| **Category** | | **Title** |
|---|---|---|
| **NFR** | 1.B.2.c | Venting and flaring |
| **SNAP** | 090203<br>090206 | Flaring in oil refinery<br>Flaring in gas and oil extraction |
| **ISIC** | | |
| **Version** | Guidebook 2023 | |

**Coordinator**
Carlo Trozzi

**Contributing authors (including to earlier versions of this chapter)**
Marlene Plejdrup, Marc Deslauriers, Jeroen Kuenen, Kristin Rypdal and Mike Woodfield

# Contents

# 1 Overview

This chapter treats emissions from venting and flaring in the extraction and refining of oil and gas. Flaring is basically combustion of gas, but without utilisation of the energy that is released. Included are flaring during extraction and first treatment of both gaseous and liquid fossil fuels and flaring in oil refineries. Also, this chapter includes emissions from incineration after a well testing.

Flaring emissions from the extraction of gas and oil are an important source of emissions for countries that produce oil and gas. Pollutants emitted are $NO_x$ and non-methane volatile organic compounds (NMVOC), but also $SO_x$, CO, heavy metals (HM), particulate matter (PM) including black carbon may be emitted.

# 2 Description of sources

## 2.1 Process description

### *2.1.1 Gas and oil extraction*

Gas is flared on oil- and gas-production installations for safety. The main reasons are lack of process or transport capacity for gas, a continuous surplus gas flow, start up, maintenance and emergency (need for pressure relief). The gas is led through a pipeline to a flare tip located high above and away from the platform.

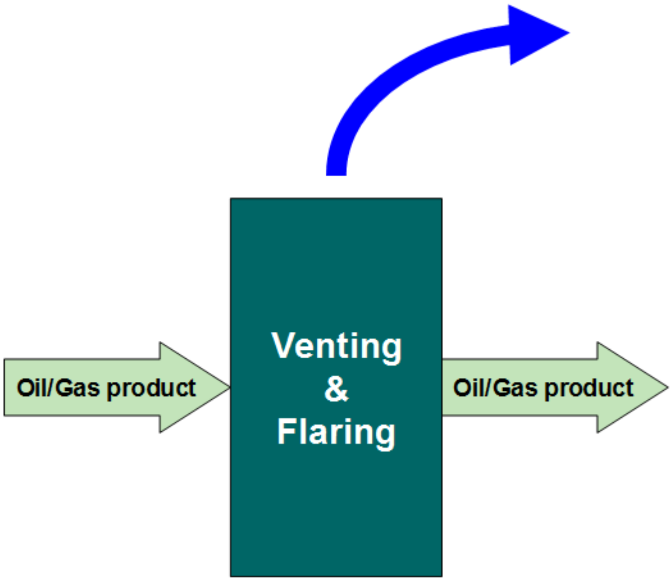
Well testing is performed as a part of the exploration activity. After a discovery, the well is tested to check the production capacity and the composition of the reservoir fluid. Due to lack of treatment, storage and transport facilities, the oil or gas extracted may be disposed by burning.

### *2.1.2 Oil refining*

Blowdown systems are used at petroleum refineries (see Chapter 1.B.2.a.iv Refining/storage) to collect and separate both liquid and vapour discharges from various refinery process units and equipment (US Environmental Protection Agency (US EPA), 1985, US EPA, 1992). The gaseous fraction, that may represent a planned or unplanned hydrocarbon discharge, may be either recycled or flared. Flaring provides a widely-used safety mechanism and emission control option for blowdown systems when the heating value of the emission stream cannot be recovered due to uncertain or intermittent releases during process upsets/emergencies. Non-condensed vapours from the blowdown system may be combusted in a flare which is designed to handle large fluctuations of both the flow rate and hydrocarbon content of the discharge. Alternatively, thermal oxidisers are used for destroying gas streams that contain more corrosive halogenated or sulphur-bearing components.

Although different types of flares exist, the steam-assisted elevated flare systems are most commonly used at petroleum refineries whereby steam is injected in the combustion zone of the flare to provide turbulence and inject air to the flame. For waste gases of insufficient heating value, auxiliary fuels may also be used to sustain combustion. Ground-level enclosed flares (oxidisers) are used for the destruction of gaseous streams with relatively low volume flows compared to elevated flare designs.

