M-665 | 2016

Cold venting and Fugitive Emissions from Norwegian Offshore Oil and Gas Activities

Module 3A report
Best available technique (BAT) assessments

Prepared for the Norwegian Environment Agency

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15.12.2016

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M Number	Year	Pages	Norwegian Environment Agency contract number
M-665|2016	2016	17	14088187

Publisher

The Norwegian Environment Agency

Financed by

The Norwegian Environment Agency

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Title

Cold venting and Fugitive Emissions from Norwegian Offshore Oil and Gas Activities
Module 3A - Best Available Techniques (BAT) assessment

(Translation of Norwegian report M-512I2016)

Summary

Based on the survey of emission sources in Module 1 of this project, possibilities for emission reduction were assessed. For new installations, best available technique (BAT) for each potential emission sources are suggested. For most of the major emission sources BAT will be the recovery of the hydrocarbon containing waste gases.

Economy is also an element of BAT. For facilities in operation, cost of rebuilding to what is BAT for new installations could be substantial. Since cost of such modifications are governed by conditions on the individual installations, BAT for installations in operation could vary significantly from facility to facility. A general scheme of BAT for installations in operation can therefore not be proposed. If such facilities will be rebuilt to meet the proposed BAT solutions of new installations, it is recommended to prioritize the measures with the lowest abatement cost.

Four Subject words

Direct emissions, methane, NMVOC, BAT

Front page photo

Heimdal. Source: Statoil, photographer: Øyvind Hagen

Summary and conclusions

The purpose of this report is to assess and propose "best available techniques" (BAT) for reduction and minimization of the direct emissions of methane and NMVOC from Norwegian offshore installations.

During module 1 and module 2 of this project a total of 48 processes/sub-processes producing HC waste gases which could potentially be emitted to the atmosphere were identified. BAT (Best available technique) have been evaluated and proposed for all the individual processes. The results are summarized in this report.

The study documented that recovering waste gases by recycling back to the process is a well-proven technique which can be used for most of the potential emission sources (processes and sub-processes) producing waste gases with methane and NMVOC. For all of the processes where recovery of waste gases is possible, it is identified that at least one Norwegian installation has chosen this solution. The survey also found that almost all existing Norwegian installations send waste gases with methane and NMVOC to the atmosphere as emissions from one or more sources, even if recovery was possible. On some installations, the emission option is selected for several of the processes that generates potentially recoverable HC waste gases. However, technical or cost related restrictions on these installations could have favoured the emission option.

When developing/constructing new facilities, recovery of the hydrocarbon containing waste gases from potential big emission sources can be regarded as BAT.

However, there are some processes/sub-processes where recycling is not possible with the current technology and methods. These are mainly processes/sub-processes with smaller emission potential. The largest of these are emissions from flaring due to safety reasons and maintenance work, gas leaks and spills in connection with the inspection of oil tanks on FPSOs. No technology or techniques have been identified that make it possible to eliminate these emissions. For some processes and installations it is not possibile to reduce emissions.

Modification of existing installations to BAT solutions could in many cases be costly. Piping systems must be altered; low pressure compressors must be installed on many of the installations, and safety and engineering challenges must be solved. Since all individual facilities are constructed differently, the reconstruction work could vary significantly from facility to facility, to supposedly solve the same problem. This might involve that a low-cost measure for one installation may be a high-cost measure for another installation.

When such modifications involve physical work in process areas, re-construction work should be carried out during planned facility shutdowns. If re-construction cannot be carried out under normal shutdowns, production must be shut down specifically for the modification work. If installations will be modified to meet the proposed BAT solutions it is recommended to prioritize the measures with the lowest abatement cost. This will in most cases be measures that focus on the largest emission sources.

Delayed ignition of flare seems to be one of the biggest sources of direct emissions. This is largely due to inefficient ignition systems. The industry is therefore recommended to improve the current ignition systems or develop new ones that both ensures rapid ignition of flare gas (within a few minutes), and are safe and reliable under all weather conditions.

Content

1 Introduction

The petroleum activities on the Norwegian shelf lead to emissions of methane and non-methane volatile organic compounds (NMVOC) to the atmosphere from a variety of emission sources. The reported direct emissions of methane and NMVOC amounted to approximately 71% of the total methane emissions and about 18% percent of the total nmVOC emissions from the sector in 2012.

The Norwegian Environment Agency has engaged *add novatech as* to improve our understanding of these emissions. The project comprises three modules. The first two modules focused on extensively identifying/mapping emissions and emission sources, and providing suggestions for improved emission calculation methods.

In Module 3 of this project, the possibilities for reducing these emissions were investigated. The work is documented in two reports.

