon/Soot.**
	Engines (Diesel and/or Gas)	Probably about the same as Base case	Probably no effect. Anti-ice technology.	Remoteness: No significant impact, possible maintenance issue. Darkness: no large impact	No discharges to sea under normal operation.	Possible higher	Heavier than gas turbines. Harder to also combine with WHRU-systems, maybe possible with e.g. heat pumps.	**Possible changes due to Arctic conditions due to aim to reduce emissions and reduction/handling of Black carbon/Soot particles.**

BAT- Assessment - Arctic Changes								
	Alternatives	Environmental Performance/Stressors - Arctic Additions: Noise	Low temperature effects	Remoteness and darkness	Discharges to Sea - Aim: Zero discharges to Sea	Black Carbon/Soot/ Particulate matter	Arctic Constraints and Possibilities (Technical, Economical, Environmental)	Additional information
Technique - Power generation	Future: Solar energy + Electrification onshore	NA	NA	Remoteness: Maintenance issue Darkness: Issue with lack of sun during large part of the year.	NA	NA	Solar energy electrification + combination with Onshore electrification/Gas turbine back-up.	**Possible changes due to Arctic conditions due to lack of sun under long periods.** Probably not relevant in Norway in nearest future. Possible if storage is available.
	Future: Wind energy + Electrification onshore	Higher than base case (turbines)	Risk of freezing on rotor blades Risk of icing and structure for the foundation	Remoteness: maintenance issue Darkness: no large impact	NA	NA	Potential issues: icing, rime, windy. Needs heating on come components in some stages. Material choices. Wind energy electrification + combination with Onshore electrification/Gas turbine back-up.	**Possible changes due to Arctic conditions due to risk of icing and other issues due to cold climate.** Probably not relevant in nearest future, possible effect from cables in sea/on seabed. Possible in combination with centralized power system. Sources: http://www.sintef.no/project/NorthSeaGrids/paper_EWEA_2011_Oyslebo.pdf
	Future: Nuclear	NA	Probably little	NA Possible motivation to use nuclear (remoteness)	"Zero"	Zero	Nuclear reactors offshore, will have very little emissions. There is the radioactive waste problem and other safety issues which is not globally solved. Severe consequences with accidents.	Probably not relevant in future due to safety issues, waste issues etc. Russia: Planning to have floating nuclear reactors in future… Building ice breaker ships with nuclear Report: Bellona http://www.bellona.org/filearchive/fil_From_Polar_to_Nuclear_-_Bellona_report.pdf Barents Observer: http://barentsobserver.com/en/articles/no-nuclear-energy-shtokman
	Future: Fuel cells	NA	NA	Remoteness: possible maintenance Darkness: possible no significant impact	NA	NA	-Reduces the emissions of CO2 and Nox. Will also mean cost efficient separation and storage of CO2. -Have today high costs and take lots of space.	Probably not relevant in nearest future, in developing phase. Have today high costs and take lots of space, possible in long-term future for new developments. Sources: Miljøteknologi page 43, http://www.regjeringen.no/nb/dep/md/dok/regpubl/stmeld/2010-2011/meld-st-10-2010-2011/10.html?id=637992

BAT- Assessment - Arctic Changes

	Alternatives	Environmental Performance/Stressors - Arctic Additions					Arctic Constraints and Possibilities (Technical, Economical, Environmental)	Additional information
		Noise	Low temperature effects	Remoteness and darkness	Discharges to Sea - Aim: Zero discharges to Sea	Black Carbon/Soot/ Particulate matter		
Technique - Heat generation	Base level: Waste heat recovery unit system (WHRU) (heating medium system)	Base case	Base case	Remoteness: maintenance Darkness: possible no significant impact	Base level	Base level	Seems to be no specific concerns. Possible increase in heat demand for Arctic environment.	**Available. Considered BAT.** if large heat demand.
	Electricity	Same or less than base case	Probably no issue, isolation.	Remoteness: maintenance Darkness: possible no significant impact	No	Same as base case.. Similar or lower depending on source		**Possible changes due to Arctic conditions due to focus on higher energy efficiency.**
	Boilers/Burners with oil/gas	Probably about the same as Base case	Probably same as base case	Remoteness: maintenance Darkness: possible no significant impact	NA	Possible higher		**Possible changes due to Arctic conditions due to reduction/handling of Black carbon/Soot particles, aim to reduce emissions, demand of focus on energy efficiency.**
	Future: Alternatives with Heat pumps (waste heat, geothermal, air etc.)	Probably lower Depends on design	NA	Remoteness: maintenance Darkness: possible no significant impact	NA	NA, some from electricity use.	Measured in COP (Coefficient Of Performance): generally a COP > 4 (can be lower in colder climate)	

