SNAP CODE :

050101
050102
050103

SOURCE ACTIVITY TITLE :

Extraction and First Treatment of Solid Fossil Fuels
Open Cast Mining
Underground Mining
Storage of Solid Fuel

1. ACTIVITIES INCLUDED

This section covers only coal, not peat or other solid fuels. Subsequent treatment of coal, such as fuel conversion, coking, gasification or liquefaction are not treated in this chapter, but are included in related chapters of the guidebook.

2. CONTRIBUTION TO TOTAL EMISSIONS

In the UK, the Extraction and First Treatment of Solid Fuels relate to emissions of methane from mining operations. This sector was estimated to be responsible for 22% of national emissions of methane in 1991. (Gilham 1994). Little accurate data is available for the other pollutants.

3. GENERAL

3.1 Description

Coalfields contain a proportion of highly volatile material which is released during the working, extraction and storage of coal. The volatile material is known as fire damp, made up primarily of methane, although other compounds are also present in minor amounts.

The release of fire damp often results in an emission to air as it not always economical to contain the gas, for flaring or use as a fuel.

3.2 Definitions

Fire damp - inflammable gas released during the working of coal mines. In general, methane is considered a safety hazard.

3.3 Techniques

Two types of mining operations are considered in this chapter - deep mines and open cast mines. In addition, it is important to note that coal varies considerably from one field to another, depending on its age and geological location. The proportion of firedamp associated with the different types of mining and the different types of coal have shown considerable variation. Attempts to model the relationship between the proportion of fire damp and factors such as depth of coal seam, nature of coal, local geology have shown some correlations although the associated uncertainty is very large.

Once coal is extracted, it may be stored, transported internally or exported, or a combination of all three. Associated gaseous emissions continue to occur and it is thought that these will be related to the coal type, the size of the coal pieces, the mechanical disturbance during handling etc.

3.4 Emissions/Controls

The primary emission of fire damp is believed to occur during the extraction of deep mine coal. Open cast mining, since it involves the extraction of coal seams close to the surface, and the handling and storage of coal are not considered to be as important.

In many cases, fire damp is actively removed from the coalfield, by various methods normally described collectively as methane drainage. This is primarily for reasons of safety. In the UK, in 1988, 16% of the fire damp released by deep mining was vented from methane drainage systems, 11% was captured and used as fuel, 61% was emitted with ventilation air and about 12% was removed in the mined coal.

Data from Russia (Tsibulski 1995) indicates that the balance of methane emissions from coal seams and enclosing rocks is distributed as follows:

60%	emitted to atmosphere from mines together with ventilation air
12%	captured in mines and if not utilised then also emitted
15%	emitted to atmosphere from coal extracted to the surface
13%	remains in the seam and surrounding rock

Firedamp may be removed before the mining of a coal seam (pre-drainage) or as a consequence of mining (post-drainage). The latter approach is likely to be the most common.

Post-drainage Technologies

Cross-measures Methane Drainage

Boreholes are drilled at an angle above, and sometimes below, the mined out area, which collapses as the coal is removed. The boreholes are drilled close to the coal face and linked to a common pipe range. Suction is applied to the pipe range to draw the gas to a discharge point. Depending on circumstances and geology, 35% to 75% of the total gas released in an underground district can be captured at purities ranging from 30% to 70%. Higher purity gas is generally not available.

Surface 'Gob' Well Post-drainage

This technology is well established in the US. Gas is drained via surface boreholes from the de-stressed zone above a caving 'long-wall' face. The gas produced is generally of high purity. The principle disadvantage is high drilling costs and surface environmental planning restrictions.

Other methods of post drainage include Super-Adjacent Drainage Heading (Sewer Road) and Super Adjacent Guided Long-hole. Both methods involve driving long bore holes or roadways adjacent to the worked coalface (typically with 30m to 40m). The applicability is very much dependent on local geology.

Pre-drainage Technologies

In-seam Boreholes

This requires drilling boreholes parallel to the undisturbed coalface. The success of this technique depends on the permeability of the coal and the gas pressure. the higher the permeability and gas pressure, the greater the efficiency.

Hydrofracced Surface Boreholes

This technique involves hydraulically fracturing a sequence of productive horizons, injecting sand into the fractures and connecting the fractures to a well head assembly. Gas and other fluids occupy the sand-filled fractures and enter the well head assembly without encountering excessive resistance. The technique has been applied in the US, but is also very dependent on geology.

Extracting Pollutants from the Ventilation Air.

Besides active drainage of gas, removal also occurs as a result of the ventilation of the mine. Organic compounds associated with ventilation air may be controlled by using the ventilation air as feed air for boilers or engines. Liquefaction of gases, catalytic or biological oxidation is generally inappropriate for low concentrations of organic compounds found in ventilation air.

Utilisation of Firedamp

Reducing Emissions by Flaring

Flaring is not a common method for controlling firedamp, since to practice this safely is often prohibitively expensive.

Reducing Emissions by Using Gas as a Fuel

This is not a new concept. Since recovering combustible material from ventilation air is expensive, the technique applies primarily to actively drained firedamp. Whether or not firedamp is used as a fuel depends primarily on financial considerations, particularly if ensuring a continuous supply requires backup fuels such as Liquid Petroleum Gas, and if competitor fuels are readily available.

4. SIMPLER METHODOLOGY

The simpler methodology involves the application of a general emission factor to an appropriate activity statistic for each of three categories:

Deep mine coal
Open mine coal
Post mining treatment and storage.

5. DETAILED METHODOLOGY

This requires data to be collected for each major coalfield. Specific emission factors for each field are obtained, primarily by measurement or inferred from related data from similar fields. The field specific emission factors are used to derive field specific emissions.

6. RELEVANT ACTIVITY STATISTICS

For the simpler methodology the relevant activity statistic is total mass of coal produced by deep-mining and the total tonnage of coal produced by opencast mining.

For the more detailed approach, the activity statistic is the tonnage of coal produced from regions or coalfields where each availble emission factor can be applied.

7. POINT SOURCE CRITERIA

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

The IPCC Guidelines for National Greenhouse Gas Inventories give a comprehensive review of emission factors derived from measurements and modelling studies.

The default Emission Factors, to be used when no better data is available, are as follows:

Mining Activities

Deep-mine coal - low methane	10m^3/Mg coal produced
Deep-mine coal - high methane	25m^3/Mg coal produced
Opencast-mine - low methane	0.3m^3/Mg coal produced
Opencast-mine - high methane	2.0m^3/Mg coal produced

Post mining activities

Deep-mine coal - low methane	0.9m^3/Mg coal produced
Deep-mine coal - high methane	4.0m^3/Mg coal produced
Opencast-mine - low methane	0.0m^3/Mg coal produced
Opencast-mine - high methane	0.2m^3/Mg coal produced

Emission factors relate to methane only. No data quality is given, although the default emission factor is based on a number of measurements, the variation is large. Use of the default emission factors would result in an estimate of data quality D.

Selection of high or low methane emission factor depends on the results of measurement data carried out at selected coalfields. If no data is available then the higher emission factor should be used.

According to information from Russia (Tsibulski 1995) there exists a strong time dependency of emission factors for post mining activities. The above emission factors for post-mining activities relate to combined storage and transport.

There is little data available on the components of fire damp other than methane. A default profile is given in section 9. This suggests that the maximum concentrations of components other than methane are:

NMVOC	8% ethane (by volume), 4% propane (by volume)
CO_2	6% (by volume)

If 1m^3 methane has a mass of 680g, then

0.08 m^3 ethane has a mass of 102g

0.04 m^3 propane has a mass of 74.8g

0.06 m^3 carbon dioxide has a mass of 112.2g

No information is available on the accuracy or uncertainty of this data and so the data quality is E.

8.2 Detailed Methodology

The range of emission factors is refined, based on country specific data, and where possible mine specific data. IPCC 1994 gives the following country specific data:

Country	**Emission factor m^3/Mg**
Former Soviet Union	17.8 - 22.2
United States	11.0 - 15.3
Germany	22.4
United Kingdom	15.3
Poland	6.8 - 12.0
Czechoslovakia	23.9
Australia	15.6

The following table contains emission data from Russia (Tsibulski 1995) on the main gases from coal mines. Methane emissions data were obtained on the basis of the average natural methane content of a coal seam and the quantity of coal extracted by underground mining. Natural methane content of a seam refers to the amount of methane contained in a virgin seam.

Coal Field	Average Natural Methane Content of Seams, m^3/t	Total Methane Resources, billion m^3	Number of mines	Emission of Fire Damp, billion m^3/year	
				CH_4	CO_2
1	17	13186	67	1381	257
2	8	4	28	20	90
3	18	1962	18	794	66
4	6	5.4	10	71	38
5	15	10	14	5	27
6	6	9	2	11	3.5
7	18	122.4	1	2	4
8	18	41382	1	0.2	0.3
9	10	12	2	0.1	10
10	10	142.5	1	0.1	2.5
11	12	8410	2	0.8	0.5
12	10	190	2	2	9
13	12	296	1	0.1	0.4
14	13	132	2	1.5	2
15	9	96	13	15	19
16	12	18	11	30	20
17	9	2	12	6.5	8.5
18	8	6	4	1.7	0.9

The detailed methodology also takes into account the use of firedamp as a fuel.