- Module 3A BAT-assessments.
- Module 3B Potential for emission abatement and reduction.

This report comprises Module 3A.

2 Direct emissions of HC-gases

Hydrocarbon gases, referred to as HC-gases, are classified under two emission groups, methane (CH_4) and NMVOC (Non-Methane Volatile Organic Compounds). There are a number of processes and sub-processes in oil and gas production which gives waste gases that completely or partially comprise of HC-gases. These waste gases are called direct emissions if they are emitted to the atmosphere via the so-called atmospheric vents/cold vents or as fugitive emissions.

Atmospheric vents are dedicated piping systems with a defined emission point. This may be emission pipes that collect waste gases from several sources. In such cases, they are often named atmospheric common vents. Atmospheric common vents often (but not always) have their release point (to the atmosphere) a short way up the facility's flare boom, in some cases at the very top of the boom, along with the flare tip.

Some processes/sub-processes send the waste gas from the source directly to the atmosphere without mixing it with other waste gases from other sources. Emissions occur in a safe location at the facility. Such emissions are often called local vents.

Reduction of direct emissions of HC-containing waste gases is not usually a matter of employing better technologies. In most cases, the choice is of practical solutions where the exhaust gas is either returned to the process and recovered, or sent to flare where it is burned. In both cases, direct emissions of methane and NMVOC are eliminated from the actual process. Compared with flaring recovery, it is a better environmental option since flaring will result in the release of exhaust gases like CO_2 and NO_X.

3 Best available techniques (BAT)

3.1 BAT on offshore installations

The EU's indistrial emissions directive (Ref: 3) defines BAT (Best Available Techniques) as follows:

"*Best AvailableTtechniques" means the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole:*

- *"techniques" includes both the technology used and the way in which the installation is designed, built, maintained, operated and decommissioned;*

- *"available" means 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" means most effective in achieving a high general level of protection of the environment as a whole.*

There is no established BAT for the problems being faced with the direct emissions of methane and NMVOC from offshore production facilities. Therefore all emission sources are assessed individually and suggestions for BAT is presented.

Whether a technique or method is BAT therefore requires that it is qualified and preferably tested against the type of issues faced. In addition, the cost of implementing the technique must be reasonable in relation to the environmental benefits that will be achieved.

BAT has been evaluated and recommended for those processes and sub-processes that generate direct emissions of methane and NMVOC in the Norwegian offshore installations. This assessment is made on a general basis. To decide if a measure that is generally considered as BAT will be BAT for a specific installation, it should be assessed whether the technique is convenient for the specific installation, and if the costs of the benefit will be a factor in the assessments (installation specific BAT assessment).

Direct emissions of the HC-gases methane and NMVOC occurs only from processes or sub-processes that generate HC-containing waste gases. In module 1 of this project (Ref: 1) it was identified that a total of 48 processes and sub-processes can generate hydrocarbon containing gases. Most installations have only a fraction of these processes/sub processes, and no installation has all.

The assessment has shown that BAT for a variety of processes and sub-processes involves recovering the waste gas by recycling it back to the main process at the facility, or burning the waste gas in flare. Since recovery normally gives a ,smaller overall environmental impact than burning in flare (which generates greenhouse gas emissions), the recovery solution is considered as BAT in most cases. If it can be documented that recovery is not possible without unreasonable additional costs or inconveniences, then flaring could be BAT.

The survey which was conducted in Module 1 and 2 of this project showed that one should differentiate between construction of new installations and modification of existing ones while considering BAT. For many of the processes and sub-processes identified, it will be possible to eliminate emissions of waste gases primarily by recovering the gas by recirculation to process or secondarily by flaring the waste gas. The fact that such measures are taken in the design/construction phase of many installations, is taken as evidence that such measure could be implemented within reasonable and acceptable costs compared to the design option that gives emissions, in many cases also without adding additional costs. This means that BAT for new installations is recovery of waste gases from a series of processes and sub-processes, resulting with the elimination of such emissions.

For facilities in operation, the situation is different. Implementing technical solutions so that the waste gases can be routed to recycling or flare can be a complicated, extensive and costly process. In its simplest form this could mean modifying the piping systems. In many cases, other factors could apply and affect what must be done, controlled by the conceptual technical solutions chosen when the plant was built. This can be:

- Pressure conditions which requires that new low-pressure compressors must be installed.
- Pressure conditions which makes both recovery and flaring difficult. This can put at risk equipment operating at atmospheric pressure for pressure build-up with backflows (which can lead to major modifications).
- Contamination of inert gases in the waste gas which makes recovery and/or flaring difficult.

