SNAP CODE:	**050200** **050201** **050202** **050301** **050302** **050303**
SOURCE ACTIVITY TITLE:	**EXTRACTION, 1ST TREATMENT AND LOADING OF LIQUID FOSSIL FUELS** ***Land-based Activities*** ***Off-shore Activities*** **EXTRACTION, 1ST TREATMENT AND LOADING OF GASEOUS FOSSIL FUELS** ***Land-based Desulfuration*** ***Land-based Activities (other than Desulfuration)*** ***Off-shore Activities***
NOSE CODE:	**106.02.01** **106.02.02** **106.03.01** **106.03.02** **106.03.03**
NFR CODE:	**1 B 2 a i** **1 B 2 b**

1 ACTIVITIES INCLUDED

These SNAP codes cover the emissions from sources in connection with the extraction and preliminary treatment of liquid and gaseous fossil fuels. This includes extraction, first treatment and loading of gaseous and liquid fossil fuels from on-shore and offshore facilities. Flaring and combustion of fossil fuels are not included in this section (see SNAP code 090206 and SNAP sectors 1 - 3).

The fugitive losses from production facilities, first loading of crude fuels, and gas processing plants prior to the national or international gas distribution systems are also included.

Subsequent loading and distribution of fuels are considered under SNAP codes 050400 and 050600. Note that production and transport facilities may not be associated with the same countries as the first treatment facilities. For example a gas production platform may be in a Norwegian field, but the gas received at a terminal in Germany.

The current section covers the following activities which may take place on land or offshore:

- cold venting,
- fugitive emissions from production platforms,
- crude oil stabilisation

- glycol regeneration,
- storage tanks associated with the production facility,
- tanker loading,
- drilling muds,
- waste water,
- test drilling,
- losses during transport in marine tankers and oil pipelines and losses from gas pipelines up to the beginning of a national or international distribution network.

A number of facilities produce both oil and gas concurrently and the techniques are quite similar. Hence, five SNAP codes are described this chapter.

2 CONTRIBUTION TO TOTAL EMISSIONS

The contribution to national emissions from extraction and first treatment varies considerably, but in countries where oil and gas are extracted, they are invariably an important contributor to the national total of NMVOCs and methane.

Table 2.1: Contributions to National Emissions from Oil & Natural Gas Production (EDGAR, 1990)

Country	%NMVOC	%Methane	Year
Canada	23 %	37 %	1990
United States	3.6 %	29 %	1990
Latin America	14 %	1.3 %	1990
Africa	8.2 %	5.1 %	1990
Norway *	34 %	3 %	
UK *	3 %	2 %	
Western Europe	8.7%	15 %	1990
Eastern Europe	5.4 %	31 %	1990
Russia *	40 % (total VOC)		
Middle East	53 %	2.2 %	1990
Japan	0.1 %	6.8 %	1990

* Emissions are specific to extraction, first treatment, and loading of liquid and gaseous fuels.

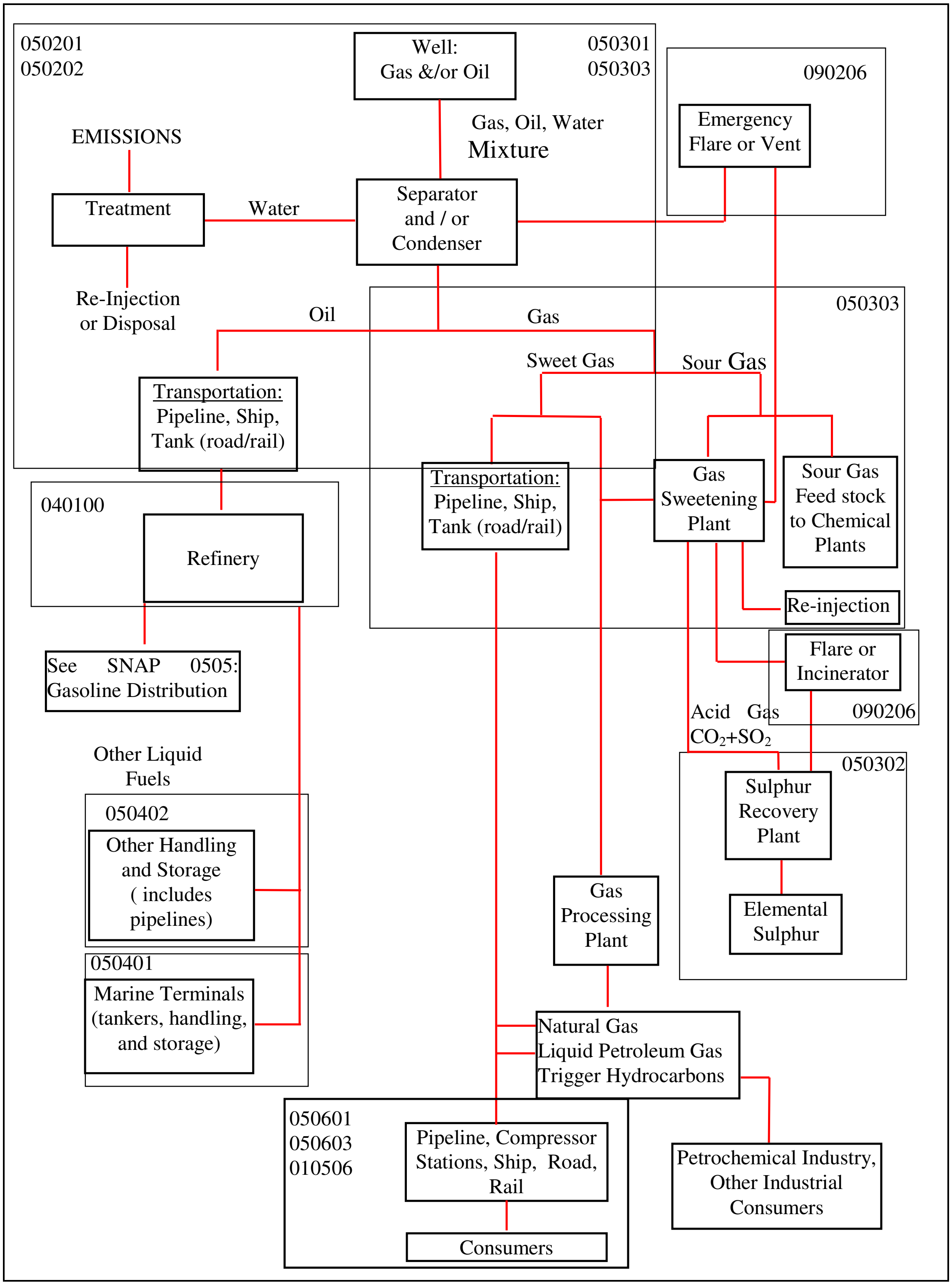
These activities are not believed to be a significant source of $PM_{2.5}$ (as of December 2006).

