

- production disposition analyses (e.g., oil and gas production; vented, flared and reinjected volumes of gas; and fuel gas consumption),
- accidental releases (i.e., well blow-outs and pipeline ruptures),
- typical design and operating practices and their impact on the overall level of emission control.

The amount of emissions is then assessed by applying appropriate emission factors, empirical correlations, process simulation results, and field measurements to these data.

Some examples of detailed emission inventories that have been developed in this manner are listed below:

- US Environmental Protection Agency (US EPA). Anthropogenic Methane Emissions in the United States. Estimates for 1990: Report to the Congress. October 1992 (US EPA, 1993).
- Picard, D.J., B.D. Ross, and D.W.H. Koon. A Detailed Inventory of CH₄ and VOC Emissions from Upstream Oil and Gas Operations in Alberta. Clearstone Engineering Ltd., for the Canadian Petroleum Association, March 1992 (Picard et al., 1992).
- UK Offshore Operators Association Ltd. (1992). Methane Emissions From Offshore Oil & Gas Exploration & Production Activities. Submitted to The Watt Committee on Energy, 1993.
- Norwegian Oil Industry Association - OLF. Report from OLF Environmental Programme - Phase 2. 1993.

1.8.7 Uncertainty

Some of these studies do analyse uncertainties, but emissions estimates in general are very uncertain. The overall magnitude of the emissions estimates that will be obtained for some countries using the methods and assumptions outlined in this chapter is driven by two key studies:

- **Rabchuk et al. (1991)** report that emissions from gas production and transportation in the former USSR is very high, about 3 to 7 per cent of total gas production. Recent visits to this region indicate that system construction, maintenance, and operations may be consistent with high emissions rates (Craig, 1992). However, a better quantitative evaluation is needed to validate the current emissions estimates.
- **Barns and Edmonds (1990)** report emissions from venting and flaring by region. The emissions estimates for the OPEC countries are relatively high, and account for most of the emissions from this category. The safety concerns associated with venting, and the value of re-injecting gas into oil reservoirs to maintain reservoir pressures, would tend to render the high emissions estimates questionable. Improved data are needed to resolve this question.

The adoption of emission factor estimates from US EPA (1992) for various regions also adds uncertainty to the overall estimates. US oil and gas production facilities and refineries are subject to emission control requirements. The US emission factors, particularly for refining, may under-estimate emissions in other regions. Nevertheless, this may not be a significant global uncertainty since, if the emission factors for oil production and oil refining were increased by a factor of 10 for the entire world, the estimate of total global emissions would only increase by about 1 to 6 Tg for 1988.



TABLE 1-60
USA AND CANADA - EMISSION FACTORS

Emissions Type	Emission factor kg/petajoule	Source
Oil and Gas Production		
Oil	290 - 4 670 of Oil Production	US EPA (1992)
Gas	39 590 - 104 220 of Gas Production	US EPA (1992)
Oil & Gas	2 870 - 13 920 of Oil & Gas Production	US EPA (1992)
Crude Oil Transportation and Refining		
Transportation	745 of Oil Tankered	API (1987)
Refining	90 - 1 400 of Oil Refined	US EPA (1992)
Storage Tanks	20 - 260 of Oil Refined	US EPA (1992)
Natural Gas Processing, Transport, and Distribution	59 660 - 116 610 of Gas Consumption	US EPA (1992)
Gas Processing	..	..
Gas Pipelines	..	..
Gas Distribution	..	..

TABLE 1-61
EASTERN EUROPE AND FORMER USSR - EMISSION FACTORS

Emissions Type	Emission factor kg/petajoule	Source
Oil and Gas Production		
Oil	290 - 4 670 of Oil Produced	US EPA (1992)
Gas	218 000 - 567 600 of Gas Produced	Rabchuk et al. (1991)
Oil & Gas	6 300 - 29 700 of Gas Produced	Barns and Edmonds (1990)
Crude Oil Transportation and Refining		
Transportation	745 of Oil Tankered	API (1987)
Refining	90 - 1 400 of Oil Refined	US EPA (1992)
Storage Tanks	20 - 260 of Oil Refined	US EPA (1992)
Natural Gas Processing, Transport, and Distribution	340 000 - 715 800 of Gas Consumption	Rabchuk et al. (1991)
Gas Processing	..	..
Gas Pipelines	..	..
Gas Distribution	..	..

