Category		Title
NFR	1.B.2.a.i	Oil – Exploration, production, transport
	1.B.2.b	Natural gas
SNAP	0502	Extraction, first treatment and loading of liquid fossil fuels
	050201	Land-based activities
	050202	Offshore activities
	050301	Land-based desulfurisation
	050302	Land-based activities (other than desulfurisation)
	050303	Offshore activities
	050601	Pipelines
	050603	Distribution networks
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Contents

1 Overview

This chapter deals with the fugitive emissions from the exploration, treatment, loading and also distribution of liquid and gaseous fossil fuels.

It includes the emissions from onshore as well as offshore activities. Flaring and combustion of fossil fuels are not included in this chapter. These can be found in chapters 1.B.2.c and 1.A.1.b, respectively. This chapter also includes emissions from production facilities, first loading of crude fuels.

The NFR source categories 1.B.2.a.i and 1.B.2.b are both discussed in this chapter, because the techniques used in extraction and first treatment of oil and natural gas are very similar. There are a number of facilities that produce both oil and gas. However, it is important to realize that both are reported in their own source category.

This chapter covers the following activities (which may take place on land or offshore):

- fugitive emissions from production platforms;
- crude oil stabilisation;
- glycerol regeneration;
- storage tanks associated with the production facility;
- tanker loading;
- drilling mud;
- waste water;
- test drilling;
- losses during transport in marine tankers and oil pipelines;
- losses from gas pipelines, compressor stations and networks.

Emissions from venting are not included in this chapter; these are discussed in the chapter on venting and flaring (chapter 1.B.2.c).

The contribution of the activities described in this chapter to the total national emissions varies considerably, but in countries where oil is extracted, they are invariably an important contributor to the national total of non-methane volatile organic compounds (NMVOCs), as well as for methane. In the Middle East, the highest contribution of both oil and natural gas production to the total emissions of NMVOC is found, equal to 53 % (EDGAR, 1990).

As for the distribution of natural gas, the most important emission is methane. Small quantities of NMVOC are emitted as well.

2 Description of sources

2.1 Process description

Oil and natural gas are produced by the same geological process: anaerobic decay of organic matter deep under the Earth's surface. As a consequence, oil and natural gas are often found together. In common usage, deposits rich in oil are known as oil fields, and deposits rich in natural gas are called natural gas fields. Oil and gas are found both onshore and offshore and can be used in a variety of processes, including heating of buildings, and in processes such as feedstock in chemical processes. Natural gas is increasingly being used as a fuel for power generation.

The extraction and first treatment of liquid and gaseous fuels involves a number of activities, each of which represents a potential source of hydrocarbon emissions. Since not all activities are carried out at a specific site, the following descriptions have been prepared by type.

 is a flow diagram that illustrates all the relevant activities in the oil and gas industry, starting from the extraction of oil and natural gas, not only as covered by this chapter but also in other related chapters.

Figure 2-1 **Flow diagram illustrating the activities covered by the source categories discussed in this chapter and their relation with activities covered by other NFR source categories**
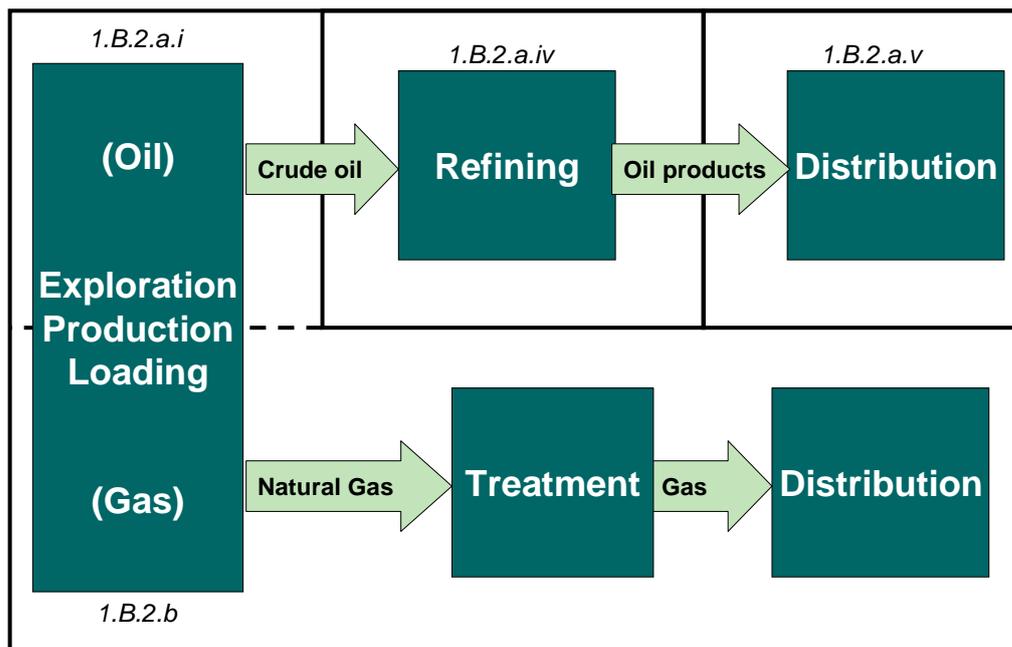

Figure 2-2 displays a process scheme containing the processes discussed in this chapter and the sources of emissions.