BAT- Assessment - Arctic Changes								
	Alternatives	Environmental Performance/Stressors - Arctic Additions					Arctic Constraints and Possibilities (Technical, Economical, Environmental)	Additional information
		Noise	Low temperature effects	Remoteness and darkness	Discharges to Sea - Aim: Zero discharges to Sea	Black Carbon/Soot/ Particulate matter		
Technique - NOx reduction (gas turbines)	Base level: No NOx reduction measures	NA	NA	NA	NA	NA	Most of the platforms on the Norwegian Continental shelf. Shelf uses Nox reducing technologies today.	
	Direct steam injection	NA	Probably not an issue	Remoteness: maintenance Darkness: possible no significant impact	Probably not an issue	NA		NOT considered BAT according to BREF p 483 Available on onshore facilities, need to be qualified for offshore (SINTEF) Sources: SINTEF report p49
	Direct water-injection	NA	Probably not an issue	Remoteness: maintenance Darkness: possible no significant impact	Probably not an issue	NA		NOT considered BAT according to BREF p 483 Available on onshore facilities, need to be qualified for offshore (SINTEF) Sources: SINTEF report p49
	Dry Low NOx combustion chamber (DLN)	NA	Probably not an issue	Remoteness: maintenance Darkness: possible no significant impact	Probably not an issue	May result in higher emissions of CO and UHC (unburned hydrocarbons).		**Available**, considered BAT (SINTEF report p 48-49) **Possible changes due to Arctic conditions regarding aim of lower emissions.**
	Selective catalytic reduction (SCR)	NA	Probably not an issue	Remoteness: maintenance Darkness: possible no significant impact	Probably not an issue	NA		Possible future Available, not considered BAT according to BREF
	Future: Cheng steam injection cycle	NA	Probably not an issue	Remoteness: maintenance Darkness: possible no significant impact	Probably not an issue	NA	Premix steam and fuel in nozzles, suppression of flame size and promote combustion efficiency to consume most of excess O2. Energy efficiency: Higher possible (total eff on system: 40% when on base load) Offshore issues with weight, space, complexity. Requirements: Homogeneous premix of steam and fuel (possible with 2 static mixers), Fuel nozzle able to operate at high steam-fuel ratios (without flame instability probably, no increase in emissions of CO or unburned hydrocarbons). Advantage when running on part-load, increased thermal efficiency, and a simple gas cycle is preferable. Possible for new plants onshore. Offshore: Weight and space limitations and requirements. Low maintenance cost.	CO2: Lower than base case, less fuel is burned in gas turbine. CO: Lower, very low (1-5 ppm typically). Nox: Lower, very low, < 5 ppm. Energy use: Higher, increased mass flow rate (power increase). Energy efficiency: Higher possible (total eff on system: 40% when on base load). Example: Tested on an LM2500 turbine fired by natural gas on a rig in California. Others are onshore power plants. Sources: BREF s 474 Nox reduction master thesis - NTNU: http://ntnu.diva-portal.org/smash/record.jsf?pid=diva2:536427

Appendix VI. BAT for Flare system

BAT for Flare system

BAT Assessment - Flare system		
	Regulations	**Guidelines & Standards**
Require-ments	Flaring is one of the systems contributing to GHG emissions and other emissions. Reduce flaring on the NCS towards "zero flaring" under normal operation Only flaring for emergency reasons. See the SINTEF and Miljøteknologi report (Stormeldings-info)	NORSOK S-003: Flaring: "Should include, but not be limited to, consideration of the following measures: -recycling of gas from high pressure relief systems during normal operation; -recycling of low pressure relief systems during normal operation (subject to cost-benefit evaluation); -process design that minimizes risk of tripping of compressors etc.; -control and condition monitoring systems to reduce the number of trips; -planning of start-up activities to reduce flaring. International Flare standard: API 521
Technology Screening Results	"Flaring is an important safety measure used offshore so any hydrocarbons are safetly disposed of, in emergency situation, power or equipment failure, other platform upset conditions. Before flaring is adopted, feasible alternatives for the use of the gas should be evaluated to the maximum extent possible and integrated into production design. Alternative options may include gas utilization for on-site energy needs, gas injection for reservoir pressure maintenance, enhanced recovery using gas lift, gas for instrumentation, or export of the gas to a neighboring facility or to market. " "If flaring is necessary, continuous improvement of flaring through implementation of best practices and new technologies should be demonstrated." Implementation of source gas reduction measures to the extent possible: -Use of efficient flare tips, and optimizing the size and number of burning nozzles. -Maximizing flare combustion efficiency by controlling and optimizing flare fuel/air/steam flow rates to ensure the correct ratio of assist stream to flare stream. -Minimizing flaring from purges and pilots, without compromising safety, by flare gas recovery units etc. -Minimizing risk of pilot blow-out by ensuring sufficient exit velocity and providing wind guards. -Use of a reliable pilot ignition system. -Minimizing flame lift off and/or flame lick; -Operating flare to control odor and visible smoke emissions (no visible black smoke). Etc. (source: http://www1.ifc.org/wps/wcm/connect/65f8ae00488558a380d4d26a6515bb18/Final%2B-%2BOffshore%2BOil%2Band%2BGas%2BDevelopment.pdf?MOD=AJPERES&id=1323153218959) See SINTEF report A4531, page 48-49,Miljøteknologi 2010, Oljedirectoratet	

BAT- Assessment

	Alternative	Description	Environmental Performance/Stressors: Volume of Flared gas	CO2	NOx	Technical Constraints	Economical Availability	Additional information
Flare design system	Base level: Open flare system	No recovery of the gas. Both HP and LP gas are flared.	Base case	Base case	Base case 1,4 g Nox/Sm3 flared gas	-Pilot flame system necessary	Economical available	Not considered BAT. Safety , emergency issue. Miljøteknologi 2010 Interview Siv and Valentin AMSA report 89439 (impact of black carbon and flaring in arctic)
	Closed flare system: Recovery LP system and Open flare HP system	The LP system (most volume) is recovered. The HP flare system is open.	Less Norway: Decrease flaring with about 10% (the continuing flaring is reduced)	Less	Less, Reduced Nox proportional	-Pilot flame system or Ignition system necessary -Different Flare gas recovery equipment exist and the cot-effective solution is found by the correct tie-in. -Different flare gas recovery packages: Cross over line, Elektro skid, Blower skid, Screw compressor skid, Liquid ring compressor skid	Economical available	**Available, considered BAT.** -Safety, measures issue -Emissions when emergency and stops: Start-up, Shut-down, Upsets Sources: Hamworthy http://www.hamworthy.com/en/Products-Systems/Oil-Gas/Gas-Systems/zero-flaring/Flare-Gas-Recovery/ Transvac http://www.offshore-technology.com/contractors/flare/transvac Interview Siv and Valentin Statoil presentation: http://siteresources.worldbank.org/EXTGGFR/Resources/578068-1268075357274/6844507-1268075388170/0920-0940_Thormod_Hope.pdf Miljøteknologi i Barents & Lofoten
	Closed flare system: Flare Gas Recovery system (LP and HP)	Both the LP and the HP system are closed and the gas are primarily recovered.	Less Norway: Decreased, more than 10%?	Less	Less Reduced Nox proportional	Pilot system is necessary if not avoided -Emissions when emergency and stops: Start-up, Shut-down, Upsets	NA, probably available	Possible Available (Goliat is being built 2013), BAT in future. -Safety, measures Sources: Miljøteknologi 2010 Interview Siv and Valentin, Hamworthy http://www.hamworthy.com/en/Products-Systems/Oil-Gas/Gas-Systems/zero-flaring/Flare-Gas-Recovery/