Such modifications would not normally be carried out during production. This means that re-construction must either be carried out during a planned shutdown or the facility must be shutdown specifically to carry out the necessary work. Planned shutdowns take place in most cases every third year (in some cases every second or every fourrth year). If the work will be done during a shutdown, then it must must compete with other tasks/work that will be done during the shutdown, or it may lead to the extension of the shutdown time to allow sufficient time to carry out the modofication work. These conditions mean that in addition to the cost of the modification alone, additional costs and loss of revenue due to production shutdown may emerge.

Since BAT is also a matter of cost (often presented as abatement cost), measures should primarily be implemented where there is the most emission reduction per kroner. This indicates that what is considered as BAT for new installations, does not necessarily need to be BAT for already existing installations. Because existing installations may have significantly different conditions, BAT should be considered at the individual installation level, and by operating company.

Development and qualification of new technologies and new methods can lead to changes on what is considered as BAT over time.

3.2 Table overview of the individual sub-processes

Emission reduction possibilities are evaluated for the identified processes that can potentially give emissions. BAT is proposed for each emission generating sub-process.

Table 1 provides a simplified overview of what can be considered as BAT for the individual processes and sub-processes. It is based on new installations. The processes and sub-processes which can be deigned without direct emissions of methane and NMVOC are presented with green cells in the table. Additional costs to achieve this will determine if emission-free solutions for the individual sources are BAT.

For existing facilities, theoretically the same result could be achieved. However, extensive reconstruction/modification work and possible production shutdowns could make the measure very costly compared to emissions reductions achieved. Therefore it can not automatically be assumed that what is proposed as BAT for new facilities is also BAT for existing facilities.

A detailed presentation for each process is given in Chapter 3.3.

Table 1 Table overview of BAT and estimated emissions (2014)[1] (green cells represent sources/sub-sources which can be technically eliminated)

Main process	Sub-process	Proposed BAT	Estimated emissions (t/year)	
			Methane	NMVOC
TEG regeneration	Degassing tank	Recovery	0	0
	Regenerator	Recovery	220	660
	Stripping gas	Recovery	310	260
Produced water treatment	Degassing tank	Recovery	300	40
	CFU / atm. Flotation tank	Recovery	50	50
	Flotation gas	Recovery	200	50
	Discharge caisson	Reduce pressure in the upstream degassing tank Recovery	1 730	440
Seal oil centrifugal-compressors	Degassing pots	Recovery	Unknown	Unknown
	Holding-/storage tanks	Recovery	160	160
Dry compressor seals	Primary seal gas	Recovery of waste gas	2 280	1000
	Secondary seal gas	Use N_2-gas as seal gas When HC-gas as seal gas: Recovery	20	10
	Leakage primary → sec seal gas	Use leak-proof seal gas system (internal labyrinth)	180	90
Seal oil reiprocating-compressors	Separator chambers	Recovery	750	130
	Shaft house	Recovery	3	3

[1] The figures refer to emission at the current situation and represents the total for all offshore installations.

Main process	Sub-process	Proposed BAT	Estimated emissions (t/year)	
			Methane	**NMVOC**
Flare gas not burnt	Extinguished flare/ ignition of flare	Ensure the use of effective ignition mechanisms	Unknown	Unknown
	Non-combustible flare gas	Recycling of waste gas from sub-sources with no or low levels of HC gases	Incl. under produced water and amine regeneration	Incl. under produced water and amine regeneration
	Open cold flare purged with inert gas	This will be a trade-off between CO_2 and CH_4/NMVOC emissions	1 510	580
Gas leaks	Bigger leaks	Improved leak detection– training and practice	1	1
	Smaller leaks/fugitive emissions	Improved leak detection– training and practice	1 250	950
Amine regeneration		Injection to underground	95	40
MEG regeneratino	Degassing tank	Recovery	0	0
	Regenerator	Recovery	25	70
	Stripping gas	N_2 as stripping gas	0	0
Drilling	Mud separator	Recovery[2]	57	57
	Shale shaker	Shaker operated in vacuum		
Gas analysators		Side stream to recovery	71	54
Crude oil storage tanks on FPSOs	Gas freeing during inspection	Flare until flaring stops	71	55
	Abnormal operating conditions	Flare until flaring stops	Unknown	Unknown
Storage tanks for diesel and other oil		Recovery	0	4
Gas freeing of the process	Gas freeing	Flare until flare extinguishes	18	16
Purge and blanket gas	HC-gas	Change gas to N_2	1 100	1 300
Flexible risers		Recovery	2	2
DBB valves		Connect to flare	1	1
Gas turbines	Purging/ depressurisation	Recovery	< 1	< 1
Depressurisation/gas freeing of instruments/instrument bridles		Maximize the use of flaring	<< 1	<< 1
Corrosion coupons	Pulling	Emission free pulling technology	<< 1	<< 1
Pig launchers and receivers	Gas freeing	Recovery	4	2
Depressurization of production riser annulus bleed		Recovery	<< 1	<< 1t

[2] Only possible on production facilities, not on mobile offshore drilling units.

