Air pollution control in a new oil and gas developments using best available techniques

S. M. S. M. K. Samarakoon & O. T. Gudmestad
Faculty of Science and Technology, University of Stavanger, Norway

Abstract

Existing offshore oil and gas developments on the Norwegian Continental Self (NCS) have been considered as a major source of air pollution, mainly due to the usage of gas driven turbines. The authorities and oil companies have a strong commitment to research and development to find out reasonably practical measures to reduce the emissions. For instance, combined electric and gas power, underground storage of emission, use of CO_2 to enhance oil recovery, power from shore etc. are some of the measures considered.

It is vital to implement the Best Available Techniques (BAT) guidelines available in the Integrated Pollution Prevention and Control (IPPC) (2008/1/EC) directive on the NCS for retaining and extending the license to operate within the oil and gas industry. The guidelines in relation to BAT deal with the determination of the best practices. One of the major challenges for an operator is to satisfy the guidelines while confirming fitness for purposes of different technology applications.

This study starts by identifying the sources of air pollution in the Norwegian offshore oil and gas industry and discussing the best available techniques to mitigate emission to air. Moreover, integration of technique qualification into the BAT evaluation is discussed to overcome challenges faced while moving to the arctic climate. An illustrative case study of power supply from shore to offshore shows how to include technique qualification in the project development process in order to develop confidence in the new solution and to satisfy health, safety and environmental (HSE) and financial concerns.

Keywords: BAT, technique qualification, pollution, IPPC, offshore, oil and gas, emissions.

www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/AIR100091

1 Introduction

The Norwegian offshore oil and gas industry is moving to petroleum reserves on the northern part of the country's shelf, into a harsh, remote and sensitive environment. Further, the northern part of the Norwegian Shelf has a sub-arctic or arctic environment with various challenges, such as limited operators' experience, large temperature variations, strong wind, risk of icing, snow drift, limited day light, etc. Similarly, these new oil and gas fields are located in a sensitive environment with rich fishing resources, bird life and wildlife. Therefore, the technical solutions must be inherently safe with a low risk level. Similarly, sea regime requirements with respect to emission to air and discharge to sea shall be fulfilled. Moreover, operator companies require concepts and technologies that minimize the emission to air at the offshore site. In addition, the technical solutions for emission to air must be consistent with the BAT described in the Integrated Pollution Prevention and Control (IPPC) directive [1].

The Best Available Techniques (BAT) are further described in BAT Reference Documents (BREFs) providing information on the techniques which can be considered as the BAT. In particular, the Large Combustion Plant BREF and the Emission from Storages BREF can be applicable for offshore oil and gas activities for controlling CO_2, NO_x, and VOC (Volatile Organic Carbon) emissions [2, 3]. The major source of emission to air has been from existing gas driven turbines used for generating power to offshore facilities. The Norwegian legislation and actions to reduce emissions, for instance tax on CO_2, Kyoto targets, the Pollution Control Act, the Petroleum Act, and the Greenhouse Gas Emission Act, etc. are playing a key role in regulating the emission from petroleum activities [4]. In addition, air pollution mitigation measures, for instance use of combined power sources, storage of CO_2, use of CO_2 to enhance oil recovery, energy management and energy efficiency, electric power from shore, etc. have been considered for controlling the major emissions and to achieve the emission targets.

Presently, all Plans for Development and Operations (PDO) of oil and gas fields must contain an analysis of potential power supply from land [4]. This condition is applicable to both new developments and major modifications of existing installations on the NCS. However, most of the new developments are located in the northern part of Norway with arctic conditions. Hence, the solution of getting power from land will be challenging because of the harsh, remote, and sensitive environment and due to limited experience. Technique qualification is an essential element in this respect to improve confidence in the technique, reduce the scheduled risk, ensure a proactive approach, identify necessary design changes at an early stage, use the recourses efficiently, identify the failures, etc.