3 GENERAL

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.

3.1 Description

Figure 3.1 below is a flow diagram that illustrates the activities covered in this section and their relation with activities covered in other sections of the guidebook.



3.1.1 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)

3.1.2 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.

3.1.3 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.

3.1.4 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 blowdown systems.

3.1.5 Oil loading and transport

This source includes the transfer of oil or liquefied gas 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.

3.1.6 Pipelines

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

3.1.7 Drilling

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

3.2 Definitions

Flaring:	Open combustion of gases from a “flare stack” without utilising the energy
Facility:	Oil and natural gas platforms, terminals, etc.
Fugitive losses:	Emission of hydrocarbon vapours from process equipment and evaporation of hydrocarbons 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.
Sm^3(Standard cubic meter):	1 m^3 of gas at 15^{o}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).

3.3 Techniques

The technology for the extraction and first treatment of liquid and gaseous fossil fuels are described in sections 3.1. and 3.4.

3.4 Emissions/Controls

3.4.1 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 a 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. See SNAP 040103 for description and emissions calculations

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.

3.4.2 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 3.4.1.

3.4.3 Facilities producing oil only

All gas produced will either 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 3.4.1.

3.4.4 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 3.4.1.

3.4.5 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, and
- 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 off shore loading by about 70%. Technologies to reduce emissions from on shore 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 EPA, 1996)

3.4.6 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 3.4.1 under fugitive emissions).

3.4.7 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 muds, and the wash of oil contaminated cuttings. The main control options are gas removal during drilling and recovery of hydrocarbons from oil based muds and cuttings.

4 SIMPLER METHODOLOGY

Emissions may be estimated using general emission factors multiplied by the level of activity as described in section 6. Emissions from the various sub-sources mentioned in section 3.4 and 6 are estimated independently and added. Countries need to know the important features of their production systems to estimate the main sources of emissions.

5 DETAILED METHODOLOGY

The detailed methodology involves quantification of emissions by source using field specific activity statistics and emission factors or direct measurements/engineering calculations. Field studies in collaboration with industry will be required to more accurately quantify the emissions at specific sites. Many of the calculations are detailed within the simpler methodology. Emission factors exist for many of the emission sources such as: venting, fugitive sources, drilling, and transportation of fuels. Several calculation methods are available and are described in the subsections 8.1 and 8.2.

6 RELEVANT ACTIVITY STATISTICS

The material in the following sections for the simple and detailed methodology has been organised in a hierarchical manner, beginning with the easiest information to obtain going to the more detailed methods as the list progresses. It is recommended to obtain all of the information possible per facility or per m3 of gas produced by facility type, then calculate the emission using the requisite methodology.

6.1 Simple Methodology

For the simpler methodology the following activity statistics are required:

> The number of facilities (platforms) - age and type.
>
> Oil and gas production, preferably by field. These data are available from national statistical offices in each country and from various international sources such as the OECD and CASPER (see section 15).
>
> The heat content of the oil and gas and density of the oil.
>
> The volume of gas processed through a gas terminal - will be available from national sources.
>
> The mass of crude oil loaded into tankers (ships or trucks). This mass will in many cases be equal to the oil production at a specific field.
>
> The frequency of drilling operations (the number of wells drilled per year or the total number of days drilled per year).
>
> The volume of gas or oil transported through a given pipeline - this volume is measured for economical reasons or it might in many cases be equal to the combined production from a number of fields.
>
> The mass and composition of drilling muds

6.2 Detailed Methodology

For the detailed methodology the following field specific activity statistics are required in addition to the above information described in the simple methodology:

The volume of gas vented.

The composition of the gas vented and its average molecular weight.

The component count of the gas handling system (e.g. number of valves, flanges and seals, etc.).

The volume of H_2S gas incinerated or the sulphur content of the gas.