**Figure 2-1 Process scheme for source category 1.B.2.c Venting and Flaring**



## 2.2 Techniques

### *2.2.1 Gas and oil extraction*

The combustion in the flare will depend on the gas composition, gas velocity (efficiency of the flare) and wind conditions. There are several types of flare burners which may also give different emissions. The design of the flare is determined primarily by the safety considerations.

### *2.2.2 Oil refining*

**Elevated open flares**

Steam-assisted elevated flares are installed at a sufficient height above the plant and located at appropriate distances from other refinery facilities. The flare generally comprises a refractory flame platform with a windshield, steam nozzles, auxiliary gas/air injectors and a pilot burner mounted upon a stack containing a gas barrier. As reported (US EPA, 1985, US EPA, 1992, MacDonald, 1990), the flare combustion efficiency typically exceeds 98 % with dependence on the following factors (i.e. for efficient performance):

- excess steam assist (i.e. steam/fuel gas ratio less than 2);
- sufficient gas heating value (i.e. greater than 10 MJ/m3);
- low wind speed conditions (i.e. above 10 m/sec.);
- sufficient gas exit velocity (i.e. above 10 m/sec.).

Similarly, different types of flare burners, designed primarily for safety requirements, may result in different efficiencies.

**Enclosed flares**

In an enclosed flare the flame is contained within a refractory-lined combustion chamber, which is installed at ground level. The containment of the flare effectively eliminates the visible flame and thermal radiation and significantly reduces noise levels. This permits the installation of this type of flare much closer to process units than elevated flares.

Burners can be designed to produce smokeless combustion by using assist air, steam or gas. Alternatively, special designs of burner permit efficient combustion without the need of assist services.

## 2.3 Emissions and controls

### *2.3.1 Gas and oil extraction*

The emissions of pollutants from flaring are either unburned fuel or by-products of the combustion process. Different burner designs may influence the characteristic of the emissions. Increased efficiency of combustion may reduce the $CH_4$ and NMVOC emissions. However, this might not reduce the $NO_x$ emissions and will not reduce the $CO_2$ emissions. Major emissions from flaring are best reduced by reducing the amount of flared gas, without increasing the amount of gas directly vented.

Currently all flaring cannot be eliminated, but there is potential for substantially reducing the amount flared and technologies are now tested to reduce flaring further. Possibilities are:

- high integrity pressure protection systems (HIPS): gas leakages are collected and brought back to the process system. The flare is only ignited when really necessary;
- use of nitrogen as a purge gas (to avoid explosions (blanking) and deoxygenating of water (stripping));
- alternative methods for glycol regeneration;
- re-injection of gas into gas reservoirs;
- increased possibilities for transport and storage capacity of gas;
- reduced requirements for a pilot flame.

### *2.3.2 Oil refining*

Depending on the waste gas composition and other factors, the emissions of pollutants from flaring may consist of unburned fuel components (e.g. methane, NMVOC), by-products of the combustion process (e.g. soot, partially combusted products, CO, $CO_2$, $NO_x$) and sulphur oxides (e.g. $SO_2$) where sulphur components are present in the waste gas. Steam injection is used to enhance combustion for smokeless burning and to reduce $NO_x$ by lowering the flame temperature. Increased combustion efficiency may reduce $CH_4$ and NMVOC, but will not reduce $CO_2$ emissions. Flaring emissions might best be reduced by minimising amounts of gases to be flared, provided that the associated wastes gases are not vented directly.