9. SPECIES PROFILES

The following profile of firedamp has been presented in a paper to the UK Watt Committee (Williams 1993).

Species	%content
Methane	80 - 95%
Ethane	0 - 8%
Propane and Higher Alkanes	0 - 4%
Nitrogen	2 - 8%
Carbon Dioxide	0.2 - 6%
Argon	trace
Helium	trace
Hydrogen	trace

The quality of this data is not known. It is assumed that % content relates to volume to volume.

Profiles from Russia (Tsibulski 1995) are as follows:

Mine	**H_2**	**CH_4**	**C_nH_{2n+2}**	**CO_2**	**N_2**	**O_2**
1	-	62	0.31	1	31.6	5.1
2	0.24	89.6	5.16	0.1	4.3	0.3
3	0.07	60.7	3.22	1.2	28.4	6.4
4	-	34.7	0.58	0.9	51.5	12.3
5	-	77.2	0.06	0.5	17.6	4.7

10. UNCERTAINTY ESTIMATES

Methane

Uncertainty in the activity statistics is very low since national data on tonnage of coal produced is generally considered to be very accurate. Uncertainty in the default emission factors for the simpler methodology is high given the range of emission factors in the data, approximately +/- 50%. Uncertainty in the emission factors for the detailed methodology is likely to be much less, in some cases less than +/- 25%.

Other components

Uncertainty for components other than methane is very high, due to the lack of data on the composition of fire damp. Uncertainty is considered greater than a factor of 2.

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The priority area for improvement is to provide accurate information on the composition of fire damp, particularly the light hydrocarbon content. This is likely to vary considerably between coalfields.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Disaggregation should be based on the production of coal per territorial unit.

13. TEMPORAL DISAGGREGATION CRITERIA

It may be assumed that emissions occur over 24 hours and consistently throughout the year.

14. ADDITIONAL COMMENTS

15. SUPPLEMENTARY DOCUMENTS

16. VERIFICATION PROCEDURES

Verification is primarily through provision of national measurement data at representative coal fields. In addition, the validity of measurements can be gauged through comparison with results form other countries.

17. REFERENCES

IPCC Guidelines for National Greenhouse Gas Inventories. Greenhouse Gas Inventory Reference Manual, 1995

Methane Emissions - Paper Presented at the 29 Consultative Conference of the Watt Committee on Energy, Edited by Professor Alan Williams, Department of Fuel and Energy, University of Leeds, UK, 1993.

Gilham CA, Couling S, Leech PK, Eggleston HS, Irwin JG 'UK Emissions of Air Pollutants 1970-1991 (Including Methodology Update) LR961, Orginally Published by Warren Spring Laboratory, Available from NETCEN Library, AEA Technology, Culham, Abingdon, Oxon UK.

Tsibulski V., Scientific Research Institute of Atmospheric Air Protection SRI Atmosphere, St Petersburg, Russia, Personal Communication, January 1995.

18. BIBLIOGRAPHY

19. RELEASE VERSION, DATE AND SOURCE

Version : 1.0

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SNAP CODE :

050201
050202
050301
050302
050303

SOURCE ACTIVITY TITLE :

Extraction And First Treatment of Liquid Fossil Fuels
Land-based Activities
Off-shore Activities
Extraction And First Treatment Of Gaseous Fossil Fuels
Land-based Desulphurisation
Land-based Activities (other than Desulphurisation)
Off-shore Activities

1. ACTIVITIES INCLUDED

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

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

Subsequent loading and distribution of fuels are considered under SNAP categories 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,
- glycol regeneration,
- storage tanks associated with the production facility,
- tanker loading,
- drilling muds,
- waste water,
- test drilling,
- desulphurisation of gaseous fossil fuels,
- 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 in the same chapter.

2. CONTRIBUTION TO TOTAL EMISSIONS

The contribution to national emissions varies considerably, but where oil and gas are extracted, they are invariably a major source of national total NMVOCs.

Country	%NMVOC Emission	%Methane Emission
Canada	16	36
Norway	29	3
Poland	1	
Russia	40 (total VOC)	
UK	3	2

3. GENERAL

3.1. Description

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

3.1.2. Facilities producing gas only

These facilities do not have crude oil separation and export. The produced water handling process 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 this 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 the well involves the use of specially formulated drilling muds which may contain organic solvents. Well breaks through small oil/gas reservoirs may also produce emissions.

3.2. Definitions

Flaring:	Combustion of gas without utilising the energy
Facility:	Platform (in this connection)
Fugitive losses:	Emissions from leakages (valves, connectors 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°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 techniques are referred to in sections 3.1. and 3.4.

3.4. Emissions/Controls

3.4.1. Combined oil and gas facilities

The emissions 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 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. Installations 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.

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 leakages from the process systems, followed by subsequent repair and upgrading.

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.

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.

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.

3.4.5. Oil loading and transport

When oil is loaded into a tanker, 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
- 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 may be available in the future that will reduce the emissions from this source by as much as 70 percent (methane emissions will not be reduced considerably).

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.

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 hydrocarbon emissions from oil based muds and cuttings.

4. SIMPLER METHODOLOGY

Emissions may be estimated from general emission factors multiplied by the level of activity (see section 6). Emissions from the various sub-sources mentioned are estimated independently and added. Countries will need to know what main sources are relevant for them and the most important features of their production system even for the simpler methodology.

5. DETAILED METHODOLOGY

The detailed methodology involves quantification of emissions by field using field specific activity statistics and emission factors or direct measurements/engineering calculations. Field studies in collaboration with the industry will be required.

6. RELEVANT ACTIVITY STATISTICS

For the simpler methodology the following activity statistics are required:

Oil and gas production, preferably by field. These data are available from national sources in each country and from various international sources.

The number of facilities (platforms) - age and type.

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 processed through a gas terminal - will be available from national sources.

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

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

The volume of gas vented

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

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

7. POINT SOURCE CRITERIA

The location of oil and gas production facilities are associated with specific oil and gas fields, where practical these fields 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 or area sources.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1. Simpler Methodology

8.1.1. Combined oil and gas facilities

Suggested emission factors for venting (kg/million Sm^3 gas produced)

	NMVOC	CH$_4$	CO$_2$	Quality codes
Norway[1]	76	98	0	C
UK	Not known	Not known		

Suggested emission factors for venting (Mg per facility)

	NMVOC	CH$_4$	CO$_2$	Quality codes
Norway[1]	30	20	0	C
UK[2]	550	660	70	C

1 OLF 1993
2 Brown and Root 1993

The volume of gas vented will be related to the volume flared. Generally, the greater the flaring the less the venting. Generally, the venting will be higher on older platforms than on newer, the main reasons 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 1993), which seems to be in reasonable agreement with estimates for Norway and UK.

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

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 75 % methane and 25 % NMVOC may be assumed if better data are not available.

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

8.1.2. Facilities producing gas only

Suggested emission factors for venting

	NMVOC	CH_4	CO_2	Unit	Quality
UK[1]	61	498	25	Mg/facility	C
Canada[2]	0.19	0.33		Mg/Gg gas	C
Russia[3]	1.4 -2.1			Mg/Gg gas	C
Netherlands[4]	0.6	6.7	0.2	Mg/Gg gas	C

* Total VOC. Vent and fugitive losses
1 Brown and Root, personal communication.
2 Picard et.al 1993
3 SRI 1994.
4 TNO

For fugitive losses Equation 1 will be relevant. Canadian emission factors give, however, a higher estimate. The high emission rate is explained by a vast amount of infrastructure.

	NMVOC	CH_4	Unit	Quality
Canada[1]	0.9	1.5	Mg/Gg gas	C

1 Picard et.al 1992

8.1.3. Facilities producing gas only

Suggested emission factors for venting

	NMVOC	CH_4	CO_2	Unit	Quality
UK[1]	300	270	240	Mg/facility	C
Canada[2]	0.24	0.44		Mg/Gg oil	C
Russia[3]	2.55			Mg/Gg oil	C
Netherlands[4]	0.9	9.3	0.3	Mg/Gg oil	C

Including methane and fugitive losses.
1 Brown and Root, personal communication.
2 Picard et.al 1993
3 SRI 1994
4 TNO

For fugitive losses equation 1 will be relevant.

Canadian emission factors, giving a higher emission estimate due to a vast amount of infrastructure:

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

1 Picard et.al 1992

8.1.4. Gas terminals

Suggested emission factors for venting (Gg/terminal):

	NMVOC	CH_4	CO_2	Throughput	Quality
UK[1]	0.280	2.447	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
1 Brown and Root, personal communication.
2 Picard 1993
3 The Norwegian State Pollution Control Authority
4 SRI 1994

Suggested emission factors for fugitive losses (Gg/terminal):

	NMVOC	CH_4	Throughput	Quality
UK[1]	0.04	0.47	-	C
Canada[2]	0.03	0.05	-	C
Norway[3]	0.76	0.44	25 bill. Sm^3	C

1 Brown and Root, personal communication.
2 Picard 1993
3 The Norwegian State Pollution Control Authority

Few data are available. The highest emission factor should be chosen if better data is not available.