Figure 2-2 **Process scheme for source categories 1.B.2.a.i and 1.B.2.b, Exploration, production and transport of oil, and Natural gas, respectively. Emissions from venting and**

flaring arise from all activities; these are discussed in Chapter 1.B.2.c Venting and flaring
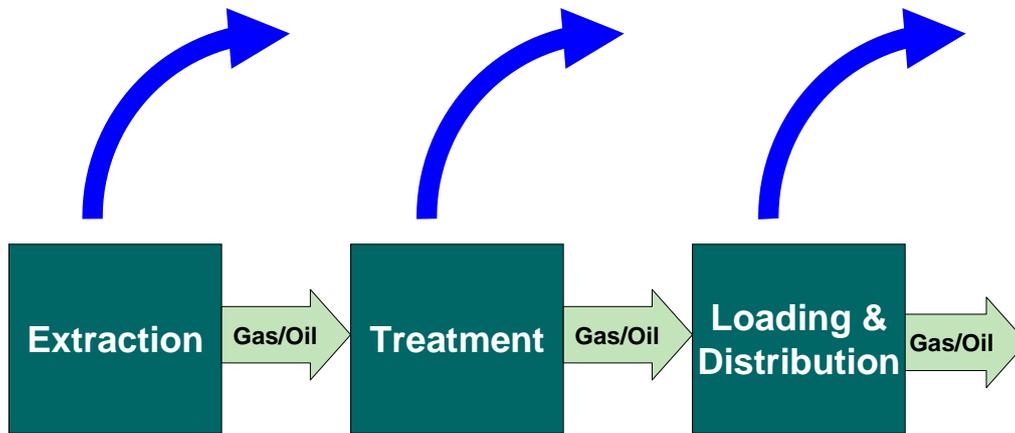
2.1.1 Combined oil and gas facilities

Production platforms handle the reception, treatment and export of well fluids. Crude oil is usually de-watered and gas is processed for platform use, re-injection, or export as required. The process system on production platforms consists of:

- separation of crude oil, gas and water and subsequent export;
- gas treatment and export;
- produced water handling;
- pressure relief and blow down;
- utilities (energy supply, etc.);
- injection systems for gas and oil;
- crude oil stabilisation;
- desulphurisation of gaseous fuels (usually land-based).

2.1.2 Facilities producing gas only

These facilities do not have crude oil separation and export. The produced water handling systems are not present or partially present.

2.1.3 Facilities producing oil only

These facilities do not have gas treatment and export process systems. However there are few examples of facilities with absolutely no gas production.

2.1.4 Gas terminals

The typical gas terminal facility receives gas by pipelines, and conditions the gas ready for export to the national or international distribution network. Gas conditioning includes separation, CO_2 and hydrogen sulphide removal, hydrogen sulphide incineration, pressure relief and blow down systems.

2.1.5 Oil loading and transport

This source includes the transfer of oil from storage tanks or directly from the well into a ship or another container specifically for transport away from the production site.

This activity also includes losses during transport. Also, during the oil loading, combustion emissions occur from the oil pump, particularly when pumps are fuelled by oil (as in the case of ships pumping oil at maritime terminals). Emissions from combustion are included in Chapter 1.A.1 Combustion in energy industries.

2.1.6 Pipelines

Oil and gas is commonly transported from oil and gas facilities to terminals by pipelines. These may cross national boundaries.

2.1.7 Drilling

Drilling of wells involves the use of specially formulated drilling mud which may contain organic solvents. When the drilling breaks through small oil/gas reservoirs ,this may result in the release of emissions.

2.1.8 Distribution of natural gas

Natural gas is transferred from the well to a processing plant where it is separated by cryogenic distillation to give 'sales' gas of the required specification as well as possibly other products such as liquid hydrocarbon fractions. After this it is transferred via a network of pipelines and networks or 'mains' to consumers ranging from large factories to small dwellings. Natural gas may also be transported in liquefied form by ship, in which case it is loaded and unloaded at specially designed marine terminals.

A gas transmission network covering a country or region consists of pipelines and mains of a variety of different sizes, materials, and pressures. It will also contain storage facilities, pumping stations and pressure reduction stations. Pipes will also make use of different types of joint.

Transmission systems

Gas transmission systems can conveniently be divided into two interconnecting systems; the national transmission system, which consists of large-diameter high-pressure pipelines spanning distances of hundreds of kilometres, forms the backbone of the network and takes gas from the terminals to each of many regional supply systems, which consist of smaller-diameter intermediate- and low-pressure pipelines and mains.

Pipelines and mains

Pipelines and mains are made from the following materials:

- welded steel
- cast iron
- ductile iron
- polyethylene.

Pipelines and mains are operated under a variety of different pressure regimes, usually classified as follows:

- high pressure — up to 75 bar

- intermediate pressure — 2 to 7 bar

- medium pressure — 2 bar to 75 mbar

- low pressure - < 75 mbar.

Service pipes, which transfer gas from a main to a customer's meter, are always at low pressure.

Pipelines and mains can also be classified as jointed or non-jointed. Jointed pipes have joints which consist of flanges bolted together or similar arrangements. In non-jointed pipes the sections are welded together.

Storage

The gas transmission system incorporates a number of different types of storage elements. These include high pressure liquid storage, underground salt cavities and gas holders.

Losses

Losses can occur in many different ways from the network. Examples are losses due to leakage and losses due to the purging of sections of pipe and items of equipment during commissioning, decommissioning and maintenance. Leakage can be further classified according to whether it is due to some malfunction, such as a crack in a pipe or a failure of a joint, or whether it occurs in fully functioning equipment as a direct consequence of its design and operation.

Gas compressor stations

Emissions resulting from the compression of natural gas in gas compressor stations are treated in chapter 1.A.3.e.i, Pipeline compressors.

Emissions from gas transmission networks arise from a large number of small sources spread over a large area (fugitive). It is estimated that up to 20 % of the gas escaping from leaky pipelines and mains is oxidised in the soil by micro-organisms.

2.2 Techniques

The techniques used in the extraction, production and distribution of oil and natural gas are described in subsections 2.1 and 2.3 of the present chapter.