This paper starts with identification of the maturity level of the technique and a discussion of the requirement to qualification. The study illustrates the involvement of technique qualification for a power supply project from shore to offshore when there is a business idea for exploration. Further, the challenges faced in the process are discussed.

2 Air pollution and mitigation in the offshore oil and gas industry on the NCS

2.1 Sources of air pollution

The Norwegian petroleum sector accounts for 31% of the Norwegian CO_2 emission, and 75% of this comes from gas turbines used for generating power, as shown in Figure 1 [4]. Further, out of the total NOx and VOC emissions, the petroleum sector contributes 24% and 41%, respectively as is shown in Figure 1. Key sources of NOx emission have been from gas combustion in turbines, from flaring of gas and from diesel consumption on the facilities. The majority of VOC emission is from storage and loading of crude oil offshore and from land terminals. It can be seen that a large part of the emission to air is from the offshore petroleum activities. The trend of CO_2 emission on the NCS is, however, increasing due to existing developments reaching a mature state and movements toward the north, as well as longer transport distances. Treatment and transport of gas, furthermore, require more energy than production of liquid.

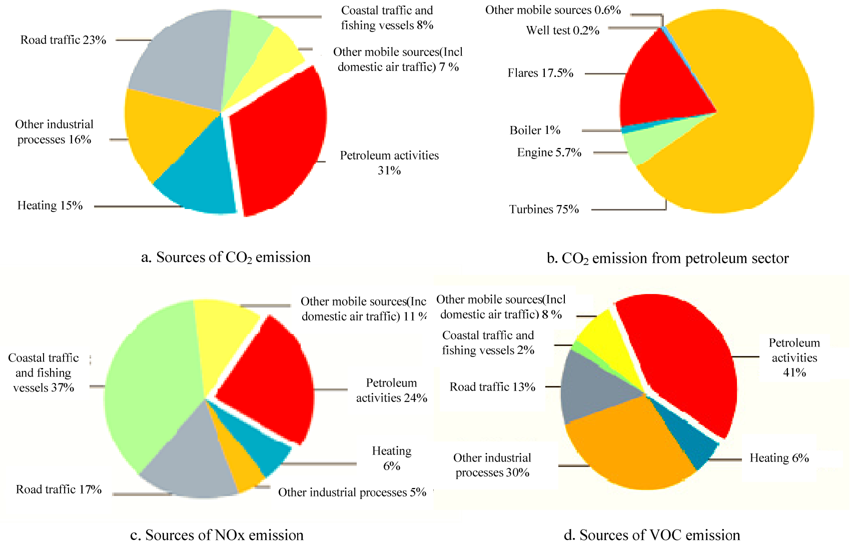

Figure 1: Sources of Norwegian emissions in 2007 [4].

2.2 Measures for air pollution control on the NCS

Both policy instruments and technical measures have been introduced to mitigate the emissions to air from offshore oil and gas activities on the NCS. In addition, the implementation of the BAT concept described in the IPPC directive is mandatory for oil and gas operators to retain the permit [5]. The BAT have been defined in the IPPC directive as follows [1]:

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

The BREFs have been developed according to requirements given in the IPPC directive for exchanging information on the BAT. The BREF on emission from storage will provide information for controlling VOC emission during crude oil handling and storage [3]. Moreover, the Large Combustion Plant BREF is providing information on the BAT for controlling emission to air from offshore oil and gas platforms, as listed in Table 1 [2]. In addition, CO_2 storage (injection of CO_2 into depleted oil and gas reservoirs or geological formations under water or land), use of CO_2 to enhance oil recovery (the injection of CO_2 into oil fields to improve the oil recovery), power from shore to offshore installations (the power supply from shore based sources to offshore installations will be done via subsea cables), etc. are some of the country's practical measures to achieve the emission targets.

Table 1: Examples of BAT for controlling emission to air from power generation in offshore oil and gas platforms [2].