Average true vapour pressure of liquid loaded onto ships, Reid Vapour Pressure (RPV), average molecular weight of vapours, density of condensed vapours, and average temperature of vapours for oil being transported from each field.

7 POINT SOURCE CRITERIA

The location of oil and gas production facilities are associated with specific oil and gas fields. Where practical individual fields and production facilities should be considered as point sources.

All pipelines, ships and trucks in movement should be considered as line sources.

All gas terminals should be considered as point sources.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

The following sections detail the simpler methodology for the calculation of emissions. Though this is the simple method some of the calculations for emission sources are quite detailed. The calculations have been arranged from the simpler to the more detailed. Methods used to calculate the emissions should be based on the available information.

For some of the calculations other sections of the Atmospheric Emissions Inventory Guidebook will be required. These sections are, but, not limited to the following:

- Desulphurisation SNAP 040103
- Flaring SNAP 090206
- Combustion of fuels SNAP sectors 1 - 3
- Loading of storage tanks and trucks SNAP 040104
- Liquid Fuel Distribution SNAP 050400
- Gas distribution networks SNAP 050600

Care must be taken when using the emission factors listed in the following sub-sections. 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 extend of possible double counting. These emission factors should be used if no other sources of information are available.

8.1.1 Combined oil and gas facilities

The following tables list the emission factors for venting per facility and per Smillion m^3 of gas produced.

Table 8.1: Suggested Emission Factors for Venting (kg/Smillion m^3 gas produced) (OLF, 1993)

	NMVOC	**CH_4**	**CO_2**	**Quality codes**
Norway	76	98	0	C

Table 8.2: 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, the highest suggested emission factor should be applied.

Suggested emission factors for fugitive losses:

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

$$\textbf{Total VOC (Mg/year)} = 40.2 * N + 1.1 * 10^{-2} * X + 8.5 * 10^{-6} * Y \qquad (1)$$

Where: N is the number of facilities (e.g. platforms)
X is the gas production (million Sm^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.

8.1.2 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), onshore (SNAP 050302), and offshore (SNAP 050303) activities. Care must be taken when using these emission factors due to the high degree of uncertainty. It is recommended to use the detailed procedure in section 8.2.2.

For desulphurisation see SNAP 040103.

Table 8.3: General Facility Emission Factors for Combined Extraction, First Treatment and Loading (CORINAIR, 1990)

	NMVOC Emissions / Unit Production		**Quality**
	g / m^3	t / PJ *	
Poland	3.1	82	C

* Assumed heat content of gas is 38 kJ / m^3

Table 8.4: Onshore Facility Emission Factors for Combined Extraction & First Treatment (CORINAIR, 1990)

	NMVOC Emissions / Unit Production		**Quality**
	g / m^3	t / PJ *	
Germany	0.079	2.1	C
Czech / 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

* Assumed heat content of oil is 38 MJ / m^3
** Emission rates may contain Methane

Table 8.5: Offshore Facility Emission Factors for Combined Extraction, First Treatment and Loading (CORINAIR, 1990)

	NMVOC Emissions / Unit Production		Quality
	g / m^3	t / 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

* Assumed heat content of oil is 38 MJ / m^3
** Leakage offshore
*** Extraction of Natural Gas

The emission factors in Tables 8.3-8.5 should be used only if all other avenues have been exhausted.

Table 8.6: Suggested Emission Factors for Venting [Brown et al, 1993; Picard et al, 1992; SRI, 1994; TNO]

	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

* Total VOC. Vent and fugitive losses

For fugitive losses Equation 1 (Section 8.1.1) will be relevant.

Table 8.7: Canadian Fugitive Emission Factors for Facilities. (Countess et al, 1993)

	NMVOC	CH_4	Unit	Quality
Canada	0.9	1.5	Mg/Gg gas	C

8.1.3 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.

Table 8.8: Onshore Facility Emission Factors for Combined Extraction & First Treatment (CORINAIR, 1990)

	NMVOC Emissions / Unit Production		Quality
	kg / t	t / PJ *	
France / Bulgaria /Italy	0.10	2.4	C
Greece / Spain / Slovak	0.090	2.1	C

* Assumed heat content of oil is 42 GJ / t

Table 8.9: Offshore Facility Emission Factors for Combined Extraction, First Treatment and Loading (CORINAIR, 1990)

	NMVOC Emissions / Unit Production		Quality
	kg / t	t / 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

* Assumed heat content of oil is 42 GJ / t
** Norway (1) and (2) assumed to be 2 different facilities

The emission factors in Tables 8.8-8.9 should be used only if all other avenues have been exhausted.

Table 8.10: Suggested Emission Factors for Venting (Brown et al, 1993; Picard et al, 1992; SRI 1994, TNO)

	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

For fugitive losses equation 1 in section 8.1.1 will be relevant.

Table 8.11: Canadian Facility Level Emission Factors for Oil Production (Countess et al, 1993)

	NMVOC	CH_4	Unit	Quality
Canada[1]	0.6	1.1	Mg/Gg oil	C

8.1.4 Gas terminals

Table 8.12: Suggested Emission Factors for Venting (Gg/Terminal) Venting (Brown et al, 1993; Picard et al, 1992; SRI 1994, TNO)

	NMVOC	CH_4	CO_2	Throughput	Quality
UK[1]	0.28	2.4	0.034	-	C
Canada[2]	0.007	0.013	-	-	C
Norway[3]	0	0	0	25 bill. Sm^3	C
Russia[4]	5-12*		-	22 bill. Sm^3	C

* Including fugitive losses and methane

Table 8.13: Suggested emission factors for fugitive losses (Gg/terminal) Venting (Brown et al, 1993; Picard et al, 1992; SRI 1994)

	NMVOC	CH_4	Throughput	Quality
UK	0.04	0.47	-	C
Canada	0.03	0.05	-	C
Norway	0.76	0.44	25 bill. Sm^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 is available.