2.3 Emissions and controls

2.3.1 Combined oil and gas facilities

The emissions from combined oil and gas facilities may be categorised as direct venting of gas into the atmosphere, fugitive losses and evaporation from contaminated waste water.

Venting is a deliberate, direct release of gas from the various processes and is usually related to pressure relief and blow down systems to ensure safe operations. The operations which result in direct venting also include stripping gas from glycol regeneration, water treatment, relieved gas in seal oil systems, equipment depressurisation and other activities leading to venting.

Venting emissions may be reduced by flaring (incinerating) the gas. This is desired from an environmental point of view as methane is a more potent greenhouse gas per molecule than CO_2. Installation of recovery systems for atmospheric vents is also a possibility. The recovered gas may be exported, used on platforms or re-injected. Nitrogen may be used as purge gas instead of hydrocarbons.

Crude oil stabilisation involves the removal of the most volatile components of the crude oil. Stabilisation of crude oil occurs either on offshore platforms, or less usually, at terminals. Although the process has the potential to cause emissions of VOC, the United Kingdom Offshore Operators Association (UKOOA) claim that emissions are in fact small since the volatiles are generally either used as fuel or are sent to flare rather than being vented directly to the atmosphere.

Desulphurisation of gaseous fossil fuels is the removal of hydrogen sulphide (H_2S) from the gas. Chapter 1.B.2.a.iv, Refining/storage provides more information on this process.

Fugitive emissions arise from several sources, in particular gas leakage through compressor seals, valves and flanges. These emissions may be reduced by implementing procedures for detecting leaks from the process systems, minimising leaks and spills through equipment changes, procedure changes, improved monitoring, house keeping, and maintenance practices.

Waste water separated from the oil/gas mixture is first cleaned before disposal. The cleaned water inevitably contains some organic compounds which may evaporate later. The organic compounds removed during cleaning may also evaporate.

2.3.2 Facilities producing gas only

These facilities are designed to sell the gas produced. Therefore, generally, there is less direct venting and flaring of gas. These facilities also produce less waste water. Control options are the same as those mentioned for the combined facilities described in subsection 2.3.1 of the present chapter.

2.3.3 Facilities producing oil only

All gas produced will be flared, vented, used as fuels or re-injected into the reservoirs. Generally, at oil-only facilities the crude oil/gas mixture reaching the surface will contain less gas than the mixture at combined or gas facilities. In general, the methane content of vented gas is less than that found in gas-producing facilities. Control options are the same as those mentioned for the combined facilities described in subsection 2.3.1 of the present chapter.

2.3.4 Gas terminals

The main emission sources are the flare at the pressure relief system associated with the compression unit, the vent from the gas-drying operation and the stack from the H_2S-incinerator. There are also several fugitive sources, leakages through compressor seals, valves and flanges. The technologies and potential for reductions in emissions will be very similar to a gas production platform. An acid gas scrubber may be applied to the H_2S incinerator. Control options are the same as those mentioned for the combined facilities described in subsection 2.3.1 of the present chapter.

2.3.5 Oil loading and transport

Crude oil is transported from production operations to a refinery by tankers, barges, rail tank cars, tank trucks, and pipelines (next section). When oil is loaded, hydrocarbon vapour will be displaced by oil and new vapour will be formed, both leading to emissions. The mass emitted will depend on:

- the movement of the vessel — the greater the movement, the greater the emissions;
- the vapour pressure of the crude;
- temperature of the crude — temperature should be as low as possible;
- loading rate into each tank — the greater the loading rate, the lower the emissions;

- method of loading — splash, submerged, or bottom loading;

- geometry of the tanks — the higher the surface area to volume, the higher the emissions;

- tank atmosphere;

- crude oil washing procedures.

Although unloading in itself is a minor source compared to loading, procedures for unloading may influence the emissions while loading. Recovery systems will be available in the near future that will reduce the NMVOC emissions from offshore loading by about 70 %. Technologies to reduce emissions from onshore loading are available. The efficiency is about 85 % (methane emissions will not be reduced considerably).

Ballasting of marine vessels is another potential source of emissions. Ballasting losses are a major source of emissions from unloading at marine terminals. Ballasting does not occur with all vessels as many (and the new vessels) have segregated tanks where ballasting is not necessary and is even not in use in some countries (e.g. Norway).

Ballasting is the partial loading of cargo tanks after cargo is unloaded to improve stability of the vessel. Cargo tanks are typically ballasted to about 80 % of their capacity, resulting in 15 to 40 % of the vessel capacity. Emissions occur when the vapours present are displaced by the ballast water. The ballast water is then pumped out prior to loading, thereby reducing the subsequent loading emissions. Emissions may be reduced by containing the vapours through displacing the ballasting vapours into a cargo tank that is simultaneously being unloaded (US Environmental Protection Agency (US EPA), 1996).

2.3.6 Pipelines

Emissions may originate from connection points, valves and damaged sections. Emissions may be controlled by inspection procedures followed by repair and upgrading (further described in subsection 2.3.1 of the present chapter under fugitive emissions).

2.3.7 Drilling

The main emission sources during drilling are penetration of shallow gas pockets, migration of reservoir fluid through the circulated drilling fluid, gas migration through poor casing and cement work, the use of oil or solvent-based drilling mud, and the wash of oil-contaminated cuttings. The main control options are gas removal during drilling and recovery of hydrocarbons from oil-based mud and cuttings.

2.3.8 Distribution of natural gas

The various emission sources within a typical gas transmission network are described in subsection 2.1.8 of the present chapter and also in the Glossary. Typically 85–90 % of the emissions consist of methane. Only small amounts of NMVOC are released.

The pollutants emitted by the various parts of a typical gas transmission network are described in Table 2-1 below, while the various emission sources within a gas transmission network are described in subsection 2.1.8 of the present chapter.