BAT- Assessment

	Alternative	Description	Environmental Performance/Stressors			Technical Constraints	Economical Availability	Additional information
			Volume of Flared gas	CO2	NOx			
Ignition system	Base level: Flame front generator (+ Pilot based system)	With this system compressed air (generally instrument or plant air) and fuel gas are metered through control valves into a mixing chamber located at grade. Downstream of the mixing chamber there is a sparking device to initiate the flame front (fire ball).	NA	NA	NA	Depended on Pilot system and its reliability! During operation the flow of fuel gas is established through the system and the flame front line is first purged, and then filled with the gas / air mix. The mix in the combustion chamber is ignited and the flame front initiated. The flame front 'fire ball' travels to the pilot tip where it ignites the pilot. Advantage of the compressed air flame front generator is that the flow controls and the sparking device are at grade and can be serviced while the flare is in operation. Systems can be fully automated or manual. Disadvantage of the flame front generator is it is more difficult to operate than an electronic type.	Economical available	Available! Most common used! Suppliers: Argoflares http://www.argoflares.com/research/introduction/pilot-burners-ignition-systems/ballistic-ignition/
	Pellet-based ignition systems (+ Ballistic based system)	Ignition pellet is launched through a guide pipe, ignite when the pellet emerge from the guide pipe. Compressed air derived a small ignition pellet.	NA	NA	NA	Independent of Pilot, but optional. Different kind of ignition pellet: Long-range ignition pellet No electronic equipment or movable parts in high heat radiation areas. Shall work in a weather conditions. The key advantages of the Pellet Ignition System are as follows: Extended service life with no flare deck maintenance required, High reliability, Sparks will ignite all flare tips within the spark radius.	Higher capital cost. Little maintenance	**Available, possible BAT.** Suppliers: ABB + Statoil: USIS 2000, Hamworthy, Wärtsilä, Argoflares Sources: Statoil presentation: http://siteresources.worldbank.org/EXTGGFR/Resources/578068-1268075357274/6844507-1268075388170/0920-0940_Thormod_Hope.pdf http://www.hamworthy.com/Products-Systems/Oil-Gas/Gas-Systems/zero-flaring/Flare-Gas-Ignition/ http://www.argoflares.com/research/introduction/pilot-burners-ignition-systems/ballistic-ignition/
	Electronic spark Ignition (+ mostly Pilot based system)	There are two basic forms of electronic ignition system, high energy and high voltage.	NA	NA	NA	Dependent on Pilot flame. There are similar systems independent of pilots exists. Suffers frequent failure in form of thermal damage to pilot, ignite ceramic rods, electric cables. Spark ignition at the flare pilot nozzle is simple and easy to automate and has therefore become wide spread. With these systems the spark generation must be located somewhere near the pilot tip where it will be exposed to the flammable mixture that exits the tip.	Economical available	**Available, possible BAT.** Suppliers: Argoflares http://www.argoflares.com/research/introduction/pilot-burners-ignition-systems/electronic-spark-ignition/

BAT- Assessment								
	Alternative	Description	Environmental Performance/Stressors			Technical Constraints	Economical Availability	Additional information
			Volume of Flared gas	CO2	NOx			
Flare managemen t	Flare management	Operation routines Shut-down procedures	Reduced flaring volume.	Less	Less	Routines and management for operations. Routines and management for shut-downs, start-ups.	NA	Issue with safety measure (safety: emergency need to reduce the gas). Important according to security. For good operation routines, focus on regularity, to reduce number of not planned stops. Sources: Miljøteknologi 2010, Interview Siv and Valentin, SINTEF report A4531, 2008

Appendix VII. Changes to BAT for Flare system due to Arctic conditions

Changes to BAT for Flare system for Arctic areas

BAT Assessment - Flare system		
	Regulations	**Guidelines & Standards**
Requirements	-Reduce flaring on the NCS "no flaring" -See the Sinter and Miljøteknologi report (Stortings melding-info) ARCTIC	ARCTIC: to reduce the flaring as much as possible (except for emergencies) -Barents 2020 recommendations: — Establishing such a standard will reduce the amount of soot, particular matter and pollutants being emitted to air and which precipitate on ice and having negative impacts on the ice and its ecosystem (e.g. from well testing, flaring, incineration). (RH07, Barents 2020 report 3 p 85) -Flaring is a key environmental issue in remote areas of Barents Sea, try to establish new standards and initiative, E.g.. Global Forum on Flaring Reduction. -Flaring shall only be used for safety purposes. Associated gas may also be used for EOR/pressure support or re-injected for disposal, (Barents 2020 report 3) For Goliat (example):HP and LP gas flare shall be recirculated, no continuing pilot flame but an automatic ignition system for critical situations which demands high safety preparedness. Considering alternatives which creates as low as possible concentrations of PAH and soot. (Goliat EIA) Minimize flaring according to BAT. Flaring in Arctic can be an unwanted source of soot pollution and GHG emissions.(Barents 2020 report 4)
Technology Screening Results	See SINTEF report A4531, page 48-49 Miljøteknologi 2010, Oljedirektoratet, EPPR-report (Arctic council) IFC - Guidelines Offshore oil and gas	