Technique	Description	Application
Power integration	Use of a central power supply to a number of participating installations	Prudhoe Bay in Alaska
Combined cycle heat and power units	Combination of gas turbine process and a steam turbine process for recovering heat in gas turbine exhaust	Currently in use on the Oseberg, Snorre, and Eldfisk fields on the NCS
Reduction of load on gas turbine driven equipment	Reduction of compressor recycling, pump by pass quantities, process control loop tuning of the plant	
Use of Dry Low NOx combustion chambers	Mixing of air fuel and combustion takes place in two successive steps	

The Norwegian governmental bodies, for instance the Petroleum Safety Authority and the Pollution Control Authority etc., provide guidelines for operators in this regard. Similarly, NORSOK-S 003 on environmental care also explains factors to be considered in determination of the BAT, as show in Figure 2 [6]. Moreover, it also recommends performing environmental design reviews at appropriate stages in the project developments process, as shown in Figure 3. However, the authorities require that all new developments and major modifications of installations must be evaluated for potential power supply from shore.

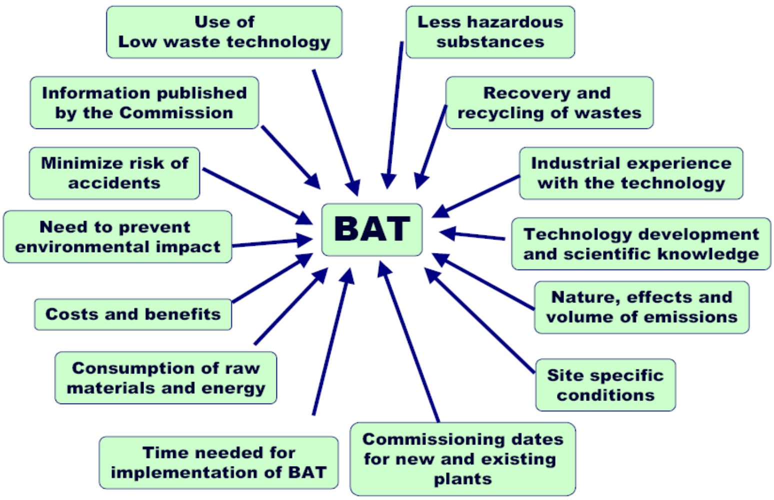

Figure 2: Factors to be considered in determination of the BAT [6].

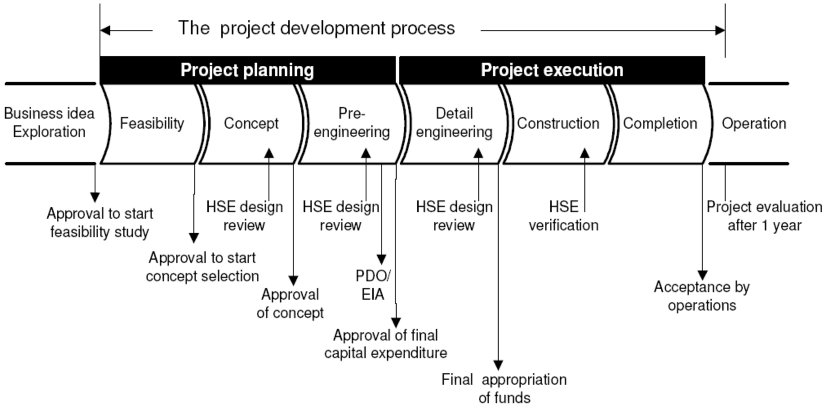

Figure 3: Project development process and decision gates [6].

Important new oil and gas developments are located in arctic regions, for instance in the Barents Sea, the Kara Sea and the Sea of Okhotsk offshore (Sakhalin [7]). Therefore, it is essential to develop robust solutions for harsh and sensitive environmental conditions in the arctic regions of interest. In this context, technical qualification is playing a major role to develop the confidence of the technique being selected. In general, DNV-RP-A203 [8] is the foundation for the current qualification procedures being used in the offshore oil and gas industry on the NCS [9–11]. DNV-RP-A203 [8] has defined technology qualification as "*Confirmation of provision of evidence that the technology is fit for purpose"*. Further, we refer to the following definition for technique qualification by considering the requirements for BAT as *"Technique Qualification" shall mean confirmation with provision of evidence that the selected BAT in accordance with the guidelines provided in the authority requirements meets specified requirements during design, installation, operation and performance for the intended use* [12].