The species profile is estimated by assuming that the composition of the emission is the same as the composition of the gas, although in practice some components of the gas may get adsorbed, e.g. by the soil. These effects are ignored in Table 2-1.

Table 2-1   Typical species profile for the emissions from gas distribution networks

	UK[1]	Netherlands[2]	Germany[3]	France[3]
Carbon dioxide(CO_2)	0.5	5.0	2.2	0.9
Nitrogen(N_2)	2.5	6.1	7.6	4.5
Methane(CH_4)	92.5	84.7	85.5	88.6
Ethane(C_2H_6)	2.9	3.8	3.3	4.7
Propane(C_3H_8)	0.9	0	0.9	0.8
2-methylpropane (C_4H_{10})	0.2	0.1	0	0
Butane(C_4H_{10})	0.2	0.1	0.4	0.2
2,2-dimethylpropane(C_5H_{10})	0.1	0	0	0
2-methylbutane(C_5H_{12})	0.1	0.1	0	0
Pentane(C_5H_{12})	0.1	0.0	0.1	0.3
Hydrogen sulphide (H_2S)	0	0.1	0	0
Total mole %	100	100	100	100

Notes
1.   [1] Gas quality (1986).
2.   [2] Procestechniek (1987).
3.   [3] International Gas Union (1976).

In this section it is estimated that up to 20 % of the gas escaping from leaky pipelines and mains is oxidised in the soil by micro-organisms. However, since it is not possible to measure how much of the gas gets oxidised in this way, it is recommended that this phenomenon is ignored in the estimation of emissions.

End-of-pipe techniques are inapplicable because the emissions cannot be collected together in a pipe or duct; instead they arise from a geographically diverse array of small sources emitting directly to the atmosphere. Consequently the only way is to reduce emissions by:

- the use of better materials for pipes, joints and seals;
- the quicker detection and rectification of leaks;
- improved maintenance;
- measures to collect gas purged during commissioning, decommissioning and other maintenance activities.

3 Methods

3.1   Choice of method

Figure 3-1 presents the procedure to select the methods for estimating emissions from the extraction, first treatment, loading and distribution of oil and natural gas. 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.a.i Exploration, production, transport
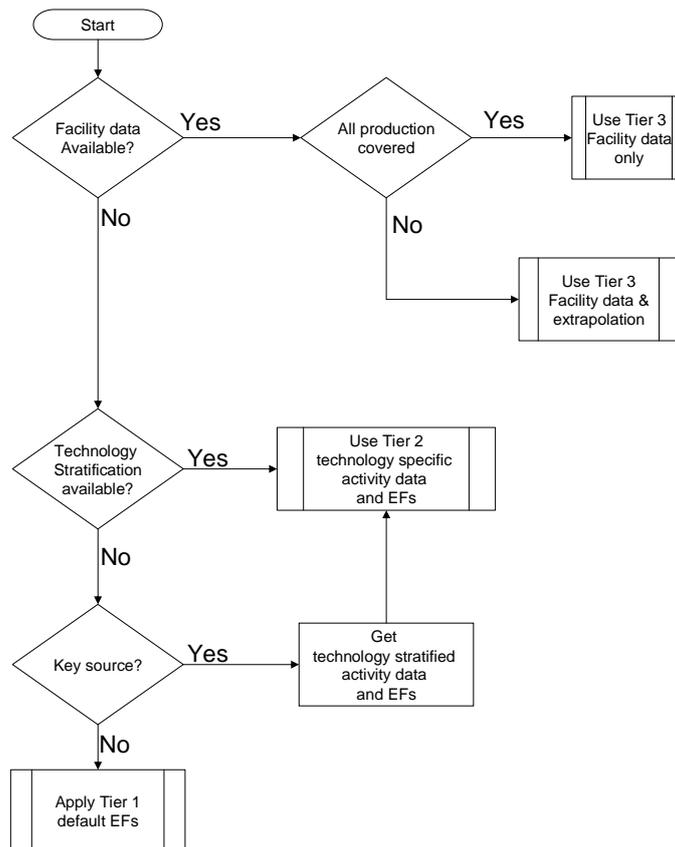
3.2   Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach 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 the exploration, production and transport of oil and natural gas. The total mass oil and gas processed can be used as activity statistics.

The Tier 1 emission factors assume an averaged or typical technology and abatement implementation in the country and integrate all different sub-processes within this 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 ort Tier 3 approach must be used.

3.2.2 Default emission factors

Table 3-1 and

Table 3-2 provide default emission factors for source categories 1.B.2.a.i, Exploration, production, transport, and 1.B.2.b Natural gas, respectively. The emission factors are the result of an assessment of the emission factors for combined extraction, first treatment and loading for onshore and offshore facilities that were available in an earlier version of the Guidebook. All these emission factors are from Corinair (1990). The heat contents assumed to recalculate the emission factors in terms of mass/volume flow is 38 MJ/m^3 for natural gas, and 42 GJ/Mg for oil.

These factors are based on the facilities producing gas or oil only. Geometric means over both onshore and offshore emission factors have been taken, which have again been averaged geometrically to get the best estimate. Due to the high degree of uncertainty in these factors and the very large variation between the factors, the uncertainty range is very wide.

For natural gas, an average factor for distribution is added to account for the distribution of natural gas as well.

Table 3-1   Tier 1 emission factors for source category 1.B.2.a.i Exploration, production, transport

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.B.2.a.i	Exploration production, transport			
Fuel	NA				
Not applicable	NOx, CO, NH3, TSP, PM10, PM2.5, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated	SOx, PCDD/F				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	0.2	kg/Mg oil	0.0045	6.4	CORINAIR (1990)

Table 3-2   Tier 1 emission factors for source category 1.B.2.b Natural gas

Tier 1 default emission factors					
	Code	Name			
NFR Source Category	1.B.2.b	Natural gas			
Fuel	NA				
Not applicable	NOx, CO, NH3, TSP, PM10, PM2.5, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated	SOx, PCDD/F				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	0.1	g/m3 gas	0.0005	6.2	CORINAIR (1990)

Emissions from methane and CO_2 are not included in the Guidebook. Guidance on reporting these greenhouse gas emissions can be found in the Intergovernmental Panel on Climate Change (IPCC) Guidelines (IPCC 2006).