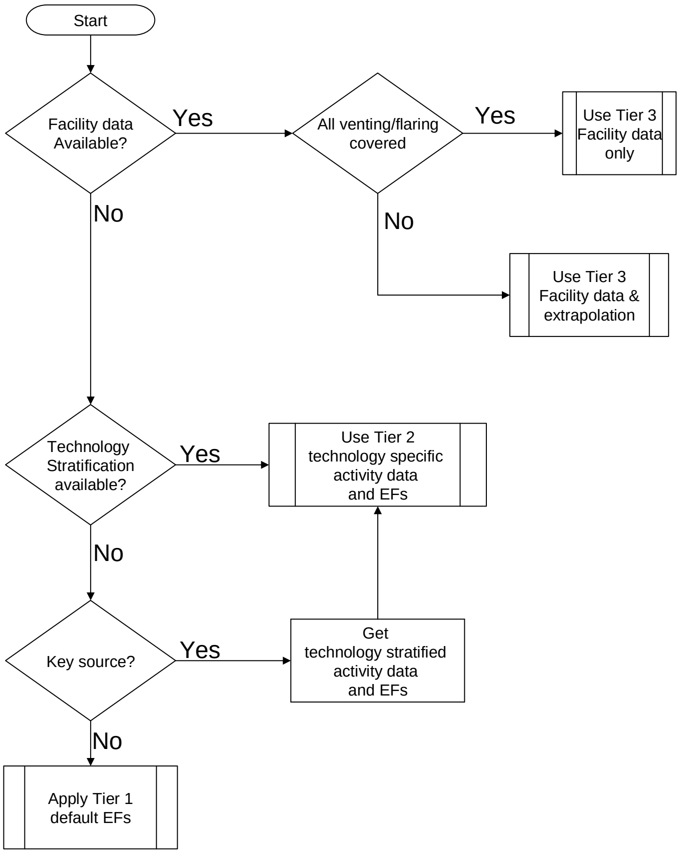
# 3 Methods

## 3.1 Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from venting and flaring. The basic idea is:

- if detailed information is available, use it;
- if the source category is a key category, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree directs the user in such cases to the Tier 2 method, since it is expected that it is more easy to obtain the necessary input data for this approach than to collect facility level data needed for a Tier 3 estimate;
- the alternative of applying a Tier 3 method, using detailed process modelling, is not explicitly included in this decision tree. However, detailed modelling will always be done at facility level and results of such modelling could be seen as 'facility data' in the decision tree.

**Figure 3-1 Decision tree for source category 1.B.2.c Venting and flaring**



## 3.2 Tier 1 default approach

### *3.2.1 Algorithm*

The Tier 1 approach for venting and flaring uses the general equation:

$$E_{pollutant} = AR_{production} \times EF_{pollutant} \tag{1}$$

This equation is applied at the national level, using annual totals for venting and flaring.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes within the source category.

In cases where specific abatement options are to be taken into account, a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used.

### *3.2.2 Default emission factors*

**Flaring in oil and gas extraction**

Table 3-1 provides the default emission factors for venting and flaring in oil and gas extraction. Emission factors for NOx, NMVOC and CO are estimated as the geometric mean of EFs provided by OLF (2012), Villasenor et al. (2003) and E&P Forum (1994), which are very similar for NOx, but show large differences for CO and NMVOC.

The emission factor for $SO_x$ is based on the assumption that the sulphur content in the flare gas is 6.4 ppm by weight. If the sulphur content is known, the $SO_x$ emission factor can be estimated by using the formula $EF_{SOx}$ = S*2.0, where S is the sulphur content in ppm by weight.

It may be assumed that fields with a high level of regulation have a more efficient flare, but in general, more measurements of emissions from flares are needed to establish a more accurate set of emission factors.

**Table 3-1 Tier 1 emission factors for source category 1.B.2.c Venting and flaring, Flaring in oil and gas extraction**

| **Tier 1 default emission factors** | | | | | |
|---|---|---|---|---|---|
| | Code | Name | | | |
| **NFR Source Category** | 1.B.2.c | Venting and flaring | | | |
| **Fuel** | NA | | | | |
| **Not applicable** | PCB, HCB | | | | |
| **Not estimated** | NH3, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene | | | | |
| **Pollutant** | **Value** | **Unit** | **95% confidence interval** | | **Reference** |
| | | | **Lower** | **Upper** | |
| $NO_x$ | 1.4 | kg/Mg gas burned | 1.1 | 2.0 | OLF (2012), Villasenor et al. (2003), E&P Forum (1994) ()[1] |
| CO | 6.3 | kg/Mg gas burned | 1.2 | 27 | OLF (2012), Villasenor et al. (2003), E&P Forum (1994) (1) |
| NMVOC | 1.8 | kg/Mg gas burned | 0.05 | 84 | OLF (2012), Villasenor et al. (2003), E&P Forum (1994) (1) |
| SOx | 0.013 | kg/Mg gas burned | 0.001 | 0.13 | E&P Forum (1994) (2) |
| TSP | 2.6 | kg/Mg throughput | 0.26 | 26 | (3) |