No data is currently available on emission factors for the H_2S scrubbing system:

8.1.5. Oil loading and transport

Very few data are available, see also SNAP 040103.

Loading to ships:

Norwegian emission factors (OLF 1993):

	Evaporation rate (% of oil loaded)	Quality code
- Field 1	0.2	C
- Field 2	0.07	C

	Methane content of vapour (%)	
- Field 1	1.2	C
- Field 2	17.2	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 forum 94).

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

The highest emission factor should be chosen if better data is not available.

Loading to storage tanks and trucks: See section 040104.

8.1.6. Pipelines

Few estimates are currently available. The emissions are probably small.

Canadian[1] emission factors for leakages (Mg/Gg transported):

	NMVOC	CH_4	Quality code
Crude oil systems	0.072	0.126	C
Natural gas systems	0.054	0.095	C

1 Picard 1993

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).

8.1.7. Drilling

The following emission factors are suggested:

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)

Drilling process:

	NMVOC	**CH_4**	**Unit**	**Quality code**
Norway[2]	700	325	kg/well drilled	C
Canada[3]	1837	3238	Mg total*	

* The number of wells is not known

2. OLF 1993

3. Picard 1993

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

8.2. Detailed Methodology

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.

For fugitive emissions component counting is 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.

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, 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 3.4.1.

8.2.3. Facilities producing oil only

See section 3.4.1.

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 which reflect the variations mentioned in section 3.4.

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

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 %.

8.2.6. Pipelines

Few data are currently available. Picard 1993 give some emission factors related to individual sources (valves, seals, compressors, connectors etc.).

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

Crude Oil Production (USEPA 1988) and natural gas venting (TNO).

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 the different emissions sources. Therefore, the above generalised species profile should only be used if better information is not available.

10. UNCERTAINTY ESTIMATES

Venting: An extremely high uncertainty is expected (greater than a factor of 2), particularly when the generalised emission factors are applied.

Fugitive emissions from oil and gas production platforms: An error of 65% has been reported for equation 1. However, this will be greater when this equation is applied to other fields.

Waste water treatment: The mass of oil in waste water discharged is normally measured accurately, particularly if it this 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 easily 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 not available.

13. TEMPORAL DISAGGREGATION CRITERIA

Monthly production data are available in major oil and gas exporting countries. If this information is not available, emissions may be assumed equally temporally distributed. Equal temporal distribution 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.

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19. RELEASE VERSION, DATE AND SOURCE

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Date : March 1995

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SNAP CODES :

050501
050502
050503

SOURCE ACTIVITY TITLES :

Gasoline Distribution
Refinery Dispatch Station
Transport and Depots
Service Stations (Including Refuelling of Cars)

1. ACTIVITIES INCLUDED

050501	Refinery dispatch station
050502	Transport and depots (except 050503)
050503	Service stations (including refuelling of cars)

Note regarding 050502

Emissions from Border Terminal Dispatch Stations should be considered under this SNAP code since in some countries the gasoline is not only produced in the respective country but also imported by pipelines ships, barges and road tankers (Schürmann, 1994).

2. CONTRIBUTION TO TOTAL EMISSIONS

Table 2.1 shows the contribution of the gasoline distribution sector to total man-made VOC emissions in different countries in Europe as presented in various emission inventories. On average this sector (050500) contributes 5%, of which more than 50% are emissions from service stations.

Table 2.1: Contribution of gasoline distribution sector to total man-made VOC emissions

Country/Region	Year	Reference	Contribution to total man-made VOC emissions [%]			
			050500	**050501**	**050502**	**050503**
OECD Europe	1980	OECD, 1990	4.4			
OECD Europe	1983	Edwards et.al,1986	5.2			3.6
EC	1985	Bouscaren, 1990	4.4			3.2
Ireland	1985	Bouscaren, 1990	4.2			3.7
Netherlands	1985	KWS2000, 1989	5.0			2.3
Slovenia	1988	Rode, 1993	6.7			
UK	1988	Passant, 1993	4.3			
Slovakia	1990	Mareckova, 1994				3.5
Bulgaria[a)]	1990	Dimov (pers.com)	2.4			1.6
Ireland	1990	McGettigan, 1993				2.5
Poland	1990	Fudala, 1993a	1.5			
Poland	1992	Fudala, 1993b	2.5			

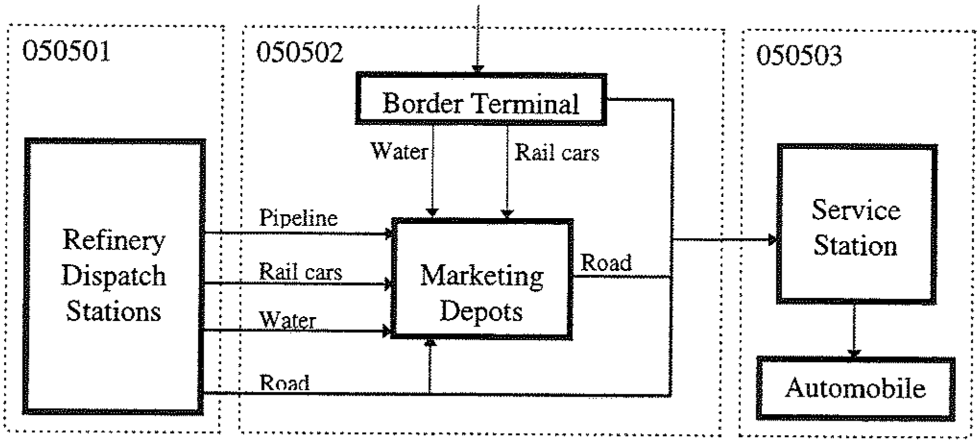
[a)] These values are preliminary and will be updated when the Bulgarian report is available.

3. GENERAL

3.1 Description

Gasoline distribution starts at the refinery dispatch station (050501) or at the border terminal dispatch station (050502) from where it is loaded into rail cars, barges, coastal tankers, pipelines for delivery to marketing depots (050502) or into road vehicles for delivery to service stations (050503) or small marketing depots (050502). From marketing depots (or directly from border terminals), gasoline is loaded into road vehicles for delivery to service stations where it is transferred into underground storage tanks and subsequently dispensed into automobile fuel tanks. This gasoline distribution chain is presented in Fig. 3.1.

Figure 3.1: The gasoline distribution system (0505)



3.2 Definitions

Fixed Roof Tank

A fixed roof tank consists of a cylindrical steel shell topped by a coned roof and could be equipped with internal floating cover in aluminium or steel as well as with a Pressure/Vacuum vent (PV vent).

Floating Roof Tank

A tank normally used in terminal operations which is equipped with a roof which floats on top of the gasoline.

Marketing Depot

One or more storage tanks where gasoline is received by pipeline, road truck, barge or rail car, and is stored in bulk for subsequent transportation or distribution by road truck.

Onboard Canister

A container filled with an adsorbent (e.g., activated carbon) which collects gasoline vapours in a motor vehicle.

Reid Vapour Pressure (RVP)

The vapour pressure of a product (e.g. gasoline) is determined by a standard laboratory method called RVP, which measures its inherent tendency to evaporate at 38 degrees C with vapour/liquid ratio of 4/1. RVP is reported in kPa. For details of the equipment and procedures refer to the following standard methods: IP 69/78 (Vapour pressure Reid method), ASTM D323 (Vapour pressure of petroleum products Reid method), ISO 3000-1974 (Petroleum products - Determination of vapour pressure - Reid method).

Service Station

Any premises at which gasoline is dispensed into the fuel tanks of motor vehicles, including marinas (gasoline fuelling point which services water craft) with land-based storage.

Stage I Controls

The equipment used to recover gasoline vapours at terminals (dispatch stations), marketing depots, and from service stations.

Stage II Controls

The equipment used to recover gasoline vapours emitted during motor vehicle refuelling at service stations.

True Vapour Pressure (TVP)

If any liquid is introduced into an evacuated container, molecules will escape from the liquid surface by virtue of their kinetic energy to form vapour. Thereafter, some vapour will condense and eventually a state of equilibrium is reached, which is sustained if the temperature remains constant. The observed pressure in absolute units in the vapour space is defined as the true vapour pressure (TVP) of the liquid at the constant temperature applicable.

Vapour Balancing

Vapours displaced from tanks receiving gasoline are returned to tanks delivering the gasoline.

Vapour Destruction Unit (VDU)

An installation, normally located at a terminal, which receives gasoline vapours from cargo tank trucks and destroys them by thermal oxidation or other means.