3.2.3 Activity data

The Tier 1 methodology requires the amount of gas or oil produced. These data are available from national statistical offices in each country and from various international sources such as the Organisation for Economic Co-operation and Development (OECD).

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 facility types that may occur in the country. The following facilities can be distinguished:

- facilities producing oil only;
- facilities producing natural gas only;
- facilities producing both oil and natural gas.

Furthermore, onshore and offshore facilities can be distinguished as different facility types.

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

Stratify the exploration and production of oil/gas in the country to model the different product and process types occurring in the national industry 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:

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

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:

$$E_{pollutant} = AR_{production} \times EF_{technology,pollutant} \qquad (3)$$

where:

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

$AR_{production}$ = the activity rate for the exploration/production of oil and natural gas,

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

The emission factors in this approach will still include all sub-processes within the industry, from the exploration until the final shipment of the oil and natural gas. Figure 2-1 shows exactly what is covered by this source category and what is covered by other categories.

3.3.2 Technology-specific emission factors

The Tier 2 emission factors are listed in the tables below for onshore as well as offshore facilities, and for facilities producing oil and facilities producing gas. For facilities that produce both, no Tier 1 emission factors are available.

Emission factors are based on an assessment of the emission factors presented in an earlier version of the Guidebook. The original source of the data is listed with the table, wherever it is known. The heat contents assumed to express the factors per unit of energy is 38 MJ/ m^3 for natural gas, and 42 GJ/ Mg for oil.

Also, this section provides Tier 2 emission factors for NMVOC emissions from gas terminals, oil loading and transport, pipelines and drilling.

Onshore facilities producing oil only

Table 3-3 provides the NMVOC emission factor for onshore facilities that only produce natural gas. The emission factor resulting from the assessment is based on emission factors for various countries for combined extraction and first treatment from Corinair (1990).

Table 3-3   Tier 2 emission factors for source category 1.B.2.a.i Exploration production, transport, Onshore facilities

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.2.a.i	Exploration production, transport			
Fuel	NA				
SNAP (if applicable)	050201	Land-based activities			
Technologies/Practices	Facilities producing oil only				
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO, NH3, TSP, PM10, PM2.5, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated	SOx, PCDD/F				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	0.1	kg/Mg oil	0.045	0.2	CORINAIR (1990)

Offshore facilities producing oil only

Table 3-4 provides the NMVOC emission factor for offshore facilities that only produce oil. The emission factor resulting from the assessment is based on emission factors for various countries for combined extraction, first treatment and loading from Corinair (1990).

Table 3-4   Tier 2 emission factors for source category 1.B.2.a.i Exploration, production, transport, Offshore facilities

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.2.a.i	Exploration production, transport			
Fuel	NA				
SNAP (if applicable)	050202	Off-shore activities			
Technologies/Practices	Facilities producing oil only				
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO, NH3, PM2.5, PM10, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated	SOx, PCDD/F				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	0.4	kg/Mg oil	0.0455	6.4	CORINAIR (1990)

Onshore facilities producing natural gas only

Table 3-5 provides the NMVOC emission factor for onshore facilities that only produce natural gas. The emission factor resulting from the assessment is based on emission factors for various countries for combined extraction and first treatment from Corinair (1990).

Table 3-5   Tier 2 emission factors for source category 1.B.2.b Natural gas, Onshore facilities

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.2.a.i	Exploration production, transport			
Fuel	NA				
SNAP (if applicable)	050302	Land-based activities (other than desulfuration)			
Technologies/Practices	Facilities producing gas only				
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO, NH3, PM2.5, PM10, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Not estimated	SOx, PCDD/F				
Pollutant	**Value**	**Unit**	**95% confidence interval**		**Reference**
			Lower	**Upper**	
NMVOC	0.1	g/m3 gas	0.0005	6.2	CORINAIR (1990)

Note
Given the very large uncertainty range, the volume of gas could either be given as Nm^3 or as Sm^3.

Offshore facilities producing natural gas only

Table 3-6 provides the NMVOC emission factor for offshore facilities that only produce natural gas. The emission factor resulting from the assessment is based on emission factors for various countries for combined extraction, first treatment and loading from Corinair (1990).

Table 3-6   Tier 2 emission factors for source category 1.B.2.b Natural gas, Offshore facilities

Tier 2 emission factors					
	Code	Name			
NFR Source Category	1.B.2.a.i	Exploration production, transport			
Fuel	NA				
SNAP (if applicable)	050303	Off-shore activities			
Technologies/Practices	Facilities producing gas only				
Region or regional conditions					
Abatement technologies					
Not applicable	NOx, CO, NH3, PM2.5, PM10, BC, Pb, Cd, Hg, As, Cr, Cu, Ni, Se, Zn, PCB, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB,				
Not estimated	SOx, PCDD/F				
Pollutant	Value	Unit	95% confidence interval		Reference
			Lower	Upper	
NMVOC	0.1	g/m3 gas	0.0045	6.2	CORINAIR (1990)

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 technologies are identified in this source category.

3.3.4 Activity data

Like the Tier 1, the Tier 2 methodology requires the amount of gas or oil produced. These data are available from national statistical offices in each country and from various international sources such as the OECD.

3.4   Tier 3 emission modelling and use of facility data

3.4.1 Algorithm

There are two different methods to apply emission estimation methods that go beyond the technology specific approach described above:

- detailed modelling of the process;
- using facility-level emission reports.