Table 8.14: Average Fugitive Emission Factors for VOC from Onshore Gas Terminal and Oil Processing Facilities (UKOOA, 1993)

	Gas Terminal	**VOC**	**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.

8.1.5 Oil loading and transport

See also SNAP 050401 to 050404 for additional information on oil loading and transport. SNAP 040104 for loading of storage tanks and trucks

The following emission factors for fugitive emissions are percent by weight of the liquid loaded

Table 8.15: Fugitive Emission Factors for Oil Loading (%wt loaded) (OLF, 1993; UKOOA, 1995; Rypal K., 1997)

	Ships		**Rail cars / Tank trucks**		
	NMVOC	Methane	NMVOC	Methane	Quality
Norway: Off Shore	0.1 - 0.3 %	5 - 15 %			C
Norway: On Shore	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 section 3.1.5.

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

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 8.16: Uncontrolled VOC Emissions Factors for Crude Oil Rail Tank Cars and Tank Trucks (US EPA, 1996)

Emission Source		VOC [a, b]	Units
Loading Operations [c]	Submerged: Dedicated Normal Service	240	g / m^3 transferred
	Submerged Vapour Balance Service	400	g / m^3 transferred
	Splash: Dedicated Normal Service	580	g / m^3 transferred
	Splash Vapour Balance Service	400	g / m^3 transferred
Ballasting Operations	No displaced vapour transfer	130	g / m^3 water ballast
Transit Losses [d]		4.3	kg / week-m^3 shipped

a NMVOC may be assumed to be 85 % of the emissions calculated with the remainder ethane and methane, if speciation data is not available.

b The example crude has an RVP of 34 kpa (5 psia).

c Loading emission factors calculated using equation 8 (Section 8.2.5) for a dispensed product with temperature of 16 °C.

d The example crude assumed to have condensed vapours with an approximate density of 0.6 kg / m^3 (rough estimate).

8.1.6 Pipelines

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).

Tables 8.17-8.19 list emission factors from CORINAIR 1990 for emissions from distribution networks. The tables are for gaseous fuels and liquid fuel distribution. Note that the emission factors are for On Shore networks and the rates would be lower for Off Shore. See also the SNAP sections 0504 and 0506 for further information. 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, the extend of possible double counting.

Table 8.17: Emission Factors for Gas Distribution (CORINAIR, 1990)

Process	Country	NMVOC Emissions / Unit Production		Quality
		g / m^3	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

* Assumed heat content of gas is 38 MJ / m^3

Table 8.18: 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

* Assumed heat content of oil is 42 GJ / t

Table 8.19: Canadian Emission Factors for Fugitive Emissions (Mg/Gg transported) (Picard et al, 1992)

	NMVOC	Methane	Quality
Crude oil systems	0.072	0.13	C
Natural gas systems	0.054	0.095	C

8.1.7 Drilling

The emission from drilling operations includes the usage of the solvents in the drilling muds and from fugitive sources, such as blow by from small trapped pockets of gas.

Use of drilling mud:

UK 50 kg/Mg of solvent[1]

1. The solvent usage in drilling muds in UK is estimated at 50 Gg per year (Passant 1993)

Table 8.20: Fugitive Emissions from Drilling Process (OLF, 1993; Picard et al, 1992)

	NMVOC	CH_4	Unit	Quality code
Norway	700	325	kg/well drilled	C
Canada	1837	3238	Mg total*	

* 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 is also not covered under this section, please see the appropriate SNAP code.

8.2 Detailed Methodology

The detailed methodology provides guidance to improve the estimates generated with the emission rates given in the simpler methodology (section 8.1). The detailed methodology should be used in conjunction with the simple methodologies and is available for most sources except for drilling muds and gas terminals.

8.2.1 Combined oil and gas facilities

For venting, the volume of gas vented should be established for each field and combined with the specific composition data for each field. If the specific composition of the gas vented is not known, use the average molecular weight and the equations developed by UK below.

$$\text{Total Vented NMVOC (kg/year)} = 5 * MW * V / 224 \qquad (4)$$
$$\text{Total Vented Methane (kg/year)} = 5 * MW * V / 224 \qquad (5)$$

Where: MW is the average molecular weight of the gas vented
V is the volume of gas vented in Standard cubic meters

For fugitive emissions the component counts are required for each platform. These are to be combined with internationally accepted emission factors, e.g. API. However, verification of these are required for the particular installation to take into account current technologies.

The following emission factors have been suggested by the UK for average fugitive emissions of total hydrocarbons for facilities with state of the art leak detection and control programmes. The emission factors are kilograms of emissions per component per year with VOC and Methane factors derived from gas composition data.

Table 8.21: Average Fugitive Emissions of Total Hydrocarbons for Facilities With State of The Art Leak Detection and Control Programmes (UKOOA, 1995)

	Connection	Valves	Open-Ended Lines	Others
	kg/a/component			
Offshore oil and gas	0.099	3.5	1.6	17

Fugitive emissions may also be estimated by tracer measurements techniques.