Vapour Recovery Unit (VRU)

An installation, normally located at a terminal, which receives gasoline vapours from cargo tanks and recovers them for subsequent use.

3.3 Techniques

The refinery products (e.g., gasoline) are stored in tanks of different construction, i.e., fixed or floating roof tanks. Then the products are transferred to tank trucks, rail cars, etc., using various techniques of loading, i.e. top, bottom, or submerged loading. The gasoline is delivered directly to service station (stored in underground tanks) or to marketing depots where it is stored in tanks similar to those used in refineries. In some countries the products are imported and stored at border terminals before distribution (see Fig. 3.1).

Fixed Roof Tank

These tanks are normally equipped with a Pressure/Vacuum vent (PV vent) and can be vapour balanced. They continue to be used for motor gasoline at the smaller installations and depots, typified by lower throughput levels (Williams et al, 1986; ECE, 1990; CCME, 1991). These tanks could be classified as follows (Schürmann, 1994):

Fixed roof tanks without internal floating roof and without pressure/vacuum (PV) vent,

Fixed roof tanks with internal floating roof and without PV vent,

Fixed roof tanks without internal floating roof and with PV valve, whereby pressure range (e.g. +20mbar/-5mbar or +180mbar/-50mbar) has an influence on storage emissions.

The internal floating roofs are typically made of steel or aluminium sheets. The steel internal covers are longitudinally welded and in direct contact with the liquid surface. The aluminium covers generally have a closed surface of clamped sheets and float several centimeters above the product surface on floats (VDI, 1985).

Floating Roof Tank

A tank normally used in terminal operations as well as at principal marketing installations away from refineries. It consists of a cylindrical steel wall equipped with a floating roof. The roof floats on top of the gasoline, and is equipped with seals to the sidewall to minimize vapour loss; the air space above a floating roof is vented to the atmosphere. Floating roof decks are of three general types: pontoons, pan, and double deck. A floating roof tank normally cannot be vapour balanced (Williams et al, 1986; ECE, 1990; CCME, 1991).

Bottom loading

A system for loading liquid petroleum products into a cargo tank truck from the bottom; through a system of pipes, valves and dry-disconnect fittings (CCME, 1991; Williams et al, 1986).

Splash Loading

The loading arm is positioned with the outlet above the tank bottom so that the gasoline falls to the liquid surface. This leads to a high vapour evolution (Williams et al, 1986; ECE, 1990).

Submerged Top Loading

A system for loading liquid petroleum products into any tank by means of a pipe to provide entry below the liquid surface, thereby minimizing splash and vapour formation (CCME, 1991; Williams et al, 1986).

Underground Storage Tank

A storage tank that is completely buried by or covered with earth, backfill or concrete, or a partially buried tank. A partially buried tank means a storage tank that has 10% or more of its volume below adjacent ground level. These tanks normally have fixed fill pipes which discharge at the bottom of the tank (CCME, 1991; Williams et al, 1986).

3.4 Emissions

Emissions of hydrocarbons to atmosphere occur in nearly every element of the gasoline distribution chain. The emissions can be classified as follows (for details see Williams et al, 1986 and ECE, 1990):

1. Emissions from bulk storage tanks (refinery dispatch station, border terminals, marketing depots),
2. Service station storage tank emissions,
3. Transport vehicle filling emissions,
4. Other emissions.

ad. 1. There are basically two types of bulk storage tanks:

Floating Roof Tanks and Fixed Roof Tanks with internal floating covers

There are two major sources of emissions associated with the storage of intermediate volatility liquids:

a) *Standing storage emissions* are caused mainly by evaporation of liquid product through imperfections in the flexible peripheral seals. Included are any evaporative emissions through the deck structure and fittings such as manholes, gauge pipes and hatches, also roof support columns or legs. The emissions vary depending on design of surface covers (steel or aluminium), see section 3.3. Techniques and 3.5. Controls. Additionally the wind can have a significant influence on the magnitude of these emissions if the tanks are ventilated.

b) *Withdrawal emissions* occur following the withdrawal of liquid product. They are due to evaporation of the film of gasoline which adheres to the surface of the tank walls, and any tank roof support columns of fitted. The magnitude of these emissions is mainly influenced by the surface condition e.g., presence of rust or a tank lining.

c) *Filling of the tank* after revisions or complete emptying when the floating roof stands on its supports causes additional emissions.

Fixed Roof Tanks without internal floating covers

d) *Displacement emissions* occur due to displacement of the mixture of air and hydrocarbon vapour by the incoming gasoline. The vapour emitted originates mainly by evaporation from the previous tank contents during storage.

e) *Withdrawal emissions* occur following intake of air via the pressure/vacuum relief valves. Dilution of the hydrocarbon vapour/air mixture previously contained in the vapour space will lead to further evaporation to restore the equilibrium.

f) *Working emissions* are defined as the sum of displacement and withdrawal emissions caused by gasoline movements.

g) *Breathing emissions* are caused by temperature variations and changes in the barometric pressure which in turn cause expansion and contraction of both liquid and vapour within the tank.

ad. 2. Service station storage tank emissions

The main contribution comes from displacement when an incoming bulk delivery of gasoline is received into tanks. There are also withdrawal and breathing emissions, the latter being of minor significance since tanks are normally double walled underground tanks and are not subject to "above-ground" diurnal temperature changes but the variation in atmospheric pressure influences the breathing emissions.

See also note in section 14. Additional Comments on emissions from leaking underground storage tanks.

ad. 3. Transport vehicle filling emissions

These occur when gasoline is transferred from storage tanks into transport vehicles, i.e. road tankers, rail cars, barges, and when dispensed into cars. The emissions are a combination of vapour from the previous tank contents and the vapour evolved as a result of splashing and turbulence during filling. The transit or breathing losses are minor and are described further. It might be worth paying more attention to vapour emissions resulting from spillage when refuelling cars. Four categories of loss were identified (see below). Most of these losses can be avoided by correct maintenance and handling of the dispensing equipment.

a) Pre-fill drip from the nozzle while being handled between the pump and the vehicle,

b) Spit-back of gasoline from the fuel tank filler pipe, resulting from the pressure build -up in the vapour space,

c) Overflow from the filler pipe,

d) Post-fill drip from the nozzle while being handled between the vehicle and the pump.

ad. 4. Other emissions

a) Emissions described here are of minor magnitude as compared to those described above and include the following:

b) *Fugitive emissions* occur following seepage of gasoline liquid through parts of handling equipment such as pipeline gaskets, also pump and valve stem seals. Pipelines are closed systems and essentially emission free. They are however subject to some fugitive losses and possible leaks due to temperature rise.

c) *Ship and barge ballasting emissions* - hydrocarbon vapours are displaced into the atmosphere when a compartment, which has previously contained gasoline, is loaded with ballast water.

d) *Transport vehicle emissions whilst travelling* are often negligible because the vapour and pressure retention capability of the tank or compartment will be above the level at which breathing will be induced by the temperature variations that may occur. However, in some cases these emissions should not be neglected; the containers of road vehicles are subject to significant heating up (depending on colour also) whilst the pressure range of their PV vents is limited to 50 mbar, corresponding to a temperature difference of +15°C, ignoring expansion of liquid. Many rail cars are free vented and their emissions are not negligible.

e) *Spillage and leakage* - any activity involving the transfer of gasoline from one form of container to another is a potential point of spillage. Also, leakage from storage and handling equipment such as loading arms, swivels and storage tanks, in addition to flanges and valves, can contribute to vapour emissions. Such emissions should only make a minimum contribution to the total which occur in the gasoline distribution sector, providing facilities are well designed and operated efficiently.

3.5 Controls

Considerable reductions of hydrocarbon emissions from gasoline distribution network are achieved by modifying truck, barge or rail car tanks loading practices, installing closed vapour recovery units (VRU), as well as providing fixed roof storage tanks with internal floating covers. Additionally Stage I and Stage II control measures are being introduced. For more details on control options described in this section see Richards et al, 1990; ECE, 1990; Williams et al, 1986; CCME, 1991; VDI, 1985; EPA, 1985.

3.5.1 Storage Tanks

There are several ways to control emissions from storage tanks. In most major terminals, vapour emissions from working tankage are controlled by the use of floating roof tanks or fixed roof tanks with internal floating covers (IFCs). These will reduce vapour emissions from tankage by at least 90% for welded steel pans (VDI, 1985). If aluminium pans are used the reduction efficiency may be lower (ca. 70%). A very simple but effective measure is to paint the shell of tank white. A white coating reflects 70% of the energy of the irradiating sunlight (see VDI, 1985 for more details on effects of different colour and type of coatings). Another option is to install Stage IA devices, described in section 3.5.2. There is an extensive experience in use of internal floating covers and replacement of fixed roof tanks by floating roof tanks. In Finland and Germany the majority of fixed roof tanks are equipped with IFCs. In Canada, in 1983, 89% of this category of tanks were equipped with floating roof (Made, 1988).