| | | | | | |
|---|---|---|---|---|---|
| $PM_{10}$ | 2.6 | kg/Mg throughput | 0.26 | 26 | Villasenor et al. (2003) |
| $PM_{2.5}$ | 2.6 | kg/Mg throughput | 0.26 | 26 | (3) |
| BC[1] | 24 | % of PM2.5 | 2.4 | 240 | McEwen & Johnson (2012) (4) |
| Pb | 4.9 | mg/Mg throughput | 0.49 | 49 | Australian Government (2010) (5) |
| Cd | 20 | mg/Mg throughput | 2 | 200 | Australian Government (2010) (5) |
| Hg | 4.7 | mg/Mg throughput | 0.47 | 47 | Australian Government (2010) (5) |
| As | 3.8 | mg/Mg throughput | 0.38 | 38 | Australian Government (2010) (5) |
| Cr | 1.3 | mg/Mg throughput | 0.13 | 13 | Australian Government (2010) (5) |
| Cu | 1.6 | mg/Mg throughput | 0.16 | 16 | Australian Government (2010) (5) |
| Ni | 38 | mg/Mg throughput | 3.8 | 380 | Australian Government (2010) (5) |
| Se | 0.43 | mg/Mg throughput | 0.043 | 4.3 | Australian Government (2010) (5) |
| Zn | 520 | mg/Mg throughput | 52 | 5200 | Australian Government (2010) (5) |

Notes:

(1) *assumption: flare gas density = 0.85 kg/m3 which is in line with natural gas density in Denmark and flare gas density for two of three refinery flares included in Martin et al. The third flare in Matrin et al. has been left out of account as the density is lower than what it expected for natural gas.*

(2) assumption: 6.4 ppm by weight sulphur content in gas

(3) assumption: TSP = PM10 = $PM_{2.5}$

(4) assumption: flare gas heating value of 45 $MJ/m^3$ and flare gas density of 0.8 $kg/m^3$

(5) Mean value of EF for combustion of associated gas and non-associated gas

### Flaring in oil refineries

The table below provides the default emission factors for flaring in oil refineries. The factors are taken from CONCAWE (2015).CONCAWE (2015) include an emission factor for $PM_{10}$ for combustion of natural gas, and it is recommended to use this EF for flaring. It is assumed that $EF_{TSP} = EF_{PM10} = EF_{PM2.5}$. Further emission factors for PAHs are provided for natural gas combustion in boilers and furnaces and are applied for flaring in correspondence with the emission factors for particulate matter.

**Table 3-2 Tier 1 emission factors for source category 1.B.2.c Venting and flaring, Flaring in oil refineries**

| **Tier 1 default emission factors** | | | | | |
|---|---|---|---|---|---|
| | Code | Name | | | |
| **NFR Source Category** | 1.B.2.c | Venting and flaring | | | |
| **Fuel** | NA | | | | |
| **Not applicable** | PCB, HCB | | | | |
| **Not estimated** | NH3, TSP, PM10, PM2.5, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, PCDD/F, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene | | | | |
| **Pollutant** | **Value** | **Unit** | **95% confidence interval** | | **Reference** |
| | | | **Lower** | **Upper** | |
| $NO_x$ | 54 | g/m3 refinery feed | 20 | 200 | CONCAWE (2015) |
| CO | 12 | g/m3 refinery feed | 4 | 40 | CONCAWE (2015) |
| NMVOC | 2 | g/m3 refinery feed | 1 | 6 | CONCAWE (2015) |
| $SO_x$ | 77 | g/m3 refinery feed | 30 | 200 | CONCAWE (2015) |

---

[1] For the purposes of this guidance, BC emission factors are assumed to equal those for elemental carbon (EC). For further information please refer to Chapter 1.A.1 Energy Industries.

