The values of the emission factors are determined using the equations presented below.

$$K_{Oil-P_{min}} = 1 - \frac{Q_{Gas-fuel} + Q_{Gas-Inj} + Q_{Gas-flared} + Q_{Gas-other}}{Q_{Oil-P} \times GOR}$$

where,

$K_{Oil-P_{min}}$ = minimum emission factor for oil production (dimensionless)

Q_{Oil-P} = oil produced (m^3/year)

GOR = gas to oil ratio (dimensionless)

$Q_{Gas-fuel}$ = quantity of gas used as fuel (m^3/year)

$Q_{Gas-flared}$ = quantity of gas flared (m^3/year)

$Q_{Gas-inj}$ = quantity of gas injected back into ground (m^3/year)

$Q_{Gas-other}$ = quantity of gas accounted for in some other manner and that is not emitted (m^3/year)

The minimum emission is the amount of gas not otherwise accounted for. If no gas is used as fuel, flared, injected, or otherwise handled, then the minimum emission factor is 1; (i.e., all the gas withdrawn from the ground in conjunction with the oil is emitted). If some amount of gas is accounted for, then the minimum emission factor is 1 minus the portion accounted for.

Emissions also occur due to leaks. The leak emissions are the amount of gas leaked during various types of handling. If no gas is used as fuel, flared, injected, or otherwise handled, then the leaks are zero. If some amount of gas is managed in these ways, then the leak emission is the amount of gas handled times the leak rate, which is expressed as a fraction. The following is the equation for the leak emission factor:

$$K_{Oil-P_{leak}} = \frac{\left(Q_{Gas-fuel} \times L_{fuel}\right) + \left(Q_{Gas-inj} \times L_{inj}\right) + \left(Q_{Gas-flared} \times L_{flared}\right) + \left(Q_{gas-other} \times L_{other}\right)}{Q_{Oil-P} \times GOR}$$

$K_{Oil-P_{leak}}$ = emission factor for leaks in the systems used to handle gas during oil production

Q_{Oil-P} = oil produced (m^3/year)

GOR = gas to oil ratio; defines the amount of gas produced (in volume) per unit of oil produced (in volume) (dimensionless)

$Q_{Gas-fuel}$ = quantity of gas used as fuel (m^3/year)

$Q_{Gas-flared}$ = quantity of gas flared (m^3/year)

$Q_{gas-inj}$ = quantity of gas injected back into ground (m^3/year)

$Q_{Gas-other}$ = quantity of gas accounted for in some other manner (m^3/year)

L_x = leak rates for the handling of the gas in the various ways, expressed as a fraction (e.g., 0.01) (dimensionless)

The total emission factor for oil production is then estimated as:

$$K_{Oil-P} = K_{Oil-P_{min}} + K_{Oil-P_{leak}}$$

If none of the gas is controlled or utilised (i.e., $L_x = 1$ for all x), then the emission factor (K_{Oil-P}) is equal to one. This situation occurs when it is not economical to conserve or reinject the gas (e.g., there is no local market for the gas and the volumes are relatively small) and when venting of the gas is preferable to disposal by flaring. It is not then necessary to evaluate the different paths by which CH_4 emissions may occur (e.g., fugitive equipment leaks, process venting, system upsets, etc.) in these cases since the end effect is the same: essentially all the CH_4 produced is emitted to the atmosphere.

Crude Oil Transportation and Refining: The crude oil from production facilities will initially contain a certain amount of gas in solution. This gas, particularly the CH_4 fraction, evaporates quickly as this oil progresses through the storage and transportation systems en route to the refinery. When the oil reaches the refinery, it is usually fully weathered and essentially free of any CH_4.

Accordingly, the basic mass balance relation for oil transportation and refining activities may be expressed as follows:

$$E_{Oil-T} = Q_{Oil-T} \times F \times Y_{F-CH_4} \times K_{Oil-T} \times D_F \times 10^{-12}$$

where,

E_{Oil-T} = methane emissions from crude oil transportation and refining (Tg/year)

Q_{Oil-T} = oil transported and refined (m^3/year)

F = factor defining the amount of gas in solution with the crude oil (per unit of oil by volume) (Dimensionless)

Y_{F-CH_4} = methane fraction; the fraction of the gas in solution in the oil that is methane, on a volume basis, for example, 0.1m^3 of methane per 1.0 m^3 of gas. (Dimensionless)

K_{Oil-T} = emission factor for oil transportation and refining, see below. (Dimensionless).

D_F = density of methane at the temperature and pressure at which F is estimated (g/m^3). The relevant temperature and pressure may vary, depending on the values used to calculate F. For example, at 0°C and at a pressure of 1 atmosphere, the density of methane is 715.4 g/m^3, and at 20°C and 1 atmosphere, the density of methane is 666.6 g/m^3.

The first two terms (Q_{Oil-T} and F) estimate the total amount of gas that is in solution with the crude oil. The term Y_{F-CH_4} converts the total gas quantity into the quantity of methane (still on a volume basis).[4] The emission factor (K_{Oil-T}) is the fraction of the total gas in solution that is emitted (at most, $K_{Oil-T} = 1$). To put the emissions estimate on a mass basis, D_F is used to estimate grams, and the conversion to teragrams follows.

The value of the solution gas factor and the corresponding mole fraction of methane is determined by the type of crude oil (light, medium, heavy, or crude bitumen), the composition of the associated gas, and the initial vapour pressure of the crude oil when it is placed in the storage tanks or compartments at the production site. Typically, the initial vapour pressure will be equal to the operating pressure of the first vessel upstream of the storage facilities.

Table 1-59 presents some estimated values for these two parameters at onshore and offshore facilities. Better estimates may be determined by performing site specific process simulations.

TABLE 1-59 SOLUTION GAS FACTORS AND CORRESPONDING CH_4 MOLE FRACTIONS FOR DIFFERENT TYPES OF CRUDE OIL PRODUCTION AT ONSHORE AND OFFSHORE FACILITIES		
Type of Crude Oil	Onshore and Offshore Facilities	
	F SOLUTION GAS FACTOR	$Y_{F\text{-}CH_4}$ MOLE FRACTION
Light	3.3 to 5.0	0.5642
Medium	3.2 to 5.0	0.1001
Heavy (Primary)	1.0	0.8723
Heavy (Thermal)	8.3	0.6666

The value of the system adjustment factor is determined using the equation below:

$$K_{Oil-T} = 1 - \frac{Q_{Collected\ CH_4}}{Q_{Oil-T} \times F \times Y_{F-CH_4}}$$

$Q_{Collected\ CH_4}$ = the amount of methane collected, and not emitted, during transportation and refining.

Often this amount is zero

Other terms defined above.

In the absence of any data regarding the volume of CH_4 collected, the value of system adjustment factor should be set to a default value of one.

Exploration and Drilling Losses

Total CH_4 emissions from the exploration and drilling sector will usually be small compared to the amount emitted by other sectors of the oil and gas industry. Consequently, a simple Tier 1 approach is perhaps most appropriate for use here.

The basic relation is shown below:

$$E_D = N_{wells} \cdot F_D$$

where,

E_D = total CH_4 emissions (Tg) from drilling and testing of oil and gas wells,

N_{wells} = number of wells drilled and tested, and

F_D = average amount of CH_4 emitted per well (Tg/well).

Tier 3 - Rigorous Source-Specific Evaluations Approach

Rigorous source-specific evaluations will generally involve compiling the following types of information and may require significant interaction with industry and associated regulatory agencies:

- detailed inventories of the amount and types of process infrastructure (e.g., wells, minor field installations, and major production and processing facilities),