Detailed process modelling

A Tier 3 emission estimate, using process details will make separate estimates for the consecutive steps in the process of exploration, production and transport of oil and natural gas.

Facility-level data

Where facility-level emission data of sufficient quality are available (see chapter 6, Inventory management, improvement and QA/QC in part A), it is good practice to indeed use these data. There are two possibilities:

- the facility reports cover all the facilities in the country;
- facility-level emission reports are not available for all facilities in the country.

If facility-level data are covering all production in the country, it is good practice to compare the implied emission factors (reported emissions divided by the national production) with the default emission factor values or technology specific emission factors. If the implied emission factors are outside the 95 % confidence intervals for the values given below, it is good practice to explain the reasons for this in the inventory report.

If the total annual production in the country is not included in the total of the facility reports, it is good practice to estimate the missing part of the national total emissions from the source category, using extrapolation by applying:

$$E_{Total,pollutant} = \sum_{Facilities} E_{Facility,pollutant} + \left(National\ Production - \sum_{Facilities} Production_{Facility} \right) \times EF \qquad (5)$$

Depending on the specific national circumstances and the coverage of the facility level reports as compared to the total national production, it is good practice to choose the emission factor (*EF*) in this equation from the following possibilities, in decreasing order of preference:

- technology-specific emission factors, based on knowledge of the types of technologies implemented at the facilities where facility-level emission reports are not available;
- the implied emission factor derived from the available emission reports:

$$EF = \left. \sum_{Facilities} E_{Facility,pollutant} \middle/ \sum_{Facilities} Production_{Facility} \right. \qquad (6)$$

- the default Tier 1 emission factor. This option should only be chosen if the facility-level emission reports cover more than 90 % of the total national production.

3.4.2 Tier 3 emission modelling and use of facility data

This section gives emission estimates for emissions from extraction, first treatment and distribution of oil and natural gas. These are all taken from an earlier version of the Guidebook, which contains a lot of detailed information about emission estimates for processes within this source category. Only the emission estimation information from the 'simpler methodology' is presented here. More detailed information is available in a former version of the Guidebook (Guidebook, 2006).

Information for emissions of CO_2 and CH_4 can be obtained from the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

Care must be taken when using the emission factors listed in the following subsections. They contain a high degree of uncertainty, and are only provided to indicate the relative differences that exist between the countries. Further investigation of the emission rates is required to determine the type of facilities they represent, and the extent of possible double counting. It is good practice to use these emission factors only if no other sources of information are available.

Combined oil and gas facilities

The following equation has been suggested for installations in USA (Countess and Browne, 1993), which seems to be in reasonable agreement with estimates for Norway and UK.

$$\text{Total VOC (Mg/year)} = 40.2 * N + 1.1 * 10^{-2} * X + 8.5 * 10^{-6} * Y \qquad (7)$$

where: N is the number of facilities (e.g. platforms),
X is the gas production (million Nm^3/year),
Y is the oil production (mill Mg/year).

Of the total VOC, a composition of 75 % methane and 25 % NMVOC may be assumed if better data is not available.

If the technology is old, emissions may be higher than estimated by this equation.

Facilities producing gas only

The tables below list emission factors for entire facilities for the extraction, first treatment, and loading of gaseous fuels. The Emission Factors are of 3 types: general (SNAP 050300, see also the Tier 1 approach), onshore (SNAP 050302), and offshore (SNAP 050303) activities (see also the Tier 2 approach).

Care must be taken when using the emission factors in Table 3-7, Table 3-8 and Table 3-9 due to the high degree of uncertainty. In fact, these emission factors should only be used if no other data are available. The emission factors in the following tables assume a heat content of gas of 38 MJ/m^3.

Table 3-7   **General facility emission factors for combined extraction, first treatment and loading (Corinair, 1990)**

	NMVOC emissions/unit production		Quality
	g/m^3	Mg/PJ *	
Poland	3.1	82	C

Table 3-8 **Onshore facility emission factors for combined extraction and first treatment (Corinair, 1990)**

	NMVOC emissions/unit production		Quality
	g/m^3	Mg/PJ	
Germany	0.079	2.1	C
Czech Rep./France/Hungary	3.1 *	82 *	C
Romania/Slovakia	3.1 *	82 *	C
Bulgaria	0.001	0.024	C
Italy	0.009	0.24	C
Spain	0.34	9.0	C
UK	0.055	1.4	C

Note
* Emission rates may contain methane.

Table 3-9 **Offshore facility emission factors for combined extraction, first treatment and loading (Corinair, 1990)**

	NMVOC Emissions/Unit Production		Quality
	g/m^3	Mg/PJ	
Denmark *	0.14	3.9	C
Germany	0.079	2.1	C
Italy	0.009	0.24	C
Spain	0.34	9.0	C
Romania	3.1	82	C
Norway **	0.097	2.6	C

Notes
1.   *   Leakage offshore.
2.   ** Extraction of natural gas.

For fugitive losses, equation 8 will be relevant.

Table 3-10 **Canadian fugitive emission factor for facilities (Countess and Browne 1993)**

	NMVOC	Unit	Quality
Canada	0.9	Mg/Gg gas	C

Facilities producing oil only

The tables below list emission factors for entire facilities for the extraction, first treatment and loading of oil from onshore (SNAP 050201) and offshore (SNAP 050202) activities. The emission factors in Table 3-11 and

Table 3-12 assume a heat content of oil of 42 GJ/Mg. These emission factors should only be used if no other data are available.