TABLE 1-62 WESTERN EUROPE - EMISSION FACTORS		
Emissions Type	Emission factor kg/petajoule	Source
Oil and Gas Production		
Oil	290 - 4 670 of Oil Produced	US EPA (1992)
Gas	14 800 - 27 000 of Gas Produced	Schneider-Fresenius et al. (1989)
Oil & Gas	13 000-16 000 of Gas Produced 3 000-8 000 of Gas Produced	Norwegian SPCA (1992) Norwegian O.I.A. OLF (1993)
Crude Oil Transportation and Refining		
Transportation	745 of Oil Tankered 2 500 of Oil Tankered	API (1987) Norwegian SPCA (1992)
Refining	90 - 1 400 of Oil Refined	US EPA (1992)
Storage Tanks	20 - 260 of Oil Refined	US EPA (1992)
Natural Gas Processing, Transport, and Distribution	58 000 - 111 000 of Gas Consumption	Schneider-Fresenius et al. (1989)
Gas Processing	1 800 of Gas Processed	Norwegian SPCA (1992)
Gas Pipelines	..	..
Gas Distribution	..	..

TABLE 1-63 OTHER OIL EXPORTING COUNTRIES - EMISSION FACTORS		
Emissions Type	Emission factor kg/petajoule	Source
Oil and Gas Production		
Oil	290 - 4 670 of Oil Produced	US EPA (1992)
Gas	39 590 - 96 000 of Gas Produced	US EPA (1992) and Barns and Edmonds (1990)
Oil & Gas	739 470 - 1 019 220 of Gas Produced	Barns and Edmonds (1990)
Crude Oil Transportation and Refining		
Transportation	745 of Oil Tankered	API (1987)
Refining	90 - 1 400 of Oil Refined	US EPA (1992)
Storage Tanks	20 - 260 of Oil Refined	US EPA (1992)
Natural Gas Processing, Transport, and Distribution	116 610 - 340 000 of Gas Consumption	US EPA (1992 and Rabchuk et al. (1991)
Gas Processing	..	..
Gas Pipelines	..	..
Gas Distribution	..	..



Emissions Type	Emission factor kg/petajoule	Source
Oil and Gas Production		
Oil	290 - 4 670 of Oil Produced	US EPA (1992)
Gas	39 590 - 96 000 of Gas Produced	US EPA (1992) and Barns and Edmonds. (1990)
Oil & Gas	170 000 - 209 000 of Gas Produced	Barns and Edmonds (1990)
Crude Oil Transportation and Refining		
Transportation	745 of Oil Tankered	API (1987)
Refining	90 - 1 400 of Oil Refined	US EPA (1992)
Storage Tanks	20 - 260 of Oil Refined	US EPA (1992)
Natural Gas Processing, Transport, and Distribution	116 610 - 340 000 of Gas Consumption	US EPA (1992 and Rabchuk et al. (1991)
Gas Processing	..	..
Gas Pipelines	..	..
Gas Distribution	..	..

1.8.8 Fugitive Emissions of Other GHGs

Methane is by far the most important greenhouse gas emitted on a fugitive basis from oil and gas activities. However, other GHGs are clearly emitted and should be included in a comprehensive national inventory.

After methane, the most significant fugitive emissions from oil and gas activities are of non-methane volatile organic compounds (NMVOCs). Oil and gas are largely composed of organic compounds, and releases through evaporation or leakages are likely at all stages wherever the fuels or their products come into contact with the atmosphere. Fugitive emissions from refining, transport and distribution of oil products are a major component of national NMVOC emissions in many countries.