### *3.2.3 Activity data*

**Oil and gas extraction**

The volume of gas flared is the most relevant activity statistics. The volume of flare gas may be measured instrumentally or calculated. In Norway, about 70 % of the platforms have metering systems, but this fraction is probably lower in most other countries. The uncertainty may be as high as 5–30 % if the gas is metered. A mass balance approach may be equally accurate. The reporting requirements to the EU Emission Trading Scheme include an uncertainty for the flaring amounts between 7.5 % and 17 % depending on which EU ETS Tier is required.

**Oil refineries**

To apply the Tier 1 default emission factors, the annual total throughput of each refinery is required, which can be obtained from Eurostat.

## 3.3 Tier 2 technology-specific approach

### *3.3.1 Algorithm*

The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country. In the venting and flaring sector, these are refinery flares and well testing.

The approach followed to apply a Tier 2 approach is as follows.

Stratify the venting and flaring in the country to model the different product and process types occurring into the inventory by:

- defining the production using each of the separate product and/or process types (together called ‘technologies’ in the formulae below) separately, and
- applying technology-specific emission factors for each process type:

$$E_{pollutant} = \sum_{technologies} AR_{production,technology} \times EF_{technology,pollutant} \tag{2}$$

where:

$AR_{production,technology}$ = the production rate within the source category, for the specific technology,

$EF_{technology,pollutant}$ = the emission factor for this technology and this pollutant.

A country where only one technology is implemented will result in a penetration factor of 100 % and the algorithm reduces to:

$$E_{pollutant} = AR_{production} \times EF_{technology,pollutant} \tag{3}$$

where:

$E_{pollutant}$ = the emission of the specified pollutant,

$AR_{production}$ = the activity rate within this source category,

$EF_{pollutant}$ = the emission factor for this pollutant.

### *3.3.2 Technology-specific emission factors*

This section presents the Tier 2 emission factors for venting and flaring.

#### Well testing

The table below presents the emission factors for well testing. These are applicable for Norway and taken from OLF (2012). An emission factor is provided for PAH (12 g/Mg oil burned). As this factor is considered to refer to total PAH and not PAH-4, it has not been included in Table 3-3

**Table 3-3 Tier 2 emission factors for source category 1.B.2.c Venting and flaring, Well testing**

| **Tier 2 emission factors** | | | | | |
|---|---|---|---|---|---|
| | Code | Name | | | |
| **NFR Source Category** | 1.B.2.c | Venting and flaring | | | |
| **Fuel** | NA | | | | |
| **SNAP (if applicable)** | 090206 | Flaring in gas and oil extraction | | | |
| **Technologies/Practices** | Well testing | | | | |
| **Region or regional conditions** | Norway | | | | |
| **Abatement technologies** | | | | | |
| **Not applicable** | HCB | | | | |
| **Not estimated** | SOx, NH3, TSP, PM10, PM2.5, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene | | | | |
| **Pollutant** | **Value** | **Unit** | **95% confidence interval** | | **Reference** |
| | | | **Lower** | **Upper** | |
| $NO_x$ | 3.7 | kg/Mg oil burned | 1 | 10 | OLF (2012) |
| CO | 18 | kg/Mg oil burned | 6 | 50 | OLF (2012) |
| NMVOC | 3.3 | kg/Mg oil burned | 1.1 | 9.9 | OLF (2012) |
| PCDD/F | 0.01 | g/Mg oil burned | 0.002 | 0.05 | OLF (2012) |
| PCB | 0.22 | g/Mg oil burned | 0.044 | 1.1 | OLF (2012) |

#### Flaring in oil refineries

Table 3-4 provides the Tier 2 emission factors for flaring in oil refineries. The factors are taken from CONCAWE (2015) and are identical to the emission factors for flaring in oil refineries as given in Tier 1.