BAT- Assessment - Arctic Changes							
	Alternative	Description	Environmental Performance/Stressors - Arctic Additions			Arctic Constraints and Possibilities (Technical, Economical, Environmental)	Additional information
			Black Carbon/Soot/ Particulate matter	Fire and smoke impact on birds	Light spills		
Flare design system	Base level: Open flare system	No recovery of the gas. Both HP and LP gas are flared.	Base case	Base case	Base case	More focused on reducing emissions to air, and the no-flaring design. So this alternative is probably going to be phased out. Possible issue with ice and snow for equipment damages, performance and blockage of vents.	Not considered BAT. **Possible changes due to Arctic conditions due to reduction/handling of Black carbon/ Soot particles, aim to reduce emissions. Problems in areas with seabirds: fire, smoke and light spills (at night/darkness).**
	Closed flare system: Recovery LP system and Open flare HP system	The LP system (most volume) is recovered. The HP flare system is open.	Less Decrease flaring with about 10%	Probably less (less flaring)	Probably less (less flaring)	More focused on reducing emissions to air, and the no-flaring design. Possible issue with ice and snow for equipment damages, performance and blockage of vents.	**Available, considered BAT.** **Possible changes due to Arctic conditions due to reduction/handling of Black carbon/ Soot particles, aim to reduce emissions.**
	Closed flare system: Flare Gas Recovery system (LP and HP)	Both the LP and the HP system are closed and the gas are primarily recovered.	Less Decrease, more than 10%?	Probably less (less flaring)	Probably less (less flaring)	More focused on reducing emissions to air, and the no-flaring design. Will be used on the Goliat-field in Barents Sea. Possible issue with ice and snow for equipment damages, performance and blockage of vents.	Possible Available (Goliat is being built 2013), BAT in future. **Possible changes due to Arctic conditions due to reduction/handling of Black carbon/ Soot particles, aim to reduce emissions.**

BAT- Assessment - Arctic Changes

	Alternative	Description	Environmental Performance/Stressors - Arctic Additions			Arctic Constraints and Possibilities (Technical, Economical, Environmental)	Additional information
			Black Carbon/Soot/ Particulate matter	Fire and smoke impact on birds	Light spills		
Ignition system	Base level: Flame front generator (+ Pilot based system)	With this system compressed air (generally instrument or plant air) and fuel gas are metered through control valves into a mixing chamber located at grade. Downstream of the mixing chamber there is a sparking device to initiate the flame front (fire ball).	Base case	Base case	Base case	For no-pilot demands this is not an option. Possible issue with ice and snow for equipment damages, performance and blockage of vents.	**Available! Maybe BAT. Possible changes due to Arctic conditions due to more focus on no-pilot based ignition.**
	Pellet-based ignition systems (+ Ballistic based system)	Ignition pellet is launched through a guide pipe, ignite when the pellet emerge from the guide pipe. Compressed air derived a small ignition pellet.	NA	NA	NA	Possible issues with colder climate. Possible issue with ice and snow for equipment damages, performance and blockage of vents.	**Available, probably BAT. Possible changes due to Arctic conditions due to**
	Electronic spark Ignition (+ mostly Pilot based system)	There are two basic forms of electronic ignition system, high energy and high voltage.	NA	NA	NA	Possible more energy use, with electricity based. Possible issue with ice and snow for equipment damages, performance and blockage of vents.	**Available, probably BAT. Possible changes due to Arctic conditions due to**
Flare management	Flare management	Operation routines Shut-down procedures	Reduced volume (depending)	Less	NA	More focus on management measures, which are often easy reduction measure.	**Possible changes due to Arctic conditions due to even more focus on flare management and no-flaring measure.**

Appendix VIII. BAT for Produced water system

BAT for Produced water system

BAT Assessment - Produced water treatment		
	Regulations	**Guidelines & Standards**
Requirements	In Barents & Lofoten Førvaltningsplan, Stortingsmelding nr 38 (2003-2004): For Produced water the general zero-emission target will be applied. Additional requirements as for the operations there is assumed that injection or other technology that prevents discharge of produced water is used. Maximum 5 % of the produced water can be discharged under disruptions, with the condition that it's treated before discharged. More exact treatment requirements will be approved for each site. Oil content in discharged produced water: max 30 ppm	-Oil content in discharges water: expected 15 ppm or below (technical available) if any is discharged at dis-ordinary events (not under normal operation) -Assumption that the Produced water is treated in some kind of way. The alternative of NO Treatment is not included due to not likely to be the case at all.
Technology Screening Results	-Article: Produced water treatment technologies (Igunnu, Chen) 2012: http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html -Miljøteknologi 2010, Oljedirektoratet -Miljøteknologi 2011, Oljedirektoratet	