The IPCC/OECD/IEA programme has not yet addressed the indirect GHGs (including NMVOCs) in detail. However, the Joint EMEP/CORINAIR Guidebook offers both a simplified and a more detailed approach to the estimation of ozone precursors and SO₂. The relevant tables and accompanying text are summarised below.

National experts interested in including the other fugitive emissions of GHGs from oil and natural gas systems should consult the existing literature which provides detailed emission factors and procedures for calculating emissions. Some key examples are:

- Default Emission Factors Handbook (EATF, 1992);
- Proceedings of the TNO/EURASAP Workshop (TNO Inst. of Environmental Sciences, 1993);
- Atmospheric Emission Inventory Guidebook (Joint EMEP/CORINAIR, 1996);
- EMEP and CORINAIR Emission Factors and Species Profiles for Organic Compounds. (Veldt, 1991);
- US EPA's Compilation of Air Pollutant Emissions Factors (AP-42), 5th Edition 1995 (US EPA, 1995);

- Criteria Pollutant Emission Factors for the 1985 NAPAP Emissions Inventory (Stockton and Stelling, 1987).

1.8.9 Refineries

OVERVIEW

A basic refinery converts crude petroleum into a variety of sub-products. Principal products of a refinery may include liquid fuels, coke, feedstocks and primary petrochemicals (like ethylene). This section covers basic refineries, not the synthesis of petrochemicals. Chemical production is included in Chapter 2, Industrial Processes, whether or not the actual production takes place at a refinery or in a separate plant.

Storage and handling of intermediates and products may account for between 1 to 8 per cent of a country's NMVOC emissions. There are also significant non-combustion emissions of SO₂, NO_x, and CO.

Refinery Operations

Refinery operations include separation processes (distillation and gas processing), petroleum conversion processes (cracking, coking, catalytic reforming, alkylation, polymerisation), petroleum treating processes (desulphurisation, chemical sweetening, acid gas removal, deasphalting) and blending.

Vacuum distillation, catalytic cracking, thermal cracking, sweetening, blowdown systems, sulphur recovery and asphalt blowing have been identified as being potentially significant sources of SO₂ and NMVOCs from these sources. Storage and handling of petroleum products will lead to NMVOC emissions.

SIMPLE METHODOLOGY FOR OZONE PRECURSORS AND SO₂

A simple estimation can be made on the basis of throughput and single emission factors. However in most cases more detailed information may be available and the more detailed approach outlined in the Joint EMEP/CORINAIR Guidebook (1996) under SNAP code 40100 or in the following section here should be adopted. This considers the actual processes taking place in the refinery and the throughput of crude and products. While emission rates will depend on the specific process and equipment in a refinery, its state of maintenance and the sulphur content of the crude oil, a very simple estimate can be made on the basis of the throughput of crude oil and simple emission factors alone. The default emission factors are shown in Table 1-65.



POLLUTANT	EMISSION FACTOR	SOURCES
SO₂(a)	0.8	Vacuum tower, catalytic cracker, fluid coking, sulphur plant, SWS, incinerator, caustic regeneration, vents, off gases, others
NO_x(a)	0.05	Catalytic cracking
CO(a)	0.08	Fluid catalytic cracker only
NMVO(b)	0.53	Fugitive and process emissions
Source :		
(a) EMEP/CORINAIR (1996).		
(b) based on CPPI and Environment CANADA (1991).		

NMVOE Emissions estimates vary widely. The proposed default value is 0.53 kg/m³ input. Estimates range from 0.085 kg/m³ from the best West European refinery to 10 kg/m³ for a Russian refinery.

In practice it may be possible to use a more detailed approach where some of the makeup of the refinery is known or where only some of the emission activities are known. Some of these constituent parts are outlined below as an alternative to the above approach.

DETAILED METHODOLOGY FOR OZONE PRECURSORS AND SO₂

In the detailed methodology, emissions are calculated separately from sub processes in the refinery. The total emissions are the sum of the emissions from each individual sub process. The calculations should be based on plant specific data.