The estimation of emissions from water treatment will require an exact knowledge of the volume of water treated, treatment method, the oil content of the discharged water, and the actual mass of water emitted to the atmosphere.

8.2.2 Facilities producing gas only

See section 8.1.2 except for gas venting if the specific composition of the gas is not known. The following has been developed by the UK for facilities producing gas, venting gas:

$$\textbf{Total Vented NMVOC (kg/year)} = 9 * MW * V / 224 \qquad (6)$$
$$\textbf{Total Vented Methane (kg/year)} = 1 * MW * V / 224 \qquad (7)$$

Where: MW is the average molecular weight of the gas vented
V is the volume of gas vented in Standard cubic meters

The following emission factors have been suggested by the UK for average fugitive emissions of total hydrocarbons. The emission factors are in kilograms of emissions per component per year with VOC and Methane factors derived from gas composition data.

Table 8.22: Facilities With State-Of-The-Art Leak Detection and Control [11]

	Connection	Valves	Open-Ended Lines	Others
	kg/a/component			
Offshore gas	0.63	18	1.8	48

Table 8.23: Offshore Facilities With Conventional Leak Detection and Control (UKOOA, 1995)

	Connection	Valves	Pressure relief devices	Rotating shafts	Others	Quality
	kg/a/component					
Gas production	11	29	24	200	65	C

For the facilities with conventional leak detection use may be made of the following table of component counts in hydrocarbon service on the generic platforms, estimated from CAD designs by the UK

Table 8.24: Generic Platform Component Counts for Conventional Leak Control (UKOOA, 1995)

Facility type	**A**	**B**	**C**	**D**	**E**	**Quality**
Connections	1114	2363	2792	3483	8289	C
Valves	514	1348	1036	1572	3002	C
Pressure relief devices	3	32	27	43	65	C
Other	110	357	311	270	557	C

Notes: Generic A Well head gas platform 150 MMSCFD
Generic B Gas treatment/compression platform 330 MMSCFD
Generic C Small simple oil platform 40000 BPD & 10 MMSCFD
Generic D Medium complexity oil platform 75000 BPD & 16 MMSCFD
Generic E Large oil/ condensate platform 80000BPD & 540 MMSCFD

8.2.3 Facilities producing oil only

See section 8.1.3 also for additional information

The following emission factors have been suggested by the UK for average fugitive emissions of total hydrocarbons. The emission factors are in kilograms of emissions per component per year with VOC and Methane factors derived from gas composition data.

Table 8.25: Facilities With State-of-The-Art Leak Detection and Control [11]

	Connection	**Valves**	**Open-Ended**	**Others**	**Quality**
	kg/a/component				
Offshore light crude	0.68	3.3	5.8	16	C
Offshore heavy crude	0.017	0.033	0.17	0.17	C

Table 8.26: Offshore Facilities With Conventional Leak Detection and Control [11]

	Connection	**Valves**	**Pressure relief devices**	**Rotating shafts**	**Others**	**Quality**
	kg/a/component					
Oil Production	7.1	36	1.5	130	14	C

Component counts from table 8.24 section 8.2.2 maybe used as estimates with the conventional leak detection and control emission factors

8.2.4 Gas terminals

Emissions from individual gas terminals should be determined separately through measurements, if possible, and engineering calculations as described in sections 8.2.1.

8.2.5 Oil loading and transport

Individual emission factors should be developed to reflect the variations mentioned in section 3.4.

It may be noted that Norwegian studies (OLF, 1993) have concluded the following:

> An amplitude of +2 degrees of the vessel while loading increases the mass of released gas by 50 % compared to calm conditions.
>
> An increase in the loading rate of 40 % decreases the mass of released gas by 14%.
>
> An increase in the temperature to 30 C to 34 C increases the mass of released gas by 10 %.

The US - EPA has developed an equation for the emissions from loading petroleum liquid into different transportation vessels (US EPA, 1996). For further information it is recommended to see the US-EPA AP-42 Sections 5.2 Transportation and marketing of petroleum Liquids, and 7.1 Organic Liquid Storage Tanks which contain further explanations as well as look-up tables for hydrocarbons. The Internet World Wide Web Site for the US-EPA emission factor information is http://www.epa.gov/ttn/chief/

$$\mathbf{L_L = 0.82947 * \frac{S * P * M}{T}} \qquad (8)$$

Note: The constant has been converted for metric use

Where L_L is the emission factor in kg / m^3 (± 30 %).

S is the Saturation Factor from table 8.29 below.

P is the true vapour pressure of the liquid loaded in pounds per square inch (1 psi = 6.89476 Pascal).

M is the molecular weight of the vapours (kg/kg-mole)

T is the temperature in Kelvin (^{o}C + 273)

P & M can be calculated using weighted averages of the molar ratios of the constituent components of the liquid loaded.