Important note:

It is believed that because of the change to unleaded gasoline, the rubber elements, like seals, are deteriorating faster. Therefore, the given reduction efficiencies for storage tanks might not be achieved in some cases (M. Wyser, J. Baumann; pers. communication).

3.5.2 Stage I Controls

Stage I controls refer to a variety of techniques reducing VOC emissions at marketing terminals (Stage IA) and when gasoline is delivered to service stations (Stage IB).

Stage IA

Stage IA systems basically include two parts:

a) *Vapour Balance Lines between Tanks and Loading Gantries* - When a group of fixed-roof gasoline tanks is subject to simultaneous receipts and deliveries, interconnecting the tank vapour spaces can reduce emissions to atmosphere by allowing displaced vapours from a receiving tank to flow into the vapour space of a delivering tank. In some areas vapour return lines have been installed to reduce exposure of vehicle loading personnel to gasoline vapours. Currently, these lines are generally installed in conjunction with a vapour recovery unit (VRU). In Switzerland all of the marketing depots are fully equipped with vapour balance lines between road tankers and tanks as well as between tanks and tank cars.

b) *Vapour Recovery Units (VRU)* remove hydrocarbons emitted from tanks or vehicle loading operations usually by either cooling/condensation, liquid loading absorption or carbon adsorption or a combination of these processes (for details of the processes see ECE, 1990). The recovered hydrocarbons are usually returned to tankage in the liquid form. VRUs are either single-stage, based on one of the above mentioned processes, with recovery efficiency of the order of 95%, or double-stage, with additional processing of the first stage tail gas, with design efficiencies close to 100%. Until 1988, relatively small number of VRUs had been installed in Europe (Richards et al, 1990) of which the large majority are for road vehicle loading. Recently installed units are designed to meet the US EPA limits of VOC emissions per litre of product loaded into a vehicle, i.e. 35g/m^3 requires single-stage unit, or more stringent TA-Luft limits, i.e. 150 mg/m^3 requiring double-stage VRUs. In Switzerland VRUs are installed at border terminals and refinery.

Richards et. al, 1990 gives average efficiencies of Stage IA systems, assuming 95% efficiency of VRU, 95% vapour collection efficiency at the loading gantry for bottom loading and 85% for top loading, as 90% and 80%, respectively. These numbers are based on an average TVP of 35 kPa. Schürmann, 1994 uses different efficiencies, namely 100% for bottom loading and 85% for top loading with gas balancing systems.

Stage IB

Stage IB applies to vapour balancing systems between service station tanks and trucks supplying gasoline to them. Saturated vapours, displaced from the tank vent pipes when receiving gasoline, are returned to the truck compartment from which the gasoline is supplied, via a piping system and/or hoses. There are several piping configurations possible, for details see Richards et. al, 1990, ECE, 1990, Williams et al, 1986. According to CONCAWE (Richards et. al, 1990) about 33% of service stations in EC12 countries in 1988 were equipped with Stage IB systems. It has been reported that with well designed systems vapour collection efficiencies are higher than 95%. Schürmann, 1994 uses in his report a reduction efficiency of 100% for stations equipped with Stage IB controls.

3.5.3 Tank Trucks

To reduce emissions modified loading techniques are recommend, namely:

a) Submerged top loading - reduce VOC emissions by 40 to 60%

b) Submerged top loading with in-line vapour return

c) Submerged top loading with external vapour return

d) Bottom loading

e) Bottom loading with vapour return

Vapour collection and return from service stations is only undertaken in five European countries and both top and bottom loading trucks are equipped there with vapour return systems. In the USA, bottom loading with vapour return has been legally enforced by EPA standards since 1982. Typical emission reduction efficiency for vapour recovery at tank truck loading points given by OECD, EEC and CONCAWE is 89%. But there are several units installed in Germany to meet its stringent regulation and their efficiency is 99.9% (ECE, 1990). This is also reported by Switzerland (Schürmann, 1994; M.Wyser pers. comm.).

3.5.4 Rail Cars

Rail cars are generally top loaded in Europe. The recommended techniques to reduce emissions are the same as for tank trucks (see 3.5.3). According to OECD, EEC, and CONCAWE, vapour recovery units are operating with an average efficiency of 89% at rail car loading points (ECE, 1990). Schürmann, 1994 reports 85% efficiency for top loading operations with gas balancing systems. This efficiency could be improved if bottom loading would be introduced on wider scale. Its introduction would require automatic overfill protection systems on all rail cars.

3.5.5 Barges/Ships

Modified loading techniques reduce loading losses by 60 to 80%. This involves low initial loading to reduce turbulence when filling the bottom, fast bulk (bottom) loading and slow final loading to reduce turbulence in the vicinity of the ullage as the liquid approaches the top (ECE, 1990). Vapour return/recovery systems are not very common. For inland barges equipped with such systems efficiency of 88% and for ocean ships of 89% is reported by the EEC (Bouscaren et. al, 1988). Sometimes the controls are installed but not used, according to M. Wyser (pers. communication) inland tankers on the Rhine river are equipped with vapour balancing systems but the systems are not used.

3.5.6 Car Refuelling

Stage II Controls

Stage II applies to vapour balancing systems between automobile fuel tanks during refuelling and the service station tank supplying the gasoline. Saturated vapours are displaced from the automobile fuel tank and returned to the service station tank via special fittings in the dispensing nozzle. Vapour escape from the automobile fill-pipe to the atmosphere is prevented by a special bellows which seals the fill pipe and routes the displaced vapours through the body of the dispensing nozzle to the hose. Different systems are available, in some of which the vapour flow is boosted by a vacuum pump. Essential to this system are standardized fill pipes and existence of Stage IB controls in place, otherwise Stage II devices may only delay the venting of vapour to the atmosphere.

In the late 80's comprehensive test programmes were carried out in Sweden and Switzerland to estimate the recovery efficiency applying Stage II controls. The recovery efficiency of the system, weighted to the Swedish car population, was determined to be 56% and for Switzerland 53% (Switzerland has decided in 1989 to introduce Stage I and II controls at all service stations and vapour recovery at the principal storage units by 1994). Similar results were achieved in an investigation of the BP oil company at one of its stations in Stockholm. The recovery efficiency varied from 11 to 89%, average 61%, depending on the car type. To achieve a better efficiency it will be necessary to introduce modifications to all new European car fill-pipes and tank vents. In the absence of these changes, an average efficiency between 50 and 60% can be assumed (Richards et. al, 1990). In the USA, where standarization has been introduced, the EPA estimates the average in-service efficiencies at 62 to 86%, depending on the level of regulatory enforcement, mainly regular inspection. Additional problems with Stage II equipment, mentioned in the literature, are that this system cannot be used with shallow fuel tanks (motorcycles) and that American experience indicates greater spillage when these systems are installed.

On-board Canisters

These are a viable alternative to Stage II controls. According to the experience in the USA and CONCAWE (McArragher et al, 1988) enlarged carbon canisters could reduce refuelling emissions by more than 95%. Canisters are filled with activated carbon to which all external fuel system vents are connected. Any diurnal, hot soak as well as refuelling hydrocarbon emissions are adsorbed by the carbon and retained in the canister. The carbon is purged of hydrocarbons during normal driving by drawing the air back through the canister and into the engine where it is burnt.

RVP Reduction

This control option requires the reduction of gasoline volatility at the refinery from May to September. A reduction of volatility (RVP) of 17 kPa (from 79 to 62 kPa) would result in a 8 to 10% reduction of the annual emissions of VOC from the gasoline distribution sector (Environment Canada, 1989). Gasoline volatility reduction is reported to reduce VOC emissions from refuelling by 23% (ECE, 1990).

4. SIMPLER METHODOLOGY

The simpler methodology is based on aggregated average emission factors (see section 8.1) combined with information on pumped volume of gasoline in the country. Where the information on type, efficiency and extent of emission control measures applied in distinguished sectors is available, the detailed methodology should be used.

This simpler approach has been applied by CONCAWE to estimate emissions of VOC from gasoline distribution sector in Western Europe (Edwards et. al, 1986). Similar average emission factors for the elements of gasoline distribution system are also given (with some reservations - see Veldt et. al, 1992) in the Second Edition of the CORINAIR Inventory Default Emission Factors Handbook (Bouscaren, 1992).

5. DETAILED METHODOLOGY

To improve the quality of emission estimates, country specific data should be taken into account. Therefore the detailed methodology requires knowledge on specific parameters of the gasoline distribution system (see section 6 below). Additionally basic physical and chemical parameters of distributed gasoline should be known. For details see procedure described in reference studies i.e., Williams et al, 1986; Foster et al, 1987; VDI, 1985.

An alternative methodology was offered by Swiss BUWAL (Bundesamt für Umwelt, Wald und Landschaft) (Schürmann, 1994). The following paragraph gives a general description of the methodology and is quoted after Schürmann, 1994.