Fluid Catalytic Cracking (SNAP 40102)

Emission factors for a petroleum refinery which uses a fluid catalytic cracking system are shown in Table I-66.

POLLUTANT	EMISSION FACTOR (VALUE)	EMISSION FACTOR (RANGE)
SO₂	1.4	0.286-1.505
NO_x	0.2	0.107-0.416
CO	39.2	NA
NMVOE	0.6	NA
Source: US EPA (1985a, 1995).		

No emission factors are currently available for cracking of coal to fluid products.

Sulphur recovery plants (SNAP 40103)

Sulphur recovery is the conversion of hydrogen sulphide to elemental sulphur. Emission factors are based on the amount of elemental sulphur produced and are shown in Table I-67.

TABLE I-67 NON-COMBUSTION EMISSION FACTORS FOR REFINERIES AND SULPHUR RECOVERY PLANTS. (KG/TONNE SULPHUR)	
POLLUTANT	EMISSION FACTOR
SO ₂	139
Source : US EPA (1993b).	

Storage and handling (SNAP 40104)

Emissions of NMVOC result from evaporation from tanks during storage, displacement of vapour during volume changes, loading and unloading and spillages. Storage may occur at a refinery or at separate locations. Emissions depend on the type and state of the tanks. Emission factors are suggested in Table I-68. Where nothing is known the highest factor should be used. The activity statistic is the crude oil throughput of the refineries.

TABLE I-68 NON-COMBUSTION EMISSION FACTORS FOR REFINERIES (STORAGE AND HANDLING. G/KG OIL THROUGHPUT)	
CONDITION	EMISSION FACTOR
• Majority of volatile products are stored in <i>floating roof tanks with secondary seals</i>	0.2
• Majority of volatile products are stored in <i>floating roof tanks with only primary seals</i>	0.7
• Majority of volatile products are stored in <i>fixed roof tanks</i>	4.9
Source : EMEP/CORINAIR (1996).	

These emissions are intended to account for evaporative losses during storage and the displacement losses resulting from the loading and unloading of storage tanks.

Emissions from this source may be higher in countries with a warm climate.



1.9 Further Work

At the end of the Experts' Meeting on GHG Emissions from Fuel Combustion (Abingdon, 29-30 March 1996), experts were asked to identify areas for future work on emissions from energy. The subsequent list was then prioritised into short/medium-term activities and longer-term activities.

Short to Medium term (1-3 years):

1. Perform sensitivity analysis to assess importance of emission factors for various sectors.
2. Critically assess key emission factors found during sensitivity analysis, and key calorific values and activity data.
3. Enhance the EDGAR emission factors that feed into the Tier I methodology with information from US country studies and from other sources.
4. Critically compare IPCC emission factors and methodology with US EPA (1995) and CORINAIR.
5. Perform a literature search on emission factors:
 - Mobile sources in developing countries
 - N₂O (all sources)
 - Biomass (especially fuelwood)
6. Perform more research on emission factors for developing countries, including emission factors for biomass.
7. Enhance the section on fugitive emissions: coal mines (CH₄), oil & gas industry (CH₄ and NMVOC).
8. Analyse double counting with Industrial Processes section of *IPCC Guidelines*. Re-evaluate the default carbon stored values provided in the *Guidelines*, including the fate of carbon stored in petroleum products.
9. Add a category for non-fuel energy related emissions, such as from geothermal energy, CH₄ from flooding to create reservoirs, etc.
10. Evaluate the adequacy of guidelines.
11. Compare the results obtained by using Tier 1 and Tier 2 calculations for the non-CO₂ gases.
12. Investigate the possibility of reporting inventories and background information on the Internet.

Long term:

1. Develop/update software to support computation and reporting of both the Tier I and Tier 2 approaches.
2. Enhance reliability of biomass consumption figures.
3. Perform statistical analysis of data reported, and validate results with globally measured concentrations of all direct greenhouse gases.

1.10 References

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