Table 3-11 **Onshore facility emission factors for combined extraction and first treatment (Corinair, 1990)**

	NMVOC emissions/unit production		Quality
	Kg/Mg	Mg/PJ	
France/Bulgaria/Italy	0.10	2.4	C
Greece/Spain/Slovakia	0.090	2.1	C

Table 3-12 **Offshore facility emission factors for combined extraction, first treatment and loading (Corinair, 1990)**

	NMVOC emissions/unit production		Quality
	kg/Mg	Mg/PJ	
Italy	0.10	2.4	C
Romania	0.10	2.4	C
Norway (1) *	0.58	14	C
Norway (2) *	2.0	47	C
UK	3.2	75	C
Spain	0.091	2.2	C

Note
* Norway (1) and (2) are assumed to be 2 different facilities.

For fugitive losses equation 8 will be relevant.

Table 3-13 **Canadian fugitive emission factor for facilities (Countess and Browne 1993)**

	NMVOC	Unit	Quality
Canada	0.6	Mg/Gg oil	C

Gas terminals

Table 3-14 **Suggested emission factors for fugitive losses (Brown and Root 1993, Picard et al. 1992; SRI 1994)**

	NMVOC	Throughput	Quality
UK	0.04	-	C
Canada	0.03	-	C
Norway	0.76	25 billion Nm^3	C

The UK has developed average fugitive emission rates of total hydrocarbons from onshore gas terminals and oil processing facilities. While probably conservative, the values given should be used unless facility-specific data are available.

Table 3-15   Average fugitive emission factors for VOC from onshore gas terminal and oil processing facilities (UKOOA, 1995)

	Gas terminal	VOC emission	Quality
Component	Average count	kg/a/component	
Connections	5546	18	C
Valves	1521	200	C
Pressure relief devices	39	120	C
Rotating shafts	41	530	C
Other	229	79	C

No data is currently available on emission factors for the H_2S scrubbing system, only for the flaring which often occurs after the scrubber (see SNAP 090206, and 040103).

Pipelines

The tables in this section list emission factors from Corinair 1990 for emissions from distribution networks. Note that the emission factors are for Onshore networks and the rates would be lower for offshore. Care must be taken when using these emission factors due to the high degree of uncertainty associated with them. They are provided only to indicate the relative differences that exist between the countries and further investigation of the emission rates is required to determine the type of facilities they represent and/or the extent of possible double counting.

For Russia, an emissions factor of 0.07–0.2 Mg/Gg gas/100 km pipeline (depending on the diameter (0.4–1.4 m)) has been derived (SRI, 1994).

Table 3-16   Emission factors for crude oil distribution (Corinair, 1990)

Process	Country	NMVOC emissions/unit production		Quality
		kg/t	t/PJ [*]	
Marine terminals	Bulgaria, Germany	0.02	0.48	C
	France, Greece, Italy, Poland, Portugal	0.30	7.1	C
	Lithuania	0.023	0.62	C
	Spain	0.27	6.5	C
Other handling and storage	Bulgaria, Greece, Hungary, Italy, Luxembourg, Poland, Romania, Spain	0.020	0.48	C
	Norway	1.1	26	C
	Portugal	0.18	4.3	C

Note
[*] Assumed heat content of oil is 42 GJ / t

Table 3-17   Emission factors for gas distribution (Corinair 1990)

Process	Country	NMVOC emissions/unit production		Quality
		g/m³	t/PJ [*]	
General	Poland	2.6	68	C
	Spain	1.1	109	C
	Luxembourg	0.45	12	C
Pipelines	Denmark, Lithuania	0.014	0.37	C
	Italy	0.016	0.42	C
	Latvia	0.003	0.084	C
Compressor	France		2.5	C
	Germany	0.079	2.1	C
	Italy	0.054	1.4	C
	Swiss		0.10	C
Networks	France		10	C
	Italy	0.88	23	C
	Denmark, Lithuania	0.87	23	C
	Slovak	0.072	1.9	C
	Swiss	0.76	20	C
	UK	0.62	16	C

Note
[*] Assumed heat content of gas is 38 MJ/m³.

Table 3-18   Canadian emission factor for fugitive emissions (Mg/Gg transported) (Picard et al. 1992)

	NMVOC	Quality
Crude oil systems	**0.072**	**C**
Natural gas systems	**0.054**	**C**

Drilling

The emission from drilling operations includes the usage of the solvents in the drilling mud and from fugitive sources, such as blow by from small trapped pockets of gas. For the use of drilling mud, an emission of 50 kg/Mg solvent is estimated for the UK, where it is estimated that the solvent usage in drilling mud in the UK is 50 Gg per year (Passant 1993).

Table 3-19   Fugitive emissions from drilling process (OLF 1993, Picard et al. 1992)

	NMVOC	Unit	Quality code
Norway	700	kg/well drilled	C
Canada	1837	Mg total[*]	

Note
The number of wells is not known.

Emissions from venting in connection with well testing are not included in these emission factors, but should also be estimated whenever possible.

Emissions from combustion of crude at test platforms are also not covered under this section (please see the appropriate SNAP code).

Oil loading and transport

This section provides the Tier 3 emission factor data available for oil loading and transport. Additional information for emissions from loading of storage tanks and trucks is available from the refineries chapter 1.B.2.a.iv, Refining, storage.

Table 3-20 contains emission factors for fugitive emissions from oil loading and transport, expressed in per cent by weight of the liquid loaded.

Table 3-20   Fugitive emission factors for oil loading (%wt loaded) (OLF 1993, UKOOA 1995, Rypdal K. 1997)

	Ships		Rail cars/tank trucks		
	NMVOC	Methane	NMVOC	Methane	Quality
Norway: offshore	0.1–0.3 %	5–15 %			C
Norway: onshore	0.02–0.06 %	5–15 %			C
UK	0.001 %	0.000018 %	0.00033 %	0.000058 %	C

The methane content of the vapour will depend mainly on the composition of gas. The evaporation rate will depend on the factors listed in subsection 3.1.5 of the present chapter.