Table 3-4 does not include an emission factor for BC. McEwen and Johnson (2012) provide BC emission factor as a function of the volumetric heating value for flaring:

$EF_{BC} = 0.0578 (HV)-2.09$

where $EF_{BC}$ is the BC emission factor [kg soot/$10^3$ $m^3$] and HV is the heating value of the flare gas [MJ/$m^3$].

McEwen and Johnson (2012) focus on flaring in upstream oil and gas industry (UOG) but this might be applied for flaring in refineries in lack of a more appropriate BC emission factor. The $EF_{BC}$ in Table 3-1 of 24 % $PM_{2.5}$ is based on the assumption of HV = 45 MJ/$m^3$ and density = 0.8 kg/$m^3$. If the heating value and density of the refinery flare gas is known, $EF_{BC}$ should be recalculated using the formula provided by McEwen and Johnson (2012).

**Table 3-4 Tier 2 emission factors for source category 1.B.2.c Venting and flaring, Flaring in oil refineries**

| **Tier 3 default emission factors** | | | | | |
|---|---|---|---|---|---|
| | Code | Name | | | |
| **NFR Source Category** | 1.B.2.c | Venting and flaring | | | |
| **Fuel** | NA | | | | |
| **Not applicable** | PCB, HCB | | | | |
| **Not estimated** | NH3, BC, Se, PCB, PCDD/F | | | | |
| **Pollutant** | **Value** | **Unit** | **95% confidence interval** | | **Reference** |
| | | | **Lower** | **Upper** | |
| NOx | 29.2 | g/GJ | 10 | 90 | USEPA (2015) |
| CO | 133 | g/GJ | 45 | 400 | USEPA (2015) |
| NMVOC | 0.005 | g/(g of NMVOC in gas flared) | 0.003 | 0.01 | CONCAWE (2015) * |
| SOx | 2 | g/(g of S in gas flared) | 1.6 | 2.4 | CONCAWE (2015) |
| TSP | 0.89 | g/GJ | 0.3 | 3 | ** |
| PM10 | 0.89 | g/GJ | 0.3 | 3 | CONCAWE (2015) |
| PM2.5 | 0.89 | g/GJ | 0.3 | 3 | ** |
| Pb | 1.61 | mg/GJ | 1.2 | 2.1 | CONCAWE (2016) |
| Cd | 2.19 | mg/GJ | 0.6 | 3.8 | CONCAWE (2016) |
| Hg | 0.372 | mg/GJ | 0.2 | 0.5 | CONCAWE (2016) |
| As | 0.352 | mg/GJ | 0.3 | 0.4 | CONCAWE (2016) |
| Cr | 6.69 | mg/GJ | 0.3 | 13.1 | CONCAWE (2016) |
| Cu | 3.29 | mg/GJ | 2.4 | 4.2 | CONCAWE (2016) |
| Ni | 7.37 | mg/GJ | 1.6 | 13.1 | CONCAWE (2016) |
| Se | 1.56 | mg/GJ | 1.1 | 2 | CONCAWE (2016) |
| Zn | 17 | mg/GJ | 12 | 22 | CONCAWE (2016) |
| Benzo(a)pyrene | 0.67 | ug/GJ | 0.134 | 3.35 | CONCAWE (2015) |
| Benzo(b)fluoranthene | 1.14 | ug/GJ | 0.228 | 5.7 | CONCAWE (2015) |
| Benzo(k)fluoranthene | 0.63 | ug/GJ | 0.126 | 3.15 | CONCAWE (2015) |
| Indeno(1,2,3-cd)pyrene | 0.63 | ug/GJ | 0.126 | 3.15 | CONCAWE (2015) |

** assumption: 0.5 % of the hydrocarbons remain unburned ** assumption: TSP = PM*$_{10}$ *= PM*$_{2.5}$

### 3.3.3 *Abatement*

A number of add-on technologies exist that are aimed at reducing the emissions of specific pollutants. The resulting emission can be calculated by replacing the technology-specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology,abated} = (1-\eta_{abatement}) \times EF_{technology,unabated} \qquad (4)$$

No abatement efficiencies are available for add-on technologies within this source category.