3 Use of qualification programs in the Norwegian offshore oil and gas industry

An offshore installation requires more inherent safety than an onshore installation due to some fundamental reasons, such as the risk of total loss due to structural failure, typically due to ballasting/stability/buoyancy issues, is excluded onshore. Further, there are several accident types that are not applicable onshore, such as ship collisions, helicopter accidents, exposure of personnel due to riser or pipeline leaks and loss of position due to failure of mooring systems, and risk related to evacuation of installation by air or sea. Similarly, space, and weight are at a premium, leading to a much higher equipment density than is common in onshore applications. In addition, the movement of offshore activities toward the northern part of the NCS will introduce new challenges due to limited experience with the harsh and sensitive environment. For instance, the Barents Sea is experiencing ice and ice bergs, polar lows, etc., which may interfere with operation or even impact on installations [7, 13]. Further, cold climate areas are relatively slow to recover from environmental impact.

The offshore oil and gas industry expands its traditional activities with the aid of novel solutions to overcome existing challenges in HSE. Similarly, these novel concepts do not have any prior in-service experience and neither are any classification rules, statutory regulations nor industry codes or standards directly applicable to them [14]. Therefore, novel concepts require a different approach to classification, including the use of new tools and techniques in order to determine that the concepts provide an acceptable level of safety in line with current offshore and marine industry practice. The company which integrates new technology into a large system needs to evaluate the effect on the total system's reliability to increase the level of confidence via a technology qualification procedure. However, the important point in technique qualification is identification of the level of maturity of a technology. DNV–RP-A203 [8] provides requirements to the classification to assess the technology as shown in Figure 4. Further, it states that classes 2 to 4 are defined as new technology, and shall be qualified according to a procedure. Similarly, this classification applies to the totality of the applied technology as well as each separate part, function, and subsystem forming it. It shall be used to highlight where care must be taken due to limited field history. The following Figure 5 shows an overview of the

Application area	Technology		
	Proven	Limited field history	New or unproven
Known	1	2	3
New	2	3	4

The classification ratings for criticality are based on:

1. No new technical uncertinities
2. New technical uncertinities
3. New technical challenges
4. Demanding new technical challenges

Figure 4: Technology classification [8].

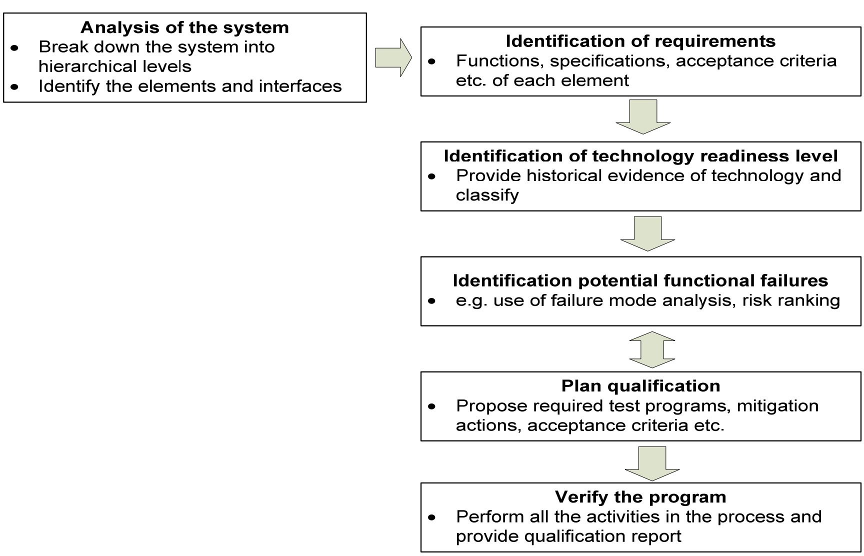

Figure 5: Overview of qualification process [9, 10].

technology qualification process for a system (consisting of various technological elements) being carried out in the offshore oil and gas industry [9, 10].