BAT- Assessment - Produced water system											
	Alternative	Description	Environmental Performance/Stressors						Technical Constraints	Economical Availability	Additional information
			Oil conc. (pro treatment)	Oil: PAH/ BTEX conc.	Use of chemicals	Production chemical conc.	Energy use	Waste generation			
Produced water treatment Techniques	Base level: Hydrocyclones (Pre-treatment)	A physical method to separate solids from liquids based on density. The cyclones made by metals, plastics, ceramics. Performance depending on angle of cone. Can remove particles in range 5-15 μm.	Reduces the dispergent oil content by 75-80%, Can come down to 20 ppm.	Base level NA/NA	No chemicals necessary.	Don't remove Dissolved components in the PW	Base level	Yes, Generates large slurry of concentrated solid waste.	Used in combination with other technologies as a pre-treatment system. Don't require pre-treatment of feed water. Depends a lot on the oil droplet size what amount of oil can be treated. Hydrocyclones need a certain minimum pressure to work and depends on the design. Pumps might be used for pressure the water into the hydrocyclones. After the hydrocyclone the PW will og through a exhaust singlet tank (avgassingstank) under atmosphere-pressure which separates the oil from the PW further.	Long lifespan.	Very common technology on NCS today. Sources: -Miljøtekonologi 2011 report http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html -Beskrivelse av miljøteknologi 2010 report -http://www.intechopen.com/books/water-treatment/state-of-the-art-treatment-of-produced-water
	C'tour	A combination Uses liquid condensate to extracted dissolved components from produced water.	1-5ppm Dispergent oil: reduction of 60-70% In field work: removal of dispergent oil 70%	Reduction -least 70-95% / Can increase concentration under certain circumstances.	No	can be decreased	Low	No	Needs condensate. Needs high pressure re-circulation equipment (>10 bar) and certain temperatures. Can be used upstream from CFU. Good for large volumes of produced water.	Available	**Available. Considered BAT** (DNV rapport 2007-0433) Installed on Statfjord, Ekofisk, Snorre Sources: DNV-Tekna rapport 2007-0433, SINTEF report A4531, Miljøteknologi report Barents sea 2010 http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html http://www.offshore-mag.com/articles/print/volume-66/issue-4/norway/ctour-technique-on-course-to-manage-two-thirds-of-norwayrsquos-produced-water.html http://www.ospar.org/documents/dbase/publications/p00162_techniques%20for%20the%20management%20of%20produced%20water.pdf http://www.touchoilandgas.com/produced-water-management-norwegian-a7807-1.html
	Compact Floatation Unit (CFU)	Modernized hydrocyclone method with addition to injected gas(nitrogen or natural gas) to lift the oil droplets. Can be done in 1 or 2 steps.	10-15 ppm dispergent oil down to 5 μm. 1 step: reduction 30-50% 2 steps: reduction 50-70%	Can have some reduction / NA	NA	Can also reduce other non-dissolved substances, PAHs etc. Further development to reduced also dissolved substances.	NA	NA	Often used after Hydrocyclones. Can remove oil droplets >5 μm and possible more. Several small installations are better than one large.	Available	**Available. Considered BAT** (DNV rapport 2007-0433) Under development (SINTEF 2008), Installed at Heidrun and Norne. Suppliers: Epcon CFU, TS technology Sources: DNV-Tekna rapport 2007-0433, Miljøteknologi Barents report 2010 http://www.ospar.org/documents/dbase/publications/p00162_techniques%20for%20the%20management%20of%20produced%20water.pdf http://www.touchoilandgas.com/produced-water-management-norwegian-a7807-1.html

BAT- Assessment - Produced water system

	Alternative	Description	Environmental Performance/Stressors: Oil conc. (pro treatment)	Oil: PAH/ BTEX conc.	Use of chemicals	Production chemical conc.	Energy use	Waste generation	Technical Constraints	Economical Availability	Additional information
Produced water treatment Techniques	Macro Porous Polymer Extraction (MPPE) (Needs pre-treatment)	One step process to remove dissolved and dispersed hydrocarbons from offshore produced water. Liquid-liquid extraction technology, extraction liquid is immobilized in macro-porous polymer particles (about 1000 µm)	Dissolved and dispersed oil < 1 ppm	Reduction up to 98% / up to 99%	No continuous consumption, extraction liquid needed	NA	Energy demanding!	Maybe (packing material, extraction liquid)?	Pre-treatment through hydrocyclones or other flotation methods is however necessary before letting produced water from oilfields flow into the MPPE unit. Flow rates of less than 1m3/hr to hundreds of m3/hr are possible. Treats: Aliphatic (dispersed oil), Aromatics (BTEX), Polyaromatic hydrocarbons (PAHs), Naphtalenes, phenanthrenes, dibenzothiophenes (NPDs). High separation performance: 99,99 % of removal efficiency. MPPE was used for the removal of dissolved and dispersed hydrocarbons, achieving 99% removal of BTEX, PAHs and aliphatic hydrocarbons at 300–800 ppm influent concentration.	Relative high cost of one unit. Energy demanding -> high costs.	**Available, BAT** (SINTEF 2008) Good for future when focus on Zero-emissions to sea, and focus on EIF of contaminants. MPPE has the highest EIF reduction according to Statoil survey (about 84% reduction). Tested on Kollsenes. Sources: SINTEF report A4531 -2008, Miljøteknologi Barents 2010 http://www.vwsmppsystems.com/mppsytems/ressources/documents/1/23577,Offshoreleaflet-red-logo.pdf http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html
	Membrane filtration	There are four established membrane separation processes, including microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO) and Nano filtration (NF)	NA	NA / NA	Little or non	Removes particles of 5.0 µm or above.	Relative Low: MF and UF: NA	NA	MF and UF can be used as a standalone technology for treating industrial wastewater, but RO and NF are usually employed in water desalination. Membrane technology operates two types of filtration processes, cross-flow filtration or dead-end filtration, that can be a pressure (or vacuum)-driven system. Small space needed, ease of operation, possible for automatic plants. Easy to combine with with other separation tech. Low membrane lifetime	Moderate capital costs	Quite NEW technology, Developing stadium Energy use: NF: Electricity, less than RO, about 0,08 Kwh/bbl. RO: Electricity, from 0,02-0,13 KWh/bbl. (BWRO) and 0,46-0,67 KWh/bbl. (SWRO) Sources: http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html http://www.intechopen.com/books/water-treatment/state-of-the-art-treatment-of-produced-water
	Drop emerging technologies (PECT-filter and Mares Tail)	Use of fibertechnology to merge the oil droplets in PW and is used in combination with Hydrocyclones	Can have up to 50% extra reduction in combination with Hydrocyclones.	NA / NA	NA	NA	NA	NA	Best when oil droplets are moderate. Good for use in combination with Hydrocyclones. Suitable for gas- and condensate fields		In developing stage? -Miljøteknologi Barents 2010