### 3.3.4 *Activity data*

For well testing, the amount of oil burned is the relevant activity statistics. For refinery flares, the annual flared amount for each refinery is required.

## 3.4 Tier 3 emission modelling and use of facility data

### *3.4.1 Algorithm*

A Tier 3 emission estimate for this source category would involve process modelling. Process modelling involves making separate estimates for each process taking account of abatement systems installed.

A few emission estimation models are discussed in this chapter.

### *3.4.2 Tier 3 emission modelling and use of facility data*

**Venting in oil and gas extraction**

For $NO_x$, the flare may be classified according to its flow rate. The lower the flow rate the lower the $NO_x$ emission factor. The following equation may be used if better data are not available.

$$\text{g NOx/Nm}^3 = X + 20, \tag{5}$$

where X is the gas flow rate in terms of million $m^3$/day (Celius 1992).

For NMVOC, $CH_4$ and CO the emissions will be dependent on the load, and subsequently the efficiency of the flare, although no data are available. It may be assumed that the emissions of these compounds run against the $NO_x$ trend.

**Pilot gas**

To estimate emissions from the combustion of the pilot gas fuel used to initiate flare combustion or the assist fuel required to sustain combustion, it is good practice to use the combustion emission factors provided in Chapter 1.A.1 ‘Combustion in energy industries’ relevant for NFR code 1.A.1.b Petroleum refining.

**Venting at oil and gas production facilities**

***Combined oil and gas facilities***

The following tables list the emission factors for venting per facility and per million $Nm^3$ of gas produced.

**Table 3-5 Suggested emission factors for venting (kg/million Nm3 gas produced) (OLF 1993)**

| | NMVOC | $CH_4$ | $CO_2$ | Quality codes |
|---|---|---|---|---|
| Norway | 76 | 98 | 0 | C |

**Table 3-6 Suggested emission factors for venting (Mg per facility) (OLF, 1993, UKOOA 1995)**

| | NMVOC | $CH_4$ | $CO_2$ | Quality codes |
|---|---|---|---|---|
| Norway | 30 | 20 | 0 | C |
| UK | 550 | 660 | 70 | C |

Generally, the venting will be higher on older platforms than on newer platforms. The main reasons for the difference are recent platforms have employed the use of low pressure systems, more recovery of hydrocarbon gases, use of electric start turbines rather than gas driven and moving away from the practice of venting. If better data is not available, it is good practice to apply the highest suggested emission factor.

***Facilities producing gas only***

**Table 3-7 Suggested emission factors for venting (Brown et al. 1993, Picard et al. 1992, SRI 1994)**

| | NMVOC | $CH_4$ | $CO_2$ | Unit | Quality |
|---|---|---|---|---|---|
| UK | 61 | 498 | 25 | Mg/facility | C |
| Canada | 0.19 | 0.33 | | Mg/Gg gas | C |
| Russia | 1.4–2.1 * | | | Mg/Gg gas | C |
| Netherlands | 0.6 | 6.7 | 0.2 | Mg/Gg gas | C |

Note: * Total VOC. Vent and fugitive losses.

***Facilities producing oil only***

**Table 3-8 Suggested emission factors for venting (Brown et al. 1993, Picard et al. 1992, SRI 1994)**

| | NMVOC | $CH_4$ | $CO_2$ | Unit | Quality |
|---|---|---|---|---|---|
| UK | 300 | 270 | 240 | Mg/facility | C |
| Canada | 0.24 | 0.44 | | Mg/Gg oil | C |
| Russia | 2.6 | | | Mg/Gg oil | C |
| Netherlands | 0.9 | 9.3 | 0.3 | Mg/Gg oil | C |

***Gas Terminals***

**Table 3-9 Suggested emission factors for venting (Gg/terminal) (Brown et al. 1993, Picard et al. 1992, SRI 1994)**

| | NMVOC | $CH_4$ | $CO_2$ | Throughput | Quality |
|---|---|---|---|---|---|
| UK | 0.28 | 2.4 | 0.034 | - | C |
| Canada | 0.007 | 0.013 | - | - | C |
| Norway | 0 | 0 | 0 | 25 billion $Nm^3$ | C |
| Russia | 5–12 * | | | 22 billion $Nm^3$ | C |

Note: * Including fugitive losses and methane.