Initially, the system is broken down into several hierarchical levels in order to identify the elements, interfaces, operating conditions, etc. For each element, functional requirements and specification parameters, and other contractual parameters, e.g. reliability/availability requirements, legal requirements, including the recommended practice of the country of operation, etc. will be identified. The technology readiness level can be identified using the classification provided in DNV-RP-A203 [8].

Then, it is required to establish a technical qualification program to document all the activities, decision gates, responsibilities, tests, acceptances, etc. in order to qualify and implement all elements as a part of the overall project execution. In a project, more than one technological element requires qualification. Acceptance criteria for all technical elements shall be established in the qualification process with focus on all relevant functions, performance (HSE and other) requirements as well as life cycle considerations. The reliability of new technology shall be assessed, based on failure mode analysis and generated reliability data. A risked-based approach is used in the process to obtain the reliability goals. Identification of failure modes and their risk, based on the level of maturity of the technology, is helpful to determine where the uncertainty is most significant. Finally, the qualified technology will be the outcome of the process.

Technology qualification is carried out for all facilities and drilling equipment, well construction and production technology, including temporary facilities and tooling systems in the offshore oil and gas industry. Further, technology qualification is required in modifications (critical process or utility systems) and for onshore plants [8, 9].

The intention for a company to have a procedure for technology qualification is to ensure a proactive approach in seeking improvements of concepts when implementing new technology, to identify the involved cost and schedule risks and balance those against the business improvement potential. Further, the procedure will also help to ensure that new technology is qualified in due time prior to implementation in projects. For instance, use of low NOx turbines with dual fuel may be challenging for a new development due to lack of experience with the technology, although it has been verified through environmental validation programs elsewhere. In these cases, verification and testing are required at the place of application. Prior to each technology development and qualification, it is important to define and establish the required competence (both internal and external) and the required combination of acceptance criteria and "evidence" methodology, in order to finalize that the technology is fit for purpose.

4 Illustrative case study: use of technology qualification process in BAT evaluations

Figure 6 shows an overview of a system which is considered for power supply to a Floating Platform, Storage and Offloading (FPSO) unit on the northern part of the NCS. The climate conditions can be considered as arctic or semi arctic in this region. In the BAT evaluation, the factors discussed in Figure 2 had to be compared with the conventional gas turbine power generation method. Further, from an economical point of view, the technique entails lesser capital expenditure than that of a conventional turbine system. The source of onshore power supply is from the Norwegian national grid. In addition, the technique will help to reduce 50% to 60% of the total emission to air from the offshore platform. The technique also helps to minimize noise pollution and potential risk of accidents.

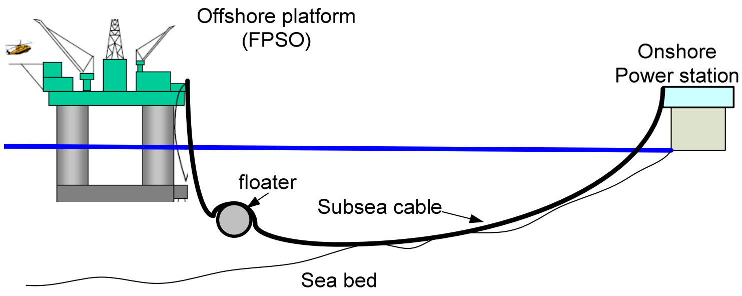

Figure 6: System overview of power supply from shore to offshore oil and gas platform.

Most of the operating companies have formally defined project phases and associated decision gate processes when passing from one phase to the next in the project development process. As per the requirements given in NORSOK – 003 [6], it is important to identify key HSE aspects in each project phase and especially to evaluate all possible concepts that could be relevant as early as possible in order to avoid later costly modifications.