Sources/sub-sources with 0 (zero) emissions: No emissions found during the survey. This means that BAT is used in the installation which has waste gas from the source.
In Table 1 estimated emissions per year from individual processes and sub-processes are given to put the abatement measures in perspective. Emission figures are taken from the Module 2 report of this project (Ref: 2) and represents emissions in 2014. For several of the sources more reliable emission figures will be established when new quantification methods are used, probably from 2017. This also applies to the sources where emission figures are given as "unknown".

3.3 Proposed BAT for the individual emission sources

3.3.1 TEG Regeneration

18 installations on the Norwegian shelf recover waste gas from the degassing tank and 9 installations from the regenerator. This shows that recycling is an approved and tested method for eliminating emissions. If fuel gas is used as the stripping gas, it can be recovered along with boiled off-gas from the regenerator.

If a cooler is used for separating water from the waste gas after the regenerator, the waste gas from the liquid separator after the cooler can be recovered. This practise is used on many facilities. Some of the NMVOC is condensed and follows the water to the produced water treatment system.

For existing facilities recovery of waste gases will be a matter of cost.

Proposed BAT for TEG-regeneration:

New facilities	Recovery of waste gases both from the degassing tank and boiler
Existing facilities	Recovery is technically possible, but can have high abatement cost

3.3.2 Produced water treatment

Waste gases from the degassing tank, compact flotation plant (CFU) and traditional flotation plant can be recovered. This is done on most facilities on the Norwegian shelf that have produced water treatment. Modification of existing facilities which do not employ recovery or flaring of waste gases can result in high abatement cost.

Emissions from discharge caisson[3] accounts for a significant part of the emissions from the produced water treatment. Discharge caisson is the discharge pipe for produced water. The end of the pipe (discharge point) is, in most cases, below sea level and in some cases right above. The discharge pipe is equipped with a ventilation pipe to prevent the formation of negative pressure in the pipe. For one installation the operator claimed that waste gas from the discharge caisson is recovered. From the remaining 45 offshore installations, the waste gas goes to atmospheric vent. Low pressure means that a low-pressure compressor must be installed to recover this gas. Such low-pressure compressors are used for other emission gases with equivalent low pressure.

Another solution is to operate the upstream degassing plant (degassing tank/CFU) at the lowest possible pressure (marginally above atmospheric pressure). This will reduce emissions from the discharge caisson significantly.

[3] Discharge caisson is the discharge pipe for produced water. The end of the pipe (discharge point) is in most cases below sea level, in some cases right above. The discharge pipe is equipped with a ventilation pipe to prevent the formation of negative pressure in the pipe.

For existing facilities, the situation is as for TEG regeneration.

Proposed BAT for produced water treatment:

New installations	Recovery of waste gases both from the degassing tank CFU/traditional flotation plant and discharge caisson Reducing the pressure in the degassing tank.
Existing installations	Recovery is technically possible, but can have high abatement cost Reducing the pressure in the degassing tank.

3.3.3 Seal oil centrifugal compressors

On most facilities on the Norwegian shelf that have centrifugal compressors with seal oil, waste gas is recovered from the degassing pots in the seal oil system. 1 of 17 installations with such compressors also recovers waste gas from the seal oil holding/storage tanks. This shows that technology and methods are available, and BAT for the new installations is therefore recovery of all waste gases.

Developments in compressor technology, however, means that seal oil is no longer BAT. Today compressors with dry seals (gas seals) have mostly replaced the older compressors with seal oil, including on the Norwegian shelf. Rebuilding older compressors with oil seals to gas seals is expensive, and will lead to production stoppages if the work cannot be done during planned shutdowns.

Proposed BAT for centrifugal compressors:

New installations	Dry compressor seals
Existing installations	Recovery is technically possible, but can have high abatement costs

3.3.4 Dry compressor seals

Sealing technology for dry compressor seals that can eliminate HC emissions is currently available and is used in a relatively large degree on the Norwegian shelf. This requires:

- Use of a barrier design which prevents leakage from the primary barrier vent to the secondary barrier vent. Recovering primary barrier gas (HC gas)
- Using N_2 as the secondary barrier gas
- If the HC gas is used as a secondary barrier gas: recovering it

For existing installations modification can be expensive and lead to production stop.