BAT- Assessment - Produced water system											
			Environmental Performance/Stressors								
	Alternative	**Description**	**Oil conc. (pro treatment)**	**Oil: PAH/ BTEX conc.**	**Use of chemicals**	**Production chemical conc.**	**Energy use**	**Waste generation**	**Technical Constraints**	**Economical Availability**	**Additional information**
Produced water Reduction techniques (reduced volume to platform)	Base level: No Produced Water Volume topside reduction	No measures to reduce the volume of produced water.	Base line	Base line	Base line	Base line	Base line	Base line	Nothing to reduce the volume of produced water.		
	Water Shut-offs (vannavstengning/vannblokkeringer)	Chemical or physical shut-off of different production zones in the wells which are producing too much water.	NA (only reduced volume not concentration)	NA / NA (only reduced volume not concentration)	No, in general. Yes, for chemical shut-off.	Less	Possible lower (probably less compared to separation and injection from platform)	Less	**Reduces Produced Water volume up to 40% per well.** Reduced chemical use and reduced risk of corrosion. Chemical: problem to find non-hazardous and approved chemicals. (SINTEF 2008)	Probably economic available.	**Available, BAT** (SINTEF 2008) Some under development. -Miljøteknologi 2010, p 30 -SINTEF A4531 report, 2008
	Subsea Separation + Re-injection	Includes both power supply and subsea compression station.	NA (only reduced volume not concentration)	NA / NA (only reduced volume not concentration)	Less (reduce use of corrosion- and hydrate inhibitors)	Less	Less (probably less compared to separation and injection from platform)	NA	**Reduces the Produced Water volume up to 90%.** Reduced energy demand and therefor reduced emissions to air compared to re-injection from platform. (SINTEF 2008). Should be combined with re-injection, preferable where there is a need for pressure support. Will also reduce the energy demand which can lead to decreased emissions to air. High potential technology in future.	Probably expensive since under development.	Under development, (SINTEF 2008), (Miljøteknologi 2010). Tested on Troll, but shut-down. Subsea compression tested on Ormen Lange, Åsgard/Midgardfeltet 2014/2015. Subsea compression suppliers: MAN, Siemens, Aker Solutions Suppliers: Well processing: Swit-technology, Framo Engineering -Miljøteknologi 2010, p 31-32 -Miljøteknologi 2011, p 45 -SINTEF A4531 report, 2008
	Downhole separation (Nedihullsseparasjon) + Re-injection	Special separator (e.g. hydrocyclone) which separates water from oil and gas in the production well. The water is re-injected, by a pump in the well, into the well/other formation. Both Vertical and Horizontal separation exists.	NA (only reduced volume not concentration)	NA / NA (only reduced volume not concentration)	NA	NA	NA	NA	**Reduces the Produced Water volume up to 90% on the platform.** Technical demanding technologies (especially the pumps). Good for resource use and environment. Both Vertical and Horizontal designs. Needs to have a well/formation to re-inject the produced water and to have continues of the injection. Good for fields with expected large portion of Produced water and where it can be used to enhanced oil production.	Relative high investment costs, on a field with several wells this about be viable.	Under development, in 2008, (SINTEF 2008), (Miljøteknologi 2010). Horizontal Downhole separation developed for wells without free gas, not tested on NCS. Different concepts exists and these are in different levels of development. Tested on Brage field. Subsea compression tested on Ormen Lange, Årgard. Sources: -Miljøteknologi 2010, p 30-31 -SINTEF A4531 report, 2008

BAT- Assessment - Produced water system

	Alternative	Description	Environmental Performance/Stressors: Oil conc. (pro treatment)	Oil: PAH/ BTEX conc.	Use of chemicals	Production chemical conc.	Energy use	Waste generation	Technical Constraints	Economical Availability	Additional information
Produced water Disposal after treatment (at platform)	Base level: Discharge to Sea	Direct discharge to sea after regulatory treatment.	Base line (shall be below 30 ppm at least)	Base line	Base line	Base line	Base line	Base line: Lots if the discharged water considered waste.	Can have certain regulations regarding when and where due to Environmental concerns.	Estimated cost \$0,03-\$0,05/barrel (2013)	**Available (depending of treatment degree before release)** -http://www.intechopen.com/books/water-treatment/state-of-the-art-treatment-of-produced-water
	Produced Water Re-injection (PWRI) - after separation at platform	Different types of re-injection (in old well or in other well). Can be used to increase the pressure in well. Either Disposal injection or Re-injection for further enhanced recovery of wells.	NA	NA / NA (not existing of re-injected)	Possible more	NA	Possible more (for re-injection process compared to discharged)	NA	Reduced the volume of Produced water on the platform (for other handling/discharge) and can be used as storage. Can increase the emissions to air (more energy), can contribute to increased chemical use and reservoir acidification (SINTEF 2008) H2S and Sulphate can contribute to reservoir acidification, H2S can be reduced by chemicals H2S-scavenger and other technique to reduce sulphate. Important to know the water composition early on at a site to avoid future problems with the re-injection (Miljøteknologi 2010).	Estimated cost \$0,70-\$4,00/barrel (2013), but consideration to increased extraction of oil/gas which would create more value.	**Available** (SINTEF 2008) BAT? Tested on Utsira field. -SINTEF A4531 report, 2008 -http://www.intechopen.com/books/water-treatment/state-of-the-art-treatment-of-produced-water