Table 8.27: Saturation Factors for Calculating Petroleum Liquid Loading Losses (US EPA, 1996)

Cargo Carrier	**Mode of Operation**	**S Factor**
Tank trucks and rail tank cars	Submerged loading: of a clean cargo tank	0.50
	Submerged loading: dedicated normal service	0.60
	Submerged loading: dedicated vapour balance service	1.0
	Splash loading: of a clean cargo tank	1.45
	Splash loading: dedicated normal service	1.45
	Splash loading: dedicated vapour balance service	1.00
Marine vessels *	Submerged loading: ships	0.2
	Submerged loading: barges	0.5

* For products other than crude oil. For marine loading of crude oil use equations 10 & 11 and table 8.30

The saturation factor S represents the expelled vapour's fractional approach to saturation, and it accounts for the variations in emission rates from the different unloading and loading methods.(US EPA, 1996)

The emissions from controlled loading operations can be calculated by multiplying equation 8 with equation 9 below which accounts for the reduction efficiency (as a percentage) of the control method. The efficiencies of the control methods often range from 90 to 99 %, but due to limitations only 70 to 90 % of the vapour is captured. Due to the limitations 90 % should be used when the tankers pass regular inspections, otherwise 70 % should be assumed. (US EPA, 1996).

$$\mathbf{Reduction = (1 - eff. / 100)} \qquad (9)$$

Where eff = efficiency of control method

For Marine Crude oil loading the following has been developed by the US-EPA specifically for loading of crude oil into ships and barges. (US EPA, 1996)

$$\mathbf{C_L = C_A + C_G} \qquad (10)$$

Where: C_L is the total loading loss in kg / m^3 of crude oil loaded.
C_A is the arrival emission factor, contributed by vapours in the empty tank compartment before loading in kg / m^3, table 8.30.
C_G is the generated emission factor contributed by evaporation in kg / m^3.

Table 8.28: Average Arrival Emission Factors, C_A, for Crude Oil Loading Emissions[a] (US EPA, 1996)

Ship / Ocean Barge Tank Condition	**Previous Cargo**	**Arrival Emission Factor, kg/m^3**
Uncleaned	Volatile[b]	0.103
Ballasted	Volatile	0.0551
Cleaned or gas-freed	Volatile	0.0395
Any Condition	Non-volatile	0.0395

a Arrival emission factors (C_A) to be added to generated emission factors (C_G) calculated in equation 11 to produce total crude oil loading loss (C_L). Factors are for total organic compounds; NMVOC emission factors average about 15% lower, because VOC does not include methane or ethane.

b Volatile cargos are those with a true vapour pressure greater than 10 kPa (1.5 psia).

The generated emission factor equation (11) below was developed empirically from test measurements of several vessel compartments.

$$\mathbf{C_G = 0.12249 * (0.44 * P - 0.42) * \frac{M * G}{T}} \qquad (11)$$

Note: The constant has been converted for metric use

Where P is the true vapour pressure of loaded crude oil in psia (pounds per square inch absolute)

M is the molecular weight of the vapours

G is the vapour growth factor = 1.02 (dimensionless)

T is the temperature of the vapours in Kelvin (^{o}C + 273)

Emission factors (C_G) derived from equation 11 is for total organic compounds. NMVOC has been found to be 55 to 100 weight percent of the vapours from crude oil in the US. If specific vapour composition is unavailable 85 % of the emission factor may be used for NMVOC. (US EPA, 1996)

Ballasting losses may be estimated from the following equation from the US-EPA. (US EPA, 1996)

$$\mathbf{L_B = 0.0371 + 0.0240 * P + 0.00120 * P * U_A} \qquad (12)$$

Note: The constant has been converted for metric use

Where L_B is the ballasting emission factor kg / m^3 of ballast water

P is the true vapour pressure of discharged oil in psia.

U_A is the arrival cargo true ullage, before dockside discharge, measured from the deck in feet, (ullage here refers to the distance between the cargo surface and the deck level, 1 foot = 0.3048 m).

Average VOC emission factors are give in Table 8.29 below for ballasting into uncleaned crude oil compartments. The fully loaded category applies when the crude oil true ullage just before unloading is less than 1.5 metres. The lightered or previously short loaded category applies to compartments with an arrival ullage of greater than 1.5 metres. These values should only be used when the information for equation 12 is unknown.

Table 8.29: Total Organic Emission Factors for Crude Oil Ballasting. (US EPA, 1996)

Compartment Condition Before Cargo Discharge	**Average Emission Factors**	
	By Category	Typical Overall [b]
	g/m^3 Ballast Water	
Fully Loaded [c]	111	129
Lightered or Previously Short Loaded [d]	171	

a Assumes crude oil temperature is 16 ^{o}C and RVP of 34 kPa (5 psia). NMVOC emission factors average about 85% of emission factors listed as NMVOC does not include methane or ethane.

b Based on observation that 70% of tested compartments had been fully loaded before ballasting. May not be represent average vessel practices.

c Assumed typical arrival ullage of 0.6 m.

d Assumed typical arrival ullage of 6.1 m.

Transit losses also occur and the losses are similar to breathing losses for storage tanks (SNAPs 040102 and 050401). Testing in the US on ships and barges indicates that transit losses may be calculated with the following equation: (US EPA, 1996)

$$\mathbf{L_T = 1.436 * P * W} \qquad (13)$$

Note: The constant has been converted for metric use

Where L_T is the transit loss form ships and barges in kg / week-m^3.

P is the true vapour pressure of the transported liquid in psia.

W is the density of the condensed vapour in kg / m^3

8.2.6 Pipelines

Little data is currently available for this source.

Picard 1993 gives some emission factors related to individual sources (valves, seals, compressors, connectors etc.). See reference 6 for additional information to that provided below.