Proposed BAT for dry compressor seals:

New installations	Internal labyrinth / no leakage from primary vent to secondary vent. Recovery of all HC barrier gases from vent openings
Existing installations	Recovery is technically possible, but can have high abatement cost

3.3.5 Reciprocating compressors

There are 4 facilities with reciprocating compressors on the Norwegian shelf. In 3 of these, waste gases are completely or partly released to the atmosphere. On one of the installations waste gas from at least one compressor goes to flare, while recovery is not used in any offshore facilities.

The working principle is to some extent the same as in centrifugal compressors with seal oil. Seal oil and leaked gas are collected in one or more separator chambers where the gas is separated from the oil. Gas may further leak into the shaft house where the gas is also separated. The problem is how this gas is handled. Principally, and in practice, there is no difference in this waste gas and other waste gases at low pressure. The gas can technically be recompressed and recycled to the process to meet BAT. This technology exists and is used on the Norwegian shelf.

This solution can be described as BAT for new installations. For existing facilities, this could lead to expensive modifications.

Proposed BAT for reciprocating compressors:

New installations	Recovery by re-compression and re-circulation of the waste gas
Existing installations	Recovery is technically possible, but can have high abatement cost

3.3.6 Flare gas not burnt

Delayed ignition of flare after it has been extinguished is a source of direct emissions of flare gas. Today there is no data that makes it possible to quantify these emissions. Therefore it is unknown if this is a significant contributor to the direct emissions of methane and NMVOC. The challenge is greatest in facilities that have closed flare, since they have a higher ignition frequency than flare that is continuously burnt. Moreover, the ignition of a closed flare would normally occur when a situation that increases the flare rate arises.

Lack of reliable systems that ensure rapid ignition of flare has been seen as a problem for years. The survey conducted with this project showed that the delayed ignition of the flare could to be one of the most significant sources of direct emissions of methane and NMVOC.

So far it does not seem that adequate solutions have been developed. The ignition methods chosen on the Norwegian shelf have been considered BAT until now, but experience shows that there may be room for improvement. The industry is therefore recommended to improve current ignition systems, or develop new ones which ensure faster ignition of flare gas (within a few minutes), and are also reliable in all conditions.

Non-combustible flare gas is an emission source that exist only on one facility. The reason is that one of the continuous sub-sources of flare gas contains so much non-combustible gas (CO_2, N_2, H_2O, etc.) that the gas is not flammable. Elimination of emissions is technically possible by reinjection of waste gas from the continuous sub-sources that holds inert gas. However, this is such a costly solution that it is unlikely to be financially viable.

Re-routing of waste gases from the non-inert gas containing sub-sources to recycling and recovery will reduce emissions. This was in fact done by an operator in 2015.

Methane and NMVOC emissions from inert gas purged open flare can be eliminated by installing a pilot flame and by changing the purge gas to HC-gas in the flare system. However, this will result in CO_2 emissions. A trade-off between the environmental benefits and drawbacks will decide what is BAT for new installations. For facilities in , modification costs will also play a role.

3.3.7 Gas leaks

As pointed out in the Module 2 report (Ref: 2) leaks of hydrocarbon gases from flanges and valves are not primarily a technological challenge. There is a considerable focus on leaks with regards to the safety aspect, resulting in the inspection of components and monitoring of valves, flanges and other components that can be sources of such emissions. The survey showed that the big gas leaks are predominantly due to human error, while wearing can be an important cause of small gas leaks.

EU's Refinery BREF (Ref: 4) specifies techniques as:

- Reducing the number of flanges (connectors), valves and screwed connections
- Reducing the number of pumps
- Closed drainage systems
- Using closed or "in-line" sampling systems
- Use of stuffing boxes with double barrier on valves
- Using high integrity seal rings
- Using pumps and compressors with mechanical seals
- Using pumps/compressors with magnetic drivers
- Using materials that are suitable for the properties of the liquid or the gas.

Some, but not all of these measures, are related to leaks. It has not been checked whether all these measures are in place on the offshore installations, but many are standard. However, there are some techniques that are not useful because they are not available in the right dimensions, pressure and temperature conditions for the offshore installations.

There is therefore no reason to assume that the flanges and valves used by the industry are not BAT, but it is also necessary to have a big focus on leak detection and maintenance to operate as BAT.

3.3.8 Amine regeneration

Aminoacyls are used as absorbents to remove CO_2 (and H_2S) from gas prior to export in two facilities on the Norwegian shelf. CO_2 is dissolved in amine and then removed from it by depressurization and boiling. Along with CO_2 (and H_2S) smaller amounts of methane and NMVOC are also dissolved in the amine solution. Compared with CO_2, the amount of methane and NMVOC is small. On one of the facilities, the methane and NMVOC containing CO_2-rich waste gas is injected underground. This is indicated as BAT in Table 1.