An evaporation rate of 0.01 %, of which methane is 15 %, has been suggested for UK in another publication (E+P Forum, 1994).

An evaporation rate of 0.2–0.6 % has been derived for Russia (SRI, 1994).

The US has developed average emission factors from its detailed methodology for the loading, ballasting, and transportation of crude oil by rail tank car and tank trucks (US EPA, 1996). As a last resort, these could be applied to marine transportation of oil on ships or barges, but every attempt should be made to utilise as much of the detailed methodology as possible.

Table 3-21   Uncontrolled VOC emissions factors for crude oil rail tank cars and tank trucks (US EPA 1996)

Emission source		VOC [a, b]	Unit
Loading operations [c]	Submerged: dedicated normal service	240	g/m³ transferred
	Submerged: vapour balance service	400	g/m³ transferred
	Splash: dedicated normal service	580	g/m³ transferred
	Splash: vapour balance service	400	g/m³ transferred
Ballasting operations	No displaced vapour transfer	130	g/m³ water ballast
Transit losses [d]		4.3	kg/week-m³ shipped

Note
1. NMVOC may be assumed to be 85 % of the emissions calculated with the remainder ethane and methane, if speciation data is not available.
2. The example crude has an RVP of 34 kpa (5 psia).
3. Loading emission factors calculated using equation 8 (subsection 8.2.5 of the present chapter) for a dispensed product with a temperature of 16 °C.
4. The example crude assumed to have condensed vapours with an approximate density of 0.6 kg/m³ (rough estimate).

3.4.3   Activity data

The detailed Tier 3 methodology needs activity statistics for each of the different processes described in the preceding section.

4 Data quality

4.1   Completeness

No specific issues.

4.2   Avoiding double counting with other sectors

No specific issues.

4.3   Verification

4.3.1   Best Available Technique emission factors

Information on emissions associated with Best Available Techniques (BAT) is not available for this source category.

4.4   Developing a consistent time series and recalculation

No specific issues.

4.5   Uncertainty assessment

4.5.1   Emission factor uncertainties

Most emission factors have a quality rating of C. However, since emission factors can differ several orders of magnitude, care should be taken in applying these emission factors.

4.5.2   Activity data uncertainties

No specific issues.

4.6   Inventory quality assurance/quality control QA/QC

No specific issues.

4.7   Gridding

No specific issues.

4.8   Reporting and documentation

No specific issues.

5 Glossary

Flaring	Open combustion of gases from a 'flare stack' without utilising the energy.
Facility	Oil and natural gas platforms, terminals, etc.
Fugitive losses	Emissions of hydrocarbon vapours from process equipment and evaporation of hydrocarbon from open areas, rather than through a stack or vent. Includes emissions from valves, connectors, flanges, seals, process drains, oil/water separators, storage, transfer operations, etc.
Glycol regeneration	A process that reduces the water content in glycol by heating and gas stripping.
Nm^3	1 m^3 of gas at 15°C and 1 atm. pressure (1.01325 bar).
Venting	Direct, controlled, release of gas to the atmosphere.
Stripping gas	Gas used to promote reduction of an unwanted component in a fluid (e.g. remove water in glycol regeneration and oxygen from water injection system).
Compressor stations	These are pumping stations designed to either raise or maintain the pressure in the pipeline or main.
Distribution system	The term 'distribution' usually refers to the low pressure part of a country's gas supply network rather than describing the system as a whole.
High pressure LNG storage	Large vessels in which natural gas is stored in liquid form under pressure.
Mains	Transmission pipes on a local level, typically the sort of gas pipes found under the streets. Classified as low, medium or intermediate pressure.

Pipeline	The term pipeline is generally restricted to the large-diameter, high-pressure pipes used in national transmissions systems and the high-pressure parts of regional transmission systems. The smaller pipes branching off from these are referred to as mains.
Ports	A facility at which liquid natural gas is loaded onto and off ships.
Service mains	Also referred to as service pipes or 'services'. These are the narrow, low pressure pipes leading directly to a customer premises.
STP	Standard temperature and pressure — refers to a temperature of 273.15 K and a pressure of 101325 Pa.
Terminals	A facility for storing and processing gas at the end of a pipeline from a well. The well can be either onshore or offshore.

6 References

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.

Corinair 1990 Database (1990). European Environmental Agency (EEA).

Countess R.J. and Browne D. (1993). 'Fugitive hydrocarbon emissions from pacific offshore oil platforms: Models, emission factors and platform emissions', J. of Air and Waste Management Association, No 43, pp. 1455–1460.

E+P Forum. 'Methods for estimating atmospheric emissions from E+P operations'. Report No 2.59/197. September 1994.

EDGAR (1990). Emission database for global atmospheric research v2.0. TNO, RIVM.

Gas quality (1986). 'Proceedings of the congress "Gas quality specification and measurement and chemical properties of natural gas"'. Groningen, 22–25.4.1986.

International Gas Union (1976). IGU working group on interchangeability of gases.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). Published: IGES, Japan.

OLF (The Norwegian Oil industry Association) (1993). OLF environmental program. Phase II. summary report.

Passant N.R. (1993). 'Emissions of Volatile Organic Compounds from Stationary Sources in the UK'. Warren Spring. ISBN 0 85624 850 9.

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.

Procestechniek 42 (1987). No 10, p. 36 (3).

Rypdal, Kristin (1997). E-mail communication. Statistics Norway, Oslo, Norway, April 1997.

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.

United States Environmental Protection Agency (US EPA) (1996). AP-42, 5th edition, Compilation of Air Pollutant Emission Factors, Volume 1, Supplement A, Office of Air Quality Planning and Standards, Research Triangle Park, NC, May 1996 (www.epa.gov/ttn/chief/)

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.