### *3.4.3 Activity data*

#### 3.4.3.1 Oil and gas extraction

For the process model described in the previous section, the total daily gas flow rate ($m^3$/day) is required.

#### 3.4.3.2 Refineries

As the gaseous streams destructed in flares may be of very variable composition, it is necessary to know the stream composition to determine the net calorific value and the mass concentration of benzene, NMVOC and sulphur.

#### 3.4.3.3 Oil and gas production

The relevant activity data is the total amount of oil or gas produced. Some factors are also given in mass emitted per terminal or facility; for these the total number of facilities in a country is the relevant activity statistics.

# 4 Data quality

No specific issues

# 5 Glossary

| | |
|---|---|
| $Nm^3$ | $m^3$ under 'normal' circumstances: p=1 bar and T=273.15 K |

# 6 References

Australian Government (2010): Emission estimation technique manual for oil & gas exploration & production. Version 1.2

Brown and Root (1993). 'Environmental atmospheric emissions from UK oil and gas exploration and production facilities in the continental shelf area'. United Kingdom Offshore Association Limited.

Concawe (2015), 'Air pollutant emission estimation methods for E-PRTR reporting by refineries, 2015 edition,' CONCAWE Report 03/15, 2015, (https://www.concawe.eu/wp-content/uploads/2017/01/rpt_15-3.pdf) accessed 13 August 2019.

Concawe (2016), Emission factors for metals from combustion of refinery fuel gas and residual fuel oil. Report No. 09/16, 2016, (https://www.concawe.eu/wp-content/uploads/2017/01/concawe-rpt_16-9.pdf), accessed 13 August 2019.

E&P Forum (1994): Methods for estimating atmospheric emissions from E&P operations. The Oil Industry International. Report no. 2.59/197

MacDonald R.J. (1990). 'Industrial flare efficiency', University of Waterloo. Report prepared for the Industrial Program Branch, Environment Canada.

McEwen, J.D.N. and Johnson, M.R. (2012): Black carbon particulate matter emission factors for buoyancy-driven associated gas flares. Journal of the air and waste management association, 62, pp. 307-321

Martin, J., Lumbreras, J. & Rodríguez, M.E.: Testing flare emission factors for flaring in refineries.

OLF (2012): Veiledning til den Årlige Utslippsrapporteringen. Gjelder: Klifs TA 2718 ”Retningslinjer for rapportering fra petroleumsvirksomhet til havs” & Statens strålevern ”Retningslinjer for årlig rapportering av utslipp fra petroleumsvirksomhet. Stavanger, January 8th, 2012. (in Norwegian)

Picard D.J., Ross B.D., Koon D.W.H. (1992). ‘A detailed inventory of CH4 and VOC emissions from upstream oil and gas operations in Alberta’, Clearstone Engineering Ltd.

SRI (Scientific Research Institute of Atmospheric Air Protection) (1994). ‘Emissions of hydrocarbons in gas industry, oil production industry, gas- and oil refining industries of Russia’. *SRI Atmosphere*. Report, St. Petersburg.

UKOOA (1995). United Kingdom Offshore Operators Association Limited, Guidelines on atmospheric emissions inventory. Issue No 1, July 1995.

USEPA, 2015, AP-42 Section 13.5, Industrial flares, dated 4/15, (https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors), accessed 19 July 2019.

Villasenor, R., Magdaleno, M., Quintanar, A., Gallardo, J.C., López, Jurado, R., Miranda, A., Aguilar, M., Melgarejo, L.A., Palmerín, E., Vallejo, C.J. & Barchet, W.R. (2003): An air quality emission inventory of offshore operations for the exploration and production of petroleum by the Mexican oil industry. Atmospheric Environment 37 (2003) 3713-3729

# 7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection’s expert panel on combustion and industry. Please refer to the TFEIP website (www.tfeip-secretariat.org/) for the contact details of the current expert panel leaders.