On the other installation, the amount of CO_2 is so small that injection was not selected as a disposal solution because of the associated high abatement cost. Waste gas with CO_2 and smaller amounts of methane, NMVOC (and H_2S) is therefore discharged to air.

If new facilities with a process for reducing CO_2 content from natural gas are to be built in the future, use of BAT (i.e. injection of waste gases) will be a trade-off between the environmental benefits and the relatively high investment cost for building a re-injection plant.

Waste gas from an amine regeneration plant consists of several waste gases (CO_2, SO_2, methane and NMVOC). Separation and recovery of HC-gases from the other waste gases is very expensive. Flaring is not a feasible solution, since the content of CO_2 and other non-combustible gases in the waste gas is so high that the waste gas cannot burn. This is, therefore, primarily a disposal challenge. Mitigation solutions other than injection in form of disposal underground, are not identified.

Proposed BAT for amine regeneration:

New installations	Re-injection underground. This applies only to big amounts of CO_2 May involve high abatement costs.

3.3.9 MEG Regeneration

Monoethylene glycol (MEG) is primarily used to bind water from pipelines and flowlines to prevent hydrate formation. MEG is 100% miscible with water and is separated along with the water in the oil and gas separators at the facility. Small amounts of methane and NMVOC dissolve in the MEG/water mixture. There are 3 facilities on the Norwegian shelf that have MEG regeneration units. In the regeneration process, dissolved methane and NMVOC in the waste gas from the degassing tank and the regenerator is removed. The waste gas from the degassing tank is recovered on 1 installation and is sent to the flare on another, while the waste gas from the regenerators is sent to air via atmospheric common vent from all 3 installations. This gas may be recovered if the facility has a low-pressure compressor (VRU), which is available on some of the new installations. For facilities that are in operation today, it will be necessary to modify the pipeline systems and to install a low-pressure compressor if such systems are not already available.

It should be noted that the waste gases can contain significant amounts of water, especially from the regenerator (boiler). Recovery will therefore also result in recirculating the water in the gas phase back to the process. This water will be separated out in the separators and will follow the produced water discharge stream to sea.

Proposed BAT for MEG-regeneration:

New installations	Recovery of waste gases from the degassing tank and regenerator (boiler)
Exisiting installations	Recycling technically possible, but may involve high abatement costs

3.3.10 Drilling

Direct emissions from drilling takes place from two sources; mud separator and shale shaker.

Waste gas from mud separator is on most installations routed to the top of the drilling tower where it is directly released to the atmosphere. For production facilities, re-routing of this to recovery will require modification of the pipeline systems and possibly installation of a low-pressure compressor. Installations built for drilling only do not have flares or processing facilities which enable gas recovery.

Waste gas from shale shaker is as much a problem for the working environment as it is for the external environment. New closed vacuum shakers, which are now being used in the industry, collect waste gas and lead it to a safe location where it is released directly to the atmosphere. Recovery and flaring is difficult since the gas may contain large amounts of air.

Proposed BAT for mud separator:

New installations	Recovery of waste gases
Existing installations	Recovery technically possible, but may involve high abatement cost

The ongoing work on developing shale shakers suggests that closed vacuum shakers are BAT today. Whether any of these developments can handle hydrocarbon-containing waste gases in such a way that they can either be recovered or flared will require more extensive surveys.

It should also be noted that the emissions of methane and NMVOC are relatively small, especially from the shale shaker unit.

3.3.11 Gas analysers

The challenge with gas analysers primarily emerges on facilities where the gas samples for analysis are taken from a continuous side-stream, which is continuously discharged to an atmospheric vent. On some facilities in the Norwegian shelf, gas samples for analysis are either directly taken from the main pipe, or from a side-stream which is kept closed when analysis gas is not taken. This must be considered as BAT for the Norwegian continental shelf and this reduces emissions from a magnitude of tonnes/year to kg/year or grams/year compared to facilities that have continuous emissions from the side-stream.

The amount of gas passing through the analyser is normally directly released to air, but the amounts are so small (mg per analysis) that this cannot be considered as a significant emission source.

Proposed BAT for gas analysers

New installations	Take the gas samples for analysis directly from the main stream
Existing installations	Modification/rebuilding the analysis station

3.3.12 Crude oil storage tanks on FPSOs

Storage tanks on FPSOs must be inspected every five years in accordance with the Norwegian regulations. This means that the tanks must be freed from oil and hydrocarbon gas.