Table 8.30: Summary of Average Emission Factors for Uncontrolled Fugitive VOC Emissions (kg/h/source) at Upstream Oil and Gas Facilities in Alberta, Canada (Picard et al, 1992)

Source	Service Type	Oil Facilities	Gas Facilities	Quality
Valves [a]	All	0.0061	0.018	C
	G/V (All)	0.014	---	C
	G/V (Sweet)	---	0.044	C
	G/V (Sour)	---	0.0052	C
	LL	0.0012	0.0023	C
Connectors	All	0.00048	0.0013	C
	G/V (All)	0.00079	---	C
	G/V (Sweet)	---	0.0025	C
	G/V (Sour)	---	0.00031	C
	LL	0.00019	0.00019	C
Compressor Seals [2]	G/V	0.80	0.80	C
Pump Seals	LL	0.021	0.021	C
Pressure Relief Devices	G/V	0.12	0.12	C
Open Ended Lines	All	0.0037	0.0037	C

G/V Gas/Vapour: the process fluid exists as a gas or vapour at the operating conditions (temperature and pressure) and contains less than 50 percent hydrogen by volume.

LL Light Liquid: the process fluid is a hydrocarbon liquid at the operating conditions hand has a vapour pressure of 0.3 kPa or more at 15°C.

HL Heavy Liquid: the process fluid is a hydrocarbon liquid at the operating conditions hand has a vapour pressure of 0.3 kPa or more at 15°C.

[1] The emission factors for valves account for leakage from the valve body and around the valve stem. Leakage down the pipe (e.g., leakage past the valve seat) is accounted for using the emission factor for open-ended lines.

[2] The emission factors for compressor seals are only applicable for uncontrolled sources (i.e., systems that do not use seal-leakage capture systems [e.g., use of barrier fluids wuth degassing reservoir and vent-to-flare system])

Table 8.31: Speciation profiles (mole percent on a moisture free basis) for Fugitive Emission from Production Facilities. (Picard et al, 1992)

	Dry Gas		**Sweet Gas**				**Sour Gas**		
Component	G[1,5]	DHY[2,6]	G[5]	V[3,7]	LL[4,8]	DHY[6]	G[1,9,10]	V[2,7]	LL[3,8]
N_2	1.0914	6.0450	0.6793	2.9668	0.0000	3.0022	0.6552	2.9668	0.0000
CO_2	0.2674	3.6656	.0.5814	1.3436	0.0000	6.3865	0.5608	1.3436	0.0000
H_2S	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	3.5460	0.0000	0.0000
C_1	97.4524	87.4598	91.8796	56.4205	0.0000	68.9410	88.6210	56.4205	0.0000
C_2	1.1439	2.8296	5.4263	15.2219	6.2600	11.4083	5.2339	15.2219	6.2600
C_3	0.0389	0.0000	1.0490	11.6300	60.4300	3.7118	1.0118	11.6300	60.4300
i-C_4	0.0018	0.0000	0.1291	2.6504	10.9300	3.2751	0.1245	2.6504	10.9300
n-C_4	0.0034	0.0000	0.1949	5.5796	16.4000	3.2751	0.1880	5.5796	16.4000
i-C_5	0.0004	0.0000	0.0254	1.2562	1.6600	0.0000	0.0245	1.2562	1.6600
n-C_5	0.0005	0.0000	0.0296	1.5784	1.4300	0.0000	0.0286	1.5784	1.4300
C_6	0.0000	0.0000	0.0060	0.9312	1.2000	0.0000	0.0058	0.9312	1.2000
C_{7+}	0.0000	0.0000	0.0000	0.4215	1.6800	0.0000	0.0000	0.4215	1.6800

(See notes for table 8.32)

Table 8.32: Speciation Profiles (mole percent on a moisture free basis) for Fugitive Emission from Production Facilities Continued. (Picard et al, 1992)

	Nat. Gas	**Conventional Oil**		**Heavy Oil (Primary)**		**Heavy Oil (Thermal)**		**Crude Bitumen**
Component	G[5]	G[1,11]	V[3,7]/LL[4]	G[13]	V/HL[12,13]	G[1,13]	V[3,13]/HL[12]	G[14]/V/HL
N_2	0.6793	0.6190	13.9989	0.1817	6.3477	0.1932	3.3516	0.0000
CO_2	0.5814	5.2430	0.3303	0.0859	0.6892	2.6094	16.1140	22.0000
H_2S	0.0000	0.0000	0.0000	0.0001	0.0000	0.0150	0.1439	0.0000
C_1	91.8796	73.2524	10.0100	98.0137	87.2337	72.9361	66.6600	70.0000
C_2	5.4263	11.9708	15.7274	0.9062	2.2616	1.9370	0.9490	8.0000
C_3	1.0490	5.3198	24.1601	0.0408	0.1905	3.0956	0.5394	0.0000
i-C_4	0.1291	0.8778	6.6404	0.0564	0.1324	1.0807	0.1922	0.0000
n-C_4	0.1949	1.7027	16.6022	0.0351	0.1137	2.3889	0.3678	0.0000
i-C_5	0.0254	0.3570	4.2113	0.0501	0.1400	1.9994	0.4541	0.0000
n-C_5	0.0296	0.3802	4.5447	0.0433	0.1230	2.2733	0.5829	0.0000
C_6	0.0060	0.2446	2.9655	0.0927	0.3949	5.8086	2.1914	0.0000
C_{7+}	0.0000	0.0327	0.7997	0.4940	2.4188	5.6628	8.4539	0.0000

[1] G - Gas.