The proposed detailed methodology is based on the analysis of gasoline flows from imports and refineries to car filling stations and the various loading and unloading techniques used. From the gasoline flow a gas flow model is derived, which is analysed with regard to gas handling techniques to give distribution emissions on one hand and on determination of storage emissions on the other hand. It involves the following steps:

a) Determination of the gasoline flows (in t/a) from the product sources (refineries and imports) to the filling stations.

b) Determination of the gas flows (in m^3/a) from the gas source (car) to the various emission locations or emission control locations

c) Determination of the VOC-emissions for gasoline distribution (in kg/a)

d) Determination of the VOC-emissions for gasoline storage (in kg/a)

This methodology has the following advantages:

- It reflects the actual emission situation better than aggregated emission factors,

- The results reflect directly the percentage of introduction of gas handling control measures (e.g stage I and stage II) and of VRU installations in terminals,
- The emission factors for the various emission sources can be adapted to the local properties of gasoline composition, to the level of introduction of integral gas balancing techniques etc.,
- The detailed methodology is a model calculation which allows an analysis of the efficiency of various control measures and as such is an instrument for the planning of the introduction of control techniques.

The current version of this methodology is being reviewed, extended and tested by Swiss BUWAL. An update is expected to be ready by summer of 1995 and then the description and the diskette may be ordered from Dr. Jürg Baumann, BUWAL, Laupenstr. 20, 3003 Bern, Switzerland.

The following sections in this chapter of the guidebook do not refer to the 'Swiss' methodology since it was not available at the time of writing.

6. RELEVANT ACTIVITY STATISTICS

6.1 Simpler methodology

To estimate VOC emissions from the gasoline distribution sector (0505) the statistics of gasoline sold in the country/region are required. For calculation of emissions resulting from activities in relevant subsectors of gasoline distribution, distinguished in CORINAIR, emission factors given in section 8.1 of this document are used.

To take into account emission control measures in place necessary data should be found in sectoral statistics or country studies. The reduction efficiencies given in section 3.5 of this document could be applied or (preferably) use the efficiencies reported in national studies. However it is considered that where information on controls is available the detailed methodology described below or the 'Swiss' method should be used.

6.2 Detailed methodology

More detailed country specific data are needed as far as the technical parameters of equipment as well as operation practices are concerned. This includes:

a) *Refinery Dispatch Station (050501)* - number, type, size of the tanks used at the refinery dispatch station as well as volume of gasoline stored in these tanks; volume of gasoline loaded into different transport modes (e.g., rail truck, pipeline, tank truck); gasoline loading practices for specific modes of transport (e.g., top-submerged, bottom); type and extent of emission control measures in place (e.g., Stage I).

b) *Transport and Depots (050502) and Border Terminal, where applicable* - number, type, size of the tanks used as well as volume of gasoline stored in these tanks; gasoline loading practices for used transport modes; type and extent of emission control measures in place (e.g., Stage I).

c) *Service Stations (050503)* - volume of gasoline sold; type and extent of emission control measures in place (e.g., Stage II, percentage of cars equipped with enlarged carbon canisters).

d) *Characteristics of distributed gasoline* - RVP, TVP, density.

Additionally some meteorological data like average annual (or seasonal) temperature are needed to improve the quality of the inventory or calculate the seasonal variation in emissions.

7. POINT SOURCE CRITERIA

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

The emission factors presented are derived from the study of CONCAWE (Williams et al, 1986). The assumed liquid gasoline density is 730 kg/m^3 and condensed vapour density is 600 kg/m^3. Hydrocarbon emission factors for uncontrolled techniques are given in Table 8.1.

Table 8.1: VOC emission factors [g VOC/t of total gasoline handled]

Category	Emission factor	Quality code
Refinery Dispatch Station (050501)	310	D
Transport and Depots (050502)	740	D
Service Station (050503)	2880	D
Gasoline Distribution (0505)	3930	D

8.2 Detailed Methodology

The emission factors given in this section are derived from the CONCAWE studies (see Williams et al, 1986; Foster et al, 1987) assuming the following typical European gasoline properties:

true vapour pressure (TVP)	35 kPa
liquid molecular weight	64 kg/kmol
condensed vapour density	600 kg/m^3

liquid gasoline density	730 kg/m^3

Additionally, emission factors reported in ECE, 1990 study are given in brackets. They are, in general, based on experience of the United States Environment Protection Agency (US EPA).

8.2.1 Refinery Dispatch Station (050501)

It is assumed that there are only external floating roof (EFR) tanks in use at the refinery. They are equipped with mechanical shoe primary seal (see section 3.3.3.1. in Williams et al, 1986). Storage tank emissions are sum of standing storage and withdrawal emissions.

The emission factors for ship/barge loading operations are weighted averages of conditions specified in the CONCAWE report (Williams et al, 1986). Where detailed data on the prior cargo and compartment treatment for the previous empty or ballasted voyage are available, emission factors specified in the section 3.3.4.5 in Williams et al, 1986 should be used. In brackets emission factors reported in ECE, 1990 are given.

One of the parameters, used to evaluate emission factors for rail/truck tank loading operation, represents the amount of splashing. Its value depends on loading practice as well as the arm outlet height from bottom of compartment. Some typical values estimated by BP, 1973 were used. Where detailed data on this exist, the values and the formulas given in section 3.3.4.3 and 3.3.4.4. in Williams et al, 1986 should be used.

Table 8.2: VOC emission factors (uncontrolled) for Refinery Dispatch Station (050501) [g VOC / t gasoline throughput]

Category	Emission factor	Quality code
Storage tank emissions (EFR)	26	D
Loading		
Pipeline	0	C
Ship/ocean barge	300 (430)	C
Shallow draft barge	560 (640)	C
Rail cars		
Top-submerged	500 (800)	C
Top-partial splashing	1060 (2000)	D
Road trucks:		
Splash loading	(2050)	E
Top - partial splashing	870	D
Top - submerged	450 (670)	C
Bottom	410 (670)	C

8.2.2 Transport and Depots and Border Terminals (050502)

The breathing emissions during transport of gasoline from the refinery to the marketing depots or service stations are not significant, they are assumed to be less than 0.001% liquid volume (see Williams et al, 1986). Ballasting emissions depend on intake of ballast water after a gasoline cargo discharge. In table 8.3 intake of water is expressed as percent volume of gasoline discharged. In the study by ECE, 1990 average emission factor, based on US EPA experience, is given. For external floating roof (EFR) and internal floating cover (IFC) tanks storage emissions are sum of standing storage and withdrawal emissions. Fixed roof tanks storage emissions are sum of working and breathing emissions (see section 3.4 of this document).

Table 8.3: VOC emission factors (uncontrolled) for gasoline - Transport and Depots [g VOC/ t gasoline throughput]

Category	Emission factor	Quality code
Transport from refinery	< 8	C
Ballasting (ships/barges)		
water intake - 100%	220	C
water intake - 30%	66	C
ECE, 1990	140	D
Storage tank emissions		
EFR - primary seal	73	D
EFR - secondary seal	5	D
IFC	160	D
Fixed roof	1570	E
Loading - road trucks		
Splash Loading	(2050)	E
Top - partial splashing	870	D
Top - submerged	450 (670)	C
Bottom	410 (670)	C
Other		
Fugitive	< 8	C
Spillage	80	C
Transport to service stations	< 8	C

Where Border Terminals are equipped with storage tanks comparable to the tanks in the refinery and other modes of transport than road trucks are used, coefficients from table 8.2 should be applied accordingly.

8.2.3 Service Stations (including refuelling of cars) (050503)

Emission factors reported here are derived from CONCAWE study (Williams et al, 1986) and from the report by ECE, 1990 (given in brackets).

Table 8.4: VOC emission factors (uncontrolled) for Service Stations (050503) [g VOC / t gasoline throughput]

Category	Emission factor	Quality code
Filling/Storage		
Submerged loading	1315 (1400)	C
Splash loading	(2050)	C
Car filling	1480 (1800)	C
Spillage	80 (110)	C

9. SPECIES PROFILES

Measurements of hydrocarbon composition in the gasoline distribution system are fairly consistent, reflecting the fact that one deals with a single product of relatively constant composition. Thus, measurements taken at tank vents, and downwind from the terminal in unrelated locations give generally the same results. Limited data on emissions from service stations are consistent with the known composition of emissions from terminals handling gasoline (Edwards, et. al, 1986). These data are presented in Table 9.1. The last column in this table shows composition of gasoline vapours from petroleum industry (adapted from Veldt et. al, 1992). The data are averages derived from literature review of measurement experience in many countries (to large extent US - for details see EPA, 1990). According to Veldt et. al, 1992, the composition of gasoline vapour is highly variable depending on liquid composition (e.g., summer and winter blend) as well as on the evaporation process (temperature and time). However, aggregating species to groups as in Table 9.1 shows quite a good agreement of composition derived from both studies.