The tanks are filled with fuel gas (blanket gas) after being freed from oil and then go through a two-step gas freeing process. In step 1 the fuel gas is displaced with inert gas (typically an exhaust gas) which is then displaced with air in step 2. The displaced gas is released to air. In step 1, the waste gas will be a mixture of fuel gas and inert gas where inert gas content will steadily increase. This waste gas cannot be recycled since it is contaminated with exhaust gas. If it is sent to flare, the inert gas will eventually extinguish the flare.

In this project, no technologies or methods that can possibly eliminate or radically reduce emissions are identified. Lowest emissions are achieved by leading the waste gas from step 1 to flare until the flare is extinguished. All FPSOs have low pressure compressors (VRU-compressor). Some modification/rebuilding work on the piping system might be required to send the gas from the VRU compressor to flare. In addition, flaring conditions will determine to what extent the emissions can be burned in the flare. There are no data which can be used to estimate this. Environmental benefits are therefore uncertain. Some of the FPSO's may already have established direct connection to flare.

Proposed BAT for Crude oil storage tanks on FPSOs

New installations	Installing piping systems from downstream VRU compressor to low pressure flare
Existing installations	Installing piping systems from downstream VRU compressor to low pressure flare. This should be carried out during a planned shut-down to avoid production loss. May involve high abatement cost. (Applies for FPSOs that do not already have such arrangements)

3.3.13 Storage tanks for diesel and other oil

These tanks are vented directly to the atmosphere on most facilities today. This is also a common practice onshore. Recovery will be technically possible by routing the waste gas pipe back to the low-pressure section of the process. This will likely require that HC gas (preferably fuel gas) is used as blanket gas in the tanks, which will increase the abatement costs. For installations that do not have a VRU compressor, the abatement costs will be higher than for those which already have such a gas compression system.

Emissions from this source are very small. Abatement costs of waste gas recovery are therefore believed to be very high. Diesel and oil tanks onshore in Norway also vents to the atmosphere. The solution is therefore considered as BAT.

Proposed BAT for storage tanks for diesel and other oil

New installations	Today's solution -vent to the atmosphere
Existing installations	Today's solution -vent to the atmosphere

3.3.14 Depressurisation of the installation

In the depressurization process under shutdowns the entire process, or part of the process, must be freed from gas and a mixture of HC gases and inert gas is flared until flare is extinguished (as a result of the declining content of the HC gases). What is left of the HC gases is then discharged through the flare stack as direct emissions.

It has not been identified if there are possibilities to either eliminate or reduce these emissions. It is, therefore, concluded that the method used by operators today is BAT.

Proposed BAT for depressurisation of the installation

All facilities	Depressurize towards flare and send the gas mixture to flare under gas freeing until flare is extinguished

3.3.15 Purge and blanket gas

Both HC gas (mostly fuel gas) and inert gas (nitrogen, N_2) is used as purge and blanket gas. In most cases where fuel gas is used, it is recycled back to the process and recovered, thereby avoiding emissions. In some cases, however, it is discharged as direct emissions.

In situations where the waste gas can hardly be recovered or flared, nitrogen (N_2) is maintly used as purge and blanket gas. In some cases, the waste gas is sent to flare. The main adopted solution is, however, sending the waste gas to air as direct emissions, mainly through common atmospheric vent.

Based on the status on the Norwegian shelf today, direct emissions of purge and blanket gas could be virtually eliminated on new installations, by recovering the gas when HC gas (fuel gas) is used and by using nitrogen wherever gas recovery is not possible.

For facilities in operation, implementing modifications to recover hydrocarbon purge and blanket gas, or to use $N_{2,}$ may result in changing the piping systems and in some cases also to the installation of a low pressure compressor. If modifications can not be done during planned shutdowns, production shutdown might be necessary. Abatement costs will therefore depend on both the cost and the achieved environmental benefits.

Proposed BAT for purge and blanket gas

New installations	Route the HC waste gas to recovery and install a VRU-compressor. Use Nitrogen as purge and blanket gas where HC-gas is not suitable or cannot be recovered
Existing installations	Same as for new installations, but installations should take place during a planned shutdown to avoid production shutdowns. May involve high abatement cost

3.3.16 Flexible risers

Modern flexible risers have gas bleeding valves at the facility connection station. Waste gas from here is sent to recovery or flaring so that emissions are avoided. This is regarded as BAT and is used on multiple installations on the Norwegian continental shelf.

Proposed BAT for flexible risers

New installations	Ensure connections for the waste gas from the bleeding valves to the low pressure side of the oil/gas process
Existing installations	For facilities that do not have such a connection, this can be set up under planned riser replacement operations

3.3.17 DBB valves (Double Block and Bleed)

Connecting the bleed valve to flare system is common for larger valve stations. Recovering the gas by recycling it to low pressure gas process is not necessarily adequate since bleeding may occur during periods when the gas system is not in operation. Flaring is therefore considered as BAT.