Preparation of an Environmental Impact Assessment (EIA) for the selected technique and approval of the EIA document are required in the project development process. Similarly, it is necessary to identify the requirements of new techniques or whether to move with conventional techniques in the project planning stage. Further, it is also important to examine whether potential improvements can be achieved with aid of a new technique at an early stage in the project development. Then, the technique qualification process can be performed as an integral part of the project development process. However, technical qualification is also a key requirement in this case if the technique itself has limited field history and is going to be applied in a new environment.

The electrification technique as a whole can be classified as class 3 category according to the classification given in DNV-RP-A203. In addition, for the main technology elements, it is important to identify whether there is an absolute need for the new technology or if there is a fallback solution. Figure 7 shows the involvement of the technical qualification process in the project development process for supplying power from shore to offshore.

According to Figure 7, the technical assessment has to be performed in the feasibility phase prior to getting approval to start the concept selection phase. The assessment helps to identify the level of maturity of the technique, based on the classification given in Figure 4. For instance, power supply from shore to offshore can be considered as a new technique, according to the classification. In the concept selection phase, the technical qualification process has to be performed as described in Figure 5. This process consists of breaking down the whole system into elements, identification of requirements and specifications, analysis of functional failures of each element, etc. The qualification process has to be completed before the detail engineering process can start. Finally, the technique is required to be qualified as a whole considering the BAT evaluation,

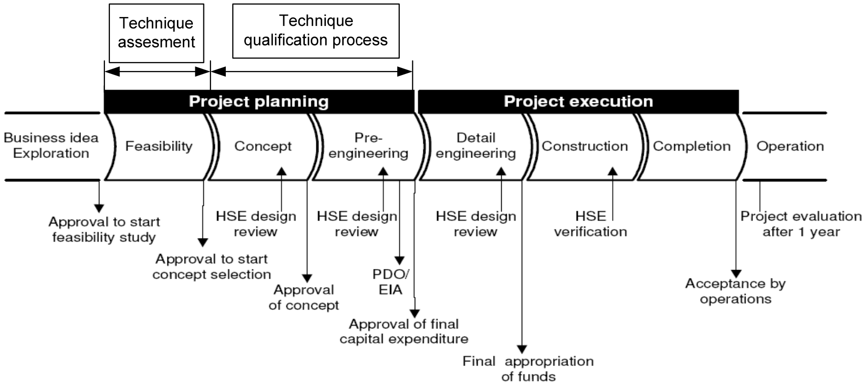

Figure 7: Use of technical qualification in project development process [8].

summarizing the results obtained from the analysis of each technological element. However, the time restriction involved in completing all testing activities at the right phase of the project would make it a challenging task. Therefore, it is necessary to prioritize the most important activities to be completed within the available time frame.

5 Discussion and conclusions

Major sources of emission to air from the Norwegian offshore oil and gas industry are from the power generation systems of the offshore facilities. Various mitigation measures have been identified to achieve country emission targets by means of introducing legislation, permit conditions, regulation, etc. as well as applying reasonably practical measures. However, the offshore oil and gas activities on the NCS are moving toward arctic or semi arctic conditions. Hence, operators will face challenges due to lack of experience working in such a harsh, sensitive and remote environment. Further, the situation is even more complex with the requirement of satisfying the pollution to sea regime requirements. Under these circumstances, technique qualification is playing a key role to satisfy the regulatory requirements and develop confidence in the technique.

The illustrative case study shows how an operator company can use the technology qualification program in a project to improve system reliability in the project development process for the utmost benefit of the project. Finally, both the BAT evaluation and the individual assessment of each element via a technical qualification procedure will help to qualify the technique as a whole for the particular purpose. However, the time it will take to complete the entire process might be a challenge during the project development process. Therefore, it is necessary to have a method to prioritize the most important activities within the project completion time.

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