Table 9.1: VOC profiles of gasoline terminal air samples (Edwards et. al, 1986) and of petroleum industry emissions of gasoline vapour (Veldt et. al, 1992) [wt. %]

Substance	Tank vent	Downwind	Petroleum ind.
Alkanes			
Ethane	-	-	-
Propane	-	2.0	1.0 (0.2 - 2)
C_4+	89.2	89.1	85.0 (>45)
Alkenes			
Ethene	-	-	-
C_3+	6.9	6.5	11.0 (>5.5)
Aromatics			
Benzene	1.1	1.5	1.0 (0.5 - 2)
Toluene	2.0	0.9	1.5 (0.5 - 3)
Xylene	0.8	-	0.5 (0.1 - 1)
TOTAL	100.0	100.0	100.0

10. UNCERTAINTY ESTIMATES

Not considered at this stage.

11. WEAKEST ASPECTS / PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Methodology presented in this chapter is based on hypothetical, representative for Western Europe distribution network but it need not reflect real situation (system configuration) in a particular region or country. Therefore measurement campaigns carried out by independent groups of experts as well as comparison of emission factors with other countries could provide a valuable input to the continuous improvement of emission estimation technique.

12. SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Where no detailed information is available on location and throughputs of considered elements of gasoline distribution network the emissions from service stations (050503) should be distributed evenly across regions (e.g., administrative units) or grids or based on population data. The same applies to emissions from subsector (050502) if the appropriate data are not available although the location and throughput of principal marketing depots as well as border terminals should be known. The location of refineries are usually known (in many countries there are few, if not only one). Therefore emissions from refinery dispatch stations (050501) can be attributed to a particular region or grid.

13. TEMPORAL DISAGGREGATION CRITERIA

The true vapour pressure (TVP) of gasoline is influenced by its temperature and reid vapour pressure (RVP). It is possible, using equations given in Williams et al, 1986, to calculate emissions, resulting from storage and loading operations, from gasoline distribution sector, including data on gasoline properties (e.g., RVP) and average annual or monthly temperature.

An experimental work carried out by Deutsche Gesellschaft für Mineralölwissenschaft und Kohlechemie (DGMK, 1976) showed a seasonal variation, in filling/storage emissions from service stations, of 0.145/0.125% mass which occurred in summer/winter, respectively.

14. ADDITIONAL COMMENTS

In this chapter the methodology to calculate the emissions from gasoline distribution system as well as from storage of gasoline in the refinery dispatch station are described. However, chapter 040104 'Storage and Handling of Petroleum Products in a Refinery' in this guidebook covers the latter source. Therefore there is a danger of double counting especially in case when the simplified methodology is used and consequently aggregated emission factors are used. There is a need to discuss this issue and possibly modify the SNAP code, i.e. exclude, for example, emissions from refinery dispatch station from this subsection or replace it by border terminal stations (where applicable) and then the gasoline distribution system would only include gasoline flow outside the refinery.

Recently, US EPA has contracted Radian Corporation to develop the methodology to estimate VOC emissions from leaking underground storage tanks (LUST) (R.Ryan, US EPA, pers. communication). LUST are typically not considered a quantifiable source of air emissions until excavation and remediation efforts are initiated. In many cases the leaking tank and surrounding soil are removed and either placed in piles or evenly spread to allow volatilization of the contaminant. It is a common practice, especially where the contaminant is highly volatile, like for example gasoline. This note is only to inform about such activity as the final results are not yet available. It is believed that this source of emissions might contribute to local ozone episodes.

To forecast the emissions of VOC from gasoline distribution system the forecast of gasoline demand is necessary as well as the extent and type of control options introduced. There are usually several energy forecasts available but it is more difficult to find information on possible technical development as well as plans for introducing particular controls. In this case the emission development scenario could be based on energy forecast and on known current and forthcoming emission regulations, and on current national or international agreements on emission reductions.

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16. VERIFICATION PROCEDURES

The emission factors presented in this chapter are not necessarily representative for a particular region/country due to substantial differences in handling practices, product properties as well as meteorological conditions. The verification can be based on local measurements or measurements performed for similar conditions.

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SNAP CODES :

050601
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081000

SOURCE ACTIVITY TITLES :

Gas Distribution Networks
Pipelines
Distribution Networks
Pipeline Compressor Stations

1. ACTIVITIES INCLUDED

This chapter considers emissions from the transmission of gaseous fossil fuel from terminals to consumers via pipelines, compressor stations and networks. Most of the information in this chapter is based on data for natural gas.

2. CONTRIBUTION TO TOTAL EMISSIONS

The following table refers to the UK only and to the year 1992. Emissions are in kilotonnes(kt). Data are from the UK Digest of Environmental Protection & Water Statistics 1994. The NMVOC component of natural gas was calculated using the UK species profile given in section 9.

	Methane	**NMVOC**	**Total**
Emission due to natural gas leakage (kt)	375	42	417
Total emission (kt)	4736	2556	7292
Natural gas leakage as % of total emission	7.9	1.6	5.7

3. GENERAL

3.1 Description

Natural gas is a combustible gas that occurs in porous rock of the earth's crust and is often found with or near accumulations of crude oil. It may also occur alone in separate reservoirs. Gas wells exist on land and offshore. Some countries may also use gas derived from coal. Coal gasification has been practised since the early nineteenth century and can be done using a number of different processes.

The main use of natural gas is heating buildings and processes and as a chemical feedstock, for example in the manufacture of ammonia and fertilisers. Also, it is increasingly being used as a fuel for power generation.

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 liquified 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 & 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 unjointed. Jointed pipes have joints which consist of flanges bolted together or similar arrangements. In unjointed 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. For example, 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.

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.

3.2 Definitions

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 transmission 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 customers premises.

STP

Standard Temperature & Pressure - refers to a temperature of 373.15 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 on shore or offshore.

3.3 Techniques

The technology which forms part of a typical gas transmission network is described in sections 3.1, Description, and 3.2, Definitions, above.

3. Emissions

The pollutants emitted by the various parts of a typical gas transmission network are described in section 9, Species Profiles, below and the various emission sources within a gas transmission network are described in sections 3.1, Description, and 3.2, Definitions, above. As mentioned in section 3.1 above 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.

3.5 Controls

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 & other maintenance activities

4. SIMPLER METHODOLOGY

In the absence of data characterising the transmission network, an emission can be estimated as a certain percentage of the total sales of gas in the region or country.

5. DETAILED METHODOLOGY

The detailed methodology requires much greater information on the gas transmission system. This information is normally available from the distribution company.

The methodology requires the following equation to be solved:

Emission =

$$(n_t{}'f_t)+(n_s{}'f_s)+(l_P{}'f_P)+(n_c{}'f_c)+(l_{Lj}{}'p_{Lj}{}'f_{Lj})+(l_{Lu}{}'p_{Lu}{}'f_{Lu})+(l_{Mj}{}'p_{Mj}{}'f_{Mj})+$$

$$(l_{Mu}{}'p_{Mu}{}'f_{Mu})+(l_{Ij}{}'p_{Ij}{}'f_{Ij})+(l_{Iu}{}'p_{Iu}{}'f_{Iu})+(n_g{}'f_g)$$

The symbols in this equation are defined in sections 6 and 8 below.

6. RELEVANT ACTIVITY STATISTICS

For the simpler methodology, only the energy value of the gas consumed is required.

For the detailed methodology, the following activity statistics are required.

The number, n_t, of terminals.

The number, n_s, of high pressure LNG storage facilities.

The number of km of high pressure pipeline, l_P.

The number of compressor stations, n_c.

The number of km of jointed low pressure and service mains, l_{Lj}.

The pressure in mbar in the jointed low pressure and service mains, p_{Lj}.

The number of km of unjointed low pressure and service mains, l_{Lu}.

The pressure in mbar in the unjointed low pressure and service mains, p_{Lu}.

The number of km of jointed medium pressure mains, l_{Mj}.

The pressure in mbar in the jointed medium pressure mains, p_{Mj}.

The number of km of unjointed medium pressure mains, l_{Mu}.

The pressure in mbar in the unjointed medium pressure mains, p_{Mu}.

The number of km of jointed intermediate pressure mains, l_{Ij}.

The pressure in mbar in the of jointed intermediate pressure mains, p_{Ij}.

The number of km of unjointed intermediate pressure mains, l_{Iu}.

The pressure in mbar in the unjointed intermediate pressure mains, p_{Iu}.

The number of gas holders, n_g.

The local composition of the natural gas.

7. POINT SOURCE CRITERIA

The major installations within the gas distribution system such as terminals, storage,processing plants and larger compressor stations may be considered as point sources if plant specific data are available. Further geographical disaggregation is discussed in section 12 below.

8. EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Simpler Methodology

The following default emission factors are expressed in terms of tonnes per PJ of energy.

	Western Europe	**US & Canada**	**Former USSR, Central & Eastern Europe**	**Other Oil Exporting Countries**	**Rest of World**
Methane*	14.8 - 27	39.6 - 104	218 - 568	40 - 96	40 - 96
Total emission†	19 - 35	51 - 130	280 - 730	51 - 120	51 - 120

* reference 4

† derived from methane figures by assuming that the gas is 78 wt% methane

Error limits: ± >100% of emission estimate.