Connecting the valve to flare system will be a matter of valve size. Where bleed valves are already routed to atmospheric common vent, there would not be any specific additional costs for routing the bleed to flare. For very small DBB dimensions, where currently only local venting of bleed is present, connecting to flare will be a matter of cost and benefit. Emissions from very small DBB valves will naturally be small.

Proposed BAT for DBB-valves

All installations	Connect the bleeding valve to low pressure flare for most possible DBB-valves. May lead to high abatement cost

3.3.18 Gas turbines

Waste gas from turbines due to gas purging and depressurisation/bleed is in many cases routed to atmospheric common vent. Routing to flare is practiced in offshore installations and should be considered as BAT. Recovery of gas may be irrelevant in situations where the turbine is shut-down due to production shut-down.

For existing facilities that bleed to atmospheric vent, this will require modifications that can be time consuming and expensive, especially if it cannot be carried out under a planned shut-down.

Emissions are very small.

Proposed BAT for gas turbines

All installations	Connect the waste gas system to flare. May involve high abatement costs

3.3.19 Purging & maintenance of instruments/instrument bridles

This is a very small emission source which can involve many components. For new installations, BAT should be considered as connecting as many instruments to flare as is practically and economically feasible.

This is a very small emission source. Modification of existing facilities to achieve a slight reduction in emissions is therefore regarded as having little effect.

Proposed BAT for instrumenter instrument bridles

New installations	Connect as many instrument systems as possible to flare

3.3.20 Corrosion coupons

Corrosion coupons are some metal elements attached to equipment or pipes to measure the corrosion rate. Today there are techniques available that make it possible to pull corrosion coupons without emissions. These techniquies are used in several installations on the Norwegian continental shelf. Although emissions from this source are very small, it is recommended that such techniques are also used on all new installations hereafter.

Because emissions are small, it is highly uncertain whether implementing modifications in exisiting facilities to employ these techniques may be done at an acceptable abatement cost.

Proposed BAT for corrosion coupons

New installations	Installing corrosion coupon stations that enable the use of pulling-gear that prevents gas emissions

3.3.21 Pig launchers

During the first survey only 2 facilities were found to have emissions from pig launchers. This indicates that pig launchers on most facilities are depressurized at low pressure tanks on the gas side of the process, or to flare. Gas freeing takes place at the ignited flare. Pig launchers are gas freed at an atmospheric common vent on the two installations with emissions from this source.

BAT is therefore considered as practices used by the majority of the installations which do not lead to emissions of methane and NMVOC. Existing installations that gassfree pig launchers against atmospheric common vent are assumed to have connections to flare already, so that the gasfreeing towards flare should be possible without any modifications.

A dilemma may arise if the facility has closed flare and recirculation (from flare). Waste gas from the gas-freeing process of the pig receiver will consist of natural gas mixed with inert gas from the gas-freeing process and may, in some cases, cause unacceptable contamination of the sales gas. If closed flare is ignited during the gasfreeing process of the pig receiver, there is a risk of releasing natural gas in the form of direct emissons, until the flare is ignited. These emissions can exceed the amount of natural gas coming from the pig receiver alone.

Proposed BAT for pig launchers

New installations	Arrange the piping system so that the maximum depressurisation of the pig receiver can take place in the low pressure gas process. Gas freeing would take place at the ignited flare.

3.3.22 Annulus bleed from production strings

Waste gas which is bled-off by depressurizing the annulus is, on most installations, led to local vent. Routing waste gas to recovery or flare is common today for newer installations, and should be easily facilitated for new installations yet to be built.

For existing production facilities this may require some modifications of the piping systems and can lead to production shut-downs, if the work cannot be accommodated during planned shut-downs. Emission quantities are small.

Proposed BAT for annulus bleed from production strings

New installations	Route the bleed gas to recovery/flare
Existing installations	Same as for new installations, but may lead to high abatement costs

4 References

Ref: 1 *«Cold venting and fugitive emissions from Norwegian offshore oil and gas activites - Module 1-Surveying installations to identify potential emission sources» add novatech for Norwegian Environmental Agency, 2015.*

Ref: 2 *«Kaldventilering og diffuse utslipp fra petroleumsvirksomheten offshore - Modul 2 Utslippsmengder og kvantifiseringsmetodikk» add novatech for Norwegian Environmental Agency, 2015 (Norwegian only).*

Ref: 3 *«Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control).*

Ref: 4 *"Best Available Techniques (BAT) Reference Document for the Refining of Mineral Oil and Gas" Industrial Emission Directive 2010/75/EU, 2015.*