[2] DHY - Vent gas from glycol dehydrators.

[3] V - Vapours from storage tanks.

[4] LL - Light Liquid.

[5] Based on a gas analysis taken at an appropriate transmission point.

[6] Estimated by simulating dehydration of the gas (G) at water-saturated conditions, 28°C and 7,000 kPa.

[7] Adapted from an analysis of the vapours from a condensate tank in northeast B.C.

[8] Estimated based on the total amount of ethane, propane, butane, and natural gas liquids produced by gas plants in 1989.

[9] The H_2S concentration is estimated based on the amount of gas and sulphur produced by sour gas processing plants in1989.

[10] The H_2S-free composition is based on an analysis taken at an appropriate transmission point.

[11] Based on an analysis of the gas from a large solution-gas gathering system in central Alberta.

[12] HL - Heavy Liquid.

[13] Adapted from results presented by Ullman et al. (1987)

[14] Provided by an operator of a major crude bitumen facility

8.2.7 Drilling

Specific emission factors for representative drilling wells should be developed taking into account the sources listed in section 3.4.7 and other possible sources.

9 SPECIES PROFILES

Speciation profiles for Crude Oil Production (US EPA, 1988) and natural gas venting (TNO) are listed in the profiles below. See also tables 8.33 and 8.34 given in section 8.2.6.

Table 9.1: Speciation Profiles

Species	wt%	
	USEPA	**TNO**
Ethane	6	72
Propane	19	14
Butanes	30	7
Pentanes	17	2
Hexanes	8	4
Heptanes	10	0
Octanes	7	0
Cycloparaffins	2	0
Benzene	0	0

The composition of the NMVOC fraction of emissions from oil and gas production can be expected to vary considerably between fields and between different emissions sources. Therefore, the above generalised species profiles should only be used if better information is not available.

10 UNCERTAINTY ESTIMATES

The quality of the emission rates provided in section 8 provides some indication of the uncertainty of the estimates that can be generated. Additional uncertainty guidance by activity is provided below.

Venting: An extremely high uncertainty is expected (greater than a factor of 2), particularly when the generalised emission factors are applied. The uncertainty may be as high as an order of magnitude in the emissions.
Fugitive emissions from oil and gas production platforms: An error of 65% has been reported for equation 1. However, this may be greater when this equation is applied to other fields. When using the general emission factors it can be seen that there is a variation of several orders of magnitude between countries.

Waste water treatment: The mass of oil in waste water discharged is normally measured accurately, particularly if it is a legal requirement. The proportion which evaporates is subject to much higher uncertainty (greater than a factor of 2).

The Norwegian data in general have estimated an uncertainty of +55%/-35% of the sum of vent and fugitive losses (OLF, 1993).

Gas terminal: Due to the few observations the uncertainty is expected to be greater than a factor of 2.

Oil loading and transport: The variation within existing data suggests that the uncertainty is greater than a factor of 2 when general emission factors are applied.

Drilling: Due to the few observations the uncertainty is expected to be greater than a factor of 2.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The variation in emissions of NMVOC and CH_4 from combined oil and gas and oil only production facilities in particular is expected to be large given the variation in the composition of the fluid and the options available to deal with the gas produced. Therefore, the weakest aspect of the simpler methodology is the use of generalised emission factors relating to oil production or the number of production facilities. Progress from the simpler methodology to the more detailed methodology is a priority. The main priority areas proposed for improvement are:

- All fields to report volume of vented gas and composition of vented gas.
- All fields to move from calculated estimates for the volume of gas vented, to measured data.
- All fields to report volume of oil loaded offshore, vapour pressure of the oil and the composition of the vapour.
- All installations to report fugitive emissions based on component counts, with selected fields providing verification through measurements.
- All gas terminals to report all emissions to atmosphere and carry out measurements to verify estimates for the major sources.
- The suggested emission factors are based on few measurements and detailed studies. More data from fields studies in different countries are needed in order to improve the general emission factors.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Currently “sea” is the only relevant NUTS code for offshore activities. If a higher spatial resolution is required or emissions are generated on-shore, production by field will be available in most countries.

Oil loading and gas terminal: These sources will generally be few, and the relevant activity statistics may easily be allocated to the correct territorial unit.

For pipelines, emissions may be assumed equally distributed along the pipe, if better information is unavailable.

13 TEMPORAL DISAGGREGATION CRITERIA

Monthly production data is available in major oil and gas exporting countries. If this information is not available, emissions may be assumed equally temporally distributed. Equal diurnal (night/day) may generally be assumed.

Oil loading can be expected to occur during the day only.

14 ADDITIONAL COMMENTS

There are a number of developments in emission estimate methodologies in this area e.g. IPCC, OLF (Norway) and OOA (UK).

This draft will have to be revised in the coming years in light of these developments.

Responsibility for emissions originating from fields shared between two countries: emissions are allocated from the economic shares of the countries in the current field.

15 SUPPLEMENTARY DOCUMENTS

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16 VERIFICATION PROCEDURES

Covered in Section 11.

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19 RELEASE VERSION, DATE AND SOURCE

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20 POINT OF ENQUIRY

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