8.2 Detailed Methodology

The following emission factors are required

Emission rate, f_t, from a typical terminal in tonnes per year.

Emission rate, f_s, from a typical high pressure storage facility in tonnes per year.

Average emission rate per unit length for high pressure pipeline, f_P, in tonnes per year per km of pipeline.

Typical emission rate from a compressor station, f_c, in tonnes per year.

Leak rates for each of the various sorts of pipeline & main, f_P, f_{Ij}, f_{Iu}, f_{Mj}, f_{Mu}, f_{Lj}, f_{Lu}, in tonnes per year per km.

Average leak rate from a typical gas holder, f_g, in tonnes per year.

8.2 Estimation of emission factors

8.2.1 Emission rate, f_t, from a typical terminal in tonnes per year

Terminals consist of a variety of equipment, including vessels, pipe-work, valves and compressors. The preferred way to estimate the emission factor is to carry out ambient concentration measurements and calculate the source strength from these. Alternatively a component-emission factor may be used. If this method is used the error limits on the emission factor will be ± 10% of the emission factor

Default emission factor: 177 t/y (from reference 1)

8.2.2 Emission rate from high pressure storage facilities, f_s in tonnes per year

Determine by ambient concentration measurements as for 8.2.1 above. If this method is used the error limits on the emission factor will be ± 10% of the emission factor

There is currently no default emission factor to propose for this source

8.2.3 Average emission rates per unit length for high pressure pipeline, f_P, in tonnes per year per km of pipeline.

Only determine if the high pressure pipeline system is old and considered to be leaky. Emission factors can be estimated by carrying out pressure decay experiments on isolated sections of pipeline. The technique for doing this is described in section 8.2.5 below. If this method is used the error limits on the emission factor will be ± 10% of the emission factor.

Default emission factor: 0 t/y (from reference 1)

8.2.4 Leak rates for medium & intermediate pressure pipeline & main, f_{Ij}, f_{Iu}, f_{Mj}, f_{Mu}.

Determine by pressure decay experiments on isolated sections of pipe as described in section 8.2.5 below

Default emission factors 0.04 m^3/km/mbar/year for jointed pipes and 0.00004 m^3/km/mbar/year for unjointed pipes. Calculate tonnages using the ideal gas equation and the average molecular weight of the gas determined from its composition (from reference 1).

8.2.5 Leak rates for low pressure main & service pipes f_{Lj}, f_{Lu}.

Determine by pressure decay experiments on isolated sections of pipe. This should be carried out as follows.

Identify a representative sample of pipes to test. The best way of doing this is to compile a table such as the figure below dividing up the national network into a number of categories based on pipe diameter and material:

Diameter	**Steel**	**Pit Cast**	**Spun Cast**	**Ductile**	**PE**
£8cm					
10-13cm					
15-18cm					
20-28cm					
^{3}30cm					

The categories described in the above figure are for illustration only. Different diameters and materials may be more appropriate in different countries.

Start by entering into the table the number of kilometres of pipe of each category in the entire distribution system. Next, decide how many sections of pipeline from each category should be chosen for the experiments. The aim is to identify a sample of experimental pipeline sections which are representative of the network as a whole. The number of test sections in each category should generally be proportional to the number of kilometres in the network and to the expected variability of leakage rates. The leakage rates from PE pipes are expected to be less variable than those from cast iron pipes and so fewer tests are required for a given size of population for PE pipes than for cast iron to establish the leak rate to the same level of uncertainty.

For each section of 'main' identified agreement will be needed from the customer supplied by that main to allow interruption of their supply for the duration of the test. Each section of pipe to be isolated should be approximately 1km long. The service pipe should be capped on the customer's side of the meter isolation valve.

Two pressure decay experiments are required for each isolated section of pipe. In one test a leak of known magnitude is introduced into the pipeline under test and a pressure decay curve plotted. In the other the control leak is stopped. From the two pressure decay curves it is possible to calculate the rate of gas leakage from the test section without prior knowledge of the internal volume of the section.

Leak rates should be determined in this way for a number of different pressures, both above, below and at the normal operating pressure of the main.

The leak rate should also be determined with the service pipe disconnected from the main. This allows separate leak rates to be calculated for the service pipe. Service pipes are made of a number of different materials and the sample of test mains should include service pipes of all the materials used.

Default emission factor: 88 m^3/km/year/mbar including leakage from service pipes. The emission factors f_{Lj}, and f_{Lu} can be calculated from these figures using the pressure in the pipe and the composition of the gas (to estimate the weight of $1m^3$ of gas). (from reference 2)

8.2.6 Typical emission rate from a compressor station, f_c, in tonnes per year.

Determine by ambient concentration measurements as for 8.2.1 above. If this method is used the error limits on the emission factor will be ± 10% of the emission factor

Default emission factor: 71.5 t/y (from reference 1)

8.2.7 Average leak rate from a typical gas holder, f_g, in tonnes per year.

This can be determined by isolating a gas holder and measuring its loss in height over a given time period. If this method is used the error limits on the emission factor will be ± 100% of the emission factor

Default emission factor: 4 t/y (from reference 1)

8.3 Summary of Emission Factors

Description	Symbol	Unit	Value	Ref
Emission rate from a typical terminal	f_t	t/y	177	1
Emission rate from high pressure storage facilities	f_s	t/y	no data	1
Average emission rates per unit length for high pressure pipeline	f_P	t/y/km	0	1
Leak rates for jointed intermediate pressure pipeline	f_{Ij}	m^3/km/mbar/year	0.04	1
Leak rates for unjointed intermediate pressure pipeline	f_{Iu}	m^3/km/mbar/year	0.00004	1
Leak rates for jointed medium pressure pipeline	f_{Mj}	m^3/km/mbar/year	0.04	1
Leak rates for unjointed medium pressure pipeline	f_{Mu}	m^3/km/mbar/year	0.00004	1
Leak rates for jointed low pressure main & service pipes	f_{Lj}	m^3/km/year/mbar	88	2
Leak rates for unjointed low pressure main & service pipes	f_{Lu}	m^3/km/year/mbar	88	2
Typical emission rate from a compressor station	f_c	t/y	71.5	1
Average leak rate from a typical gas holder	f_g	t/y	4	1

9. SPECIES PROFILES

Species profiles can be estimated by assuming that the composition of the emission is the same as the composition of the gas, although in practice for some types of emission, eg leaks from underground pipes, some components of the gas may get adsorbed, eg by the soil. However, we recommend that these effects are ignored because they cannot be quantified.

The following table lists typical species profiles for a number of countries:

	UK*	Netherlands†	Germany††	France††
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

* reference 5
† reference 6
†† reference 7

The data in the above table are mole percentages.

The following default profile has been derived from the above profiles by taking the average and rounding to the nearest whole percent:

	mole %	**wt %**
Carbon Dioxide(CO_2)	2	5
Nitrogen(N_2)	5	8
Methane(CH_4)	88	78
Ethane(C_2H_6)	4	7
Propane(C_3H_8)	1	2

In the absence of any other data this profile should be used.

10. UNCERTAINTY ESTIMATES

10.1 Simpler method

For the simpler method the only available way of estimating the degree of uncertainty is by intuition based on experience. We think that the uncertainty limits for estimated derived using the simpler method are about a factor of 2.

10.2 Detailed method

The detailed method requires the determination of emission factors for various sources within the gas transmission network and the error in the final emission estimate will depend on the way in which these factors are determined. Section 8.2, suggests error limits for each of the methods discussed. However, in practice the error limits may differ from these if the techniques used to estimate the emission factors are not identical to those described in section 8.2. Section 8.2 also gives error limits for the default emission factors.

The error limits for the emission factors should be combined with the error limits for the activity statistics (which should be available from the source of the statistics) according to the usual rules of the propagation of errors to give an error limit for the total emission.

11. WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHOD

11.1 Simpler method

This method depends on the default emission factor. However, better estimates of the emission factor can only be obtained by using the detailed method.

11.2 Detailed Method

The main weakness of the detailed method is that it can be quite effort intensive to determine accurate emission factors.

12. SPATIAL DISAGGREGATION

The gas transmission system can be divided into two, the two parts being the national transmission system consisting of a relatively small number of high pressure pipelines covering distances of hundreds of kilometres, the second part being the rest of the transmission system. Data on the locations of the various pipelines which form the national transmission system should be readily available for most countries. These can then be regarded as line sources. Emissions from the rest of the system can be broken down into a mixture of area sources, proportional to population density, and point sources corresponding to the locations of major installations such as terminals, storage, processing plants and larger compressor stations.

13. TEMPORAL DISAGGREGATION CRITERIA

Leakage rate is a function of pressure rather than throughput. It is therefore safe to assume that the leakage rate is constant.

14. ADDITIONAL COMMENTS

15. SUPPLEMENTARY DOCUMENTS

16. VERIFICATION PROCEDURES

The accuracy of the methods for the determination of emission factors can be checked by repeating the tests and by comparing the results with data obtained by other gas utilities in other countries on similar components.

17. REFERENCES

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