Other Produced Water Treatment Techniques	Additional Produced water treatment techniques	-**Thermal technologies**: Multistage flash (MSF) distillation, vapour compression distillation (VCD), multieffect distillation (MED) are the major thermal desalination technologies, (http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html) -**Biological aerated filters (BAF)** (mainly onshore): Permeable media that uses aerobic conditions to facilitate biochemical oxidation and removal of organic constituents in polluted water. No use of chemicals need during normal operation. Can't treat Dissolved solids. Removes Organic and Ammonia compounds. BAF can remove oil, ammonia, suspended solids, nitrogen, chemical oxygen demand (COD), biological oxygen demand (BOD), heavy metals, iron, soluble organics, trace hydrogen sulphide from produced water. It is most effective for produced water with chloride levels below 6600 mg/l. This process requires upstream and downstream sedimentation to allow the full bed of the filter to be used. Removal efficiencies of up to 70% nitrogen, 80% oil, 60% COD, 95% BOD and 85% suspended solids have been achieved with BAF treatment. Little maintenance, long lifespan, normally no cleaning necessary. Total cost consist mostly of capital cost. Cost for required solid disposal (up to 40% of total cost), (http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html , SINTEF report A4531, 2008) -**Gas floatation** (Pre-treatment): Uses fine gas bubble to separate suspended particles which are not easily separated by sedimentation. Particulates and oil droplets will attached to the air bubbles which rises, resulting in foam on surface which is skimmed off as froth. 2 types of gas floatation techno: Dissolved gas floatation and Induced gas floatation). Can remove particles as small as 25 µm and can remove contaminants up to 3 µm if coagulation is added as pre-treatment. Cannot remove soluble oil continuants form water. Most effective when gas bubbles size is less than oil droplet size. Estimated cost: 0,60 \$/m3 of produced water. Waste: solid disposal from sludge, (http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html) -**Physical Adsorption:** activated carbon etc.: can remove TPH, oil content (up to 85%), BTEX. For large oil droplets. Tested offshore -**Sand filters:** to remove metals (up to 90%)from PW, needs pre-treatments -**Evaporation:** no chemical treatment, very high energy demand, high operating costs, could use hot vapour to decrease costs -**Dissolved air precipitation (DAP):** formation of air bubbles, removes aliphatic compounds -**Media filtration** (oil and grease remove): offshore, -**Ion exchange tech** -**Chemical oxidation**, -**Electro dialysis/electro dialysis reversal**, -**Dew evaporation:** AltelaRain process, -**Freeze thaw evaporation** (works in cold climate?): called below freezing point, can be coupled with other process, needs large land area -**Others:** Hydroflokk and G-floc, Cetco filter CrudeSep (under development, reduces oil, particles, some org. dissolved substances), Cetco filter CrudeSorb (available, reduces oil, PAH, heavy metals)	-Miljøteknologi Barents report 2010 -SINTEF report A4531 http://www.ospar.org/documents/dbase/publications/p00162_techniques%20for%20the%20management%20of%20produced%20water.pdf http://www.touchoilandgas.com/produced-water-management-norwegian-a7807-1.html http://www.intechopen.com/books/water-treatment/state-of-the-art-treatment-of-produced-water

Appendix IX. Changes to BAT for Produced water system due to Arctic conditions

Additional BAT for BAT for Produced water system		
	BAT Assessment - Produced water system	
	Regulations	**Others**
Requirements	Zero discharges from produced water under normal operation in Barents Sea nd Lofoten area (probably for rest of Arctic areas in Norway as well) (Stortingsmelding nr 38 2003-2004). 100% re-injection or other disposal alternatives during normal operations, "Additional requirements as for the operations there is assumed that injection or other technology that prevents discharge of produced water is used". Max 5 % can be discharged during operational stops, disruptions etc. with condition if the produced water is treated before the discharge. Exact treatment requirements will be approved for each site. Oil content, OSPAR: max 30 ppm (expected to be lower 10-15 ppm, which is technical available).	Demand of no discharges from cuttings or produced water (zero emissions) represents a stricter requirement in relation to the requirements applied to other parts on NCS. The produced water re-injected needs treatment before the injection (at least the produced water is bought up on the platform).
Technology Screening Results	Sources: Produced water treatment technologies (Igunnu, Chen) 2012: http://ijlct.oxfordjournals.org/content/early/2012/07/04/ijlct.cts049.full.pdf+html Miljøteknologi 2010 and 2011, Oljedirektoratet SINTEF report A4531	

BAT- Assessment - Arctic Changes - Produced water system

	Description	Function	Environmental Performance/Stressors - Arctic Additions: Zero discharges to Sea	Warmer water release to Sea	Energy use	Arctic Constraints/Availability -Technical, Economical, Environmental	Additional information
Produced water treatment Techniques	Base level: Hydrocyclones (Pre-treatment)	A physical method to separate solids from liquids based on density. The cyclones made by metals, plastics, ceramics. Performance depending on angle of cone. Can remove particles in range 5-15 µm.	No, unless combined with re-injection. Oil content: 20 ppm	Probably warmer water release.	Base level	Possible issue with ice and snow for equipment damages, performance and blockage of drains.	Very common technology on NCS today. **Possible changes due to Arctic conditions due to expectations for lower oil concentration, if released can have warmer water impacts. Might be used as a pre-treatment technology.** Will be on Goliat in Barents Sea. Sources: Miljøteknologi 2010, Eni Goliat EIA.
	C'tour	A combination Uses liquid condensate to extracted dissolved components from produced water.	No, unless combined with re-injection. Oil content: 1-5ppm	Probably warmer water release.	Low	Needs condensate. Probably more usage in future. Possible issue with ice and snow for equipment damages, performance and blockage of drains.	**Available. Considered BAT. Possible changes due to Arctic conditions due to if released can have warmer water impacts.**
	Compact Floatation Unit (CFU)	Modernized hydrocyclone method with addition to injected gas(nitrogen or natural gas) to lift the oil droplets. Can be done in 1 or 2 steps.	No, unless combined with re-injection. Oil content: 10-15 ppm dispergent oil down to 5 µm.	Probably warmer water release.	NA	Possible issue with ice and snow for equipment damages, performance and blockage of drains.	**Available. Considered BAT. Possible changes due to Arctic conditions due to expectations on even lower oil concentration, if released can have warmer water impacts.** Will be on Goliat in Barents Sea. Sources: Miljøteknologi 2010, Eni Goliat EIA.
	Macro Porous Polymer Extraction (MPPE) (Needs pre-treatment)	One step process to remove dissolved and dispersed hydrocarbons from offshore produced water. Liquid-liquid extraction technology, extraction liquid is immobilized in macro-porous polymer particles (about 1000 µm)	No, unless combined with re-injection. Oil content: < 1 ppm	Probably warmer water release.	High	More maintenance and operational issues? (Goliat KU - Eni EIA) Possible issue with ice and snow for equipment damages, performance and blockage of drains.	**Available, BAT (SINTEF 2008) Possible changes due to Arctic conditions due to energy use which might decrease the overall energy efficiency.**
	Membrane filtration	There are four established membrane separation processes, including microfiltration (MF), ultrafiltration (UF), reverse osmosis (RO) and Nano filtration (NF)	No, unless combined with re-injection.	Probably warmer water release.	Low, mostly	Possible low membrane lifespan leads to more maintenance and possible remoteness issues and higher costs. Possible issue with ice and snow for equipment damages, performance and blockage of drains.	Future BAT possible. **Possible changes due to Arctic conditions due to if discharged to sea might have warmer water release.**

BAT- Assessment - Arctic Changes - Produced water system							
			Environmental Performance/Stressors - Arctic Additions				
	Description	Function	Zero discharges to Sea	Warmer water release to Sea	Energy use	Arctic Constraints/Availability -Technical, Economical, Environmental	Additional information
Produced water treatment Techniques	Drop emerging technologies (PECT-filter and Mares Tail)	Use of fibertechnology to merge the oil droplets in PW and is used in combination with Hydrocyclones	No, unless combined with re-injection.	Probably warmer water release.	NA	More suitable for gas fields, so might be more applicable in Arctic (findings of gas fields). Possible issue with ice and snow for equipment damages, performance and blockage of drains.	Future BAT possible. **Possible changes due to Arctic conditions due to if discharged to Sea have warmer water.**
Produced water Reduction techniques (reduced volume to platform)	Base level: No Produced Water Volume topside reduction	No measures to reduce the volume of produced water.	NA	NA	Base line	The alternative to not having any volume reducing technology might not be an option for Arctic operations.	**Possible changes due to Arctic conditions due to zero discharges to sea.**
	Water Shut-offs (vannavstengning/ vannblokkeringer)	Chemical or physical shut-off of different production zones in the wells which are producing too much water.	NA	NA	Less (probably less compared to separation and injection from platform)	Increased demand of using non-hazardous chemicals in Arctic areas possible and hard to find substitute. Possible Noise issue in Arctic relatively undisturbed areas when using subsea equipment. Possible issue with colder climates, waves etc. for equipment damages, performance and blockage of drains.	**Available, BAT.** **Possible changes due to Arctic conditions due to non-hazardous chemical use but might be an option if reduced energy use compared to topside separation.**
	Subsea Separation + Injection	Includes both power supply and subsea compression station.	NA	NA	Less (probably less compared to separation and injection from platform)	Possible Noise issue in Arctic relatively undisturbed areas when using subsea equipment. Might be issue with risk of subsea spills. Possible issue with colder climates, waves etc. for equipment damages, performance and blockage of drains.	**Possible changes due to Arctic conditions due to an attractive alternative for future development.**
	Downhole separation (Nedihullsseparasjon) + Injection	Special separator (e.g. hydrocyclone) which separates water from oil and gas in the production well. The water is re-injected, by a pump in the well, into the well/other formation. Both Vertical and Horizontal separation exists.	NA	NA	NA (probably less compared to separation and injection from platform)	Possible Noise issue in Arctic relatively undisturbed areas when using subsea equipment. Possible issue with colder climates, waves etc. for equipment damages, performance and blockage of drains.	**Possible changes due to Arctic conditions due to an attractive alternative for future development.**

BAT- Assessment - Arctic Changes - Produced water system							
	Description	Function	Environmental Performance/Stressors - Arctic Additions			Arctic Constraints/Availability -Technical, Economical, Environmental	Additional information
			Zero discharges to Sea	Warmer water release to Sea	Energy use		
Produced water Disposal after treatment (at platform)	Base level: Discharge to Sea	Direct discharge to sea after regulatory treatment.	No, discharges to Sea.	Base line Possible issue?	Base line	Not an option at a regular basis in Arctic areas (or should be at least).	**Available (depending on treatment degree before release). Possible changes due to Arctic conditions due to will probably not be an alternative under normal operation in Arctic areas due to requirement of zero discharges to sea.**
	Produced Water Re-injection (PWRI) - after separation at platform	Different types of re-injection (in old well or in other well). Can be used to increase the pressure in well. Either Disposal injection or Re-injection for further enhanced recovery of wells.	Yes, zero discharges under normal operation	Lower, since no discharge to sea.	Possible more (for re-injection process). Comparable to other injection for enhanced recovery?	Possible Noise issue in Arctic relatively undisturbed areas when using subsea equipment. Possible issue with colder climates, waves etc. for equipment damages performance. Also possible availability for maintenance and other issues with Arctic conditions.	**Available and BAT. Possible changes due to Arctic conditions due to requirement of re-injection or disposal injection of produced water to 100% under normal operation.** Will be on Goliat in Barents Sea. Sources: Miljøteknologi 2010, Eni Goliat EIA.