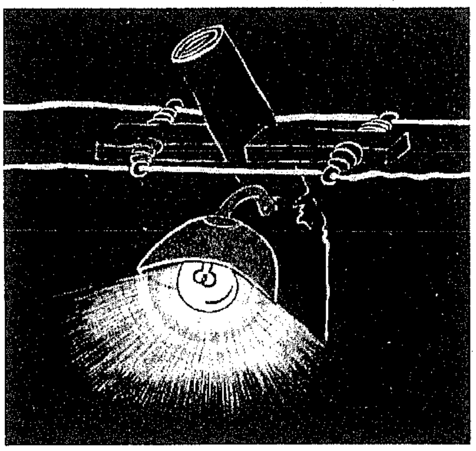
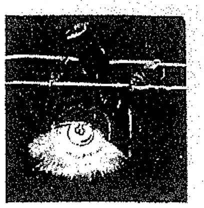
ENERGY





ENERGY REFERENCE MANUAL

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ENERGY SECTOR

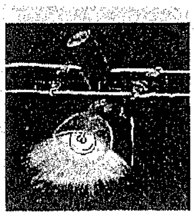
Reference Manual

1.1 INTRODUCTION

Fuel combustion and fuel production activities involving coal, oil, and natural gas are the two major sources of greenhouse gas (GHG) emissions from the Energy sector. Of the two, fuel combustion accounts for most (>90%) of the energy-related GHGs emitted into the atmosphere. Greenhouse gases released from fuel production activities such as coal mining, exploration, production, and processing of oil and gas products are minimal and are termed collectively as fugitive emissions.

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the GHGs released in the combustion of fuels. Also released in the process are the GHG precursors carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOCs). Of these six gases, the major gas emitted is CO_2 and the bulk of calculations in the Energy sector involves determining the amount of CO_2 released in fuel combustion activities. In the 1994 GHG inventory, fuel combustion accounts for 99.55% of the Philippines' energy-related GHG emissions.

In general, the heavy use of fuels can be attributed to activities associated with the energy industries (for power generation), transportation, and manufacturing industries. These three subsectors mainly utilize fossil-based fuels such as coal, fuel oil, diesel, and natural gas, which are found to contribute substantially to CO_2 emissions. According to the Department of Energy (DOE) data archives, these fuel types dominate about 60% of the country's energy mix in 1994 as shown in Figure 1-1. Furthermore, fossil based fuels to comprise 67% of the national energy mix by the year 2008 [DOE, 1999]. New and renewable energy (NRE) systems such as biomass fuel, wind, solar, hydroelectric, and geothermal energy systems account for about 40% of the energy mix in 1994 and a projected 33% for 2008. These NRE systems are assumed to have no net CO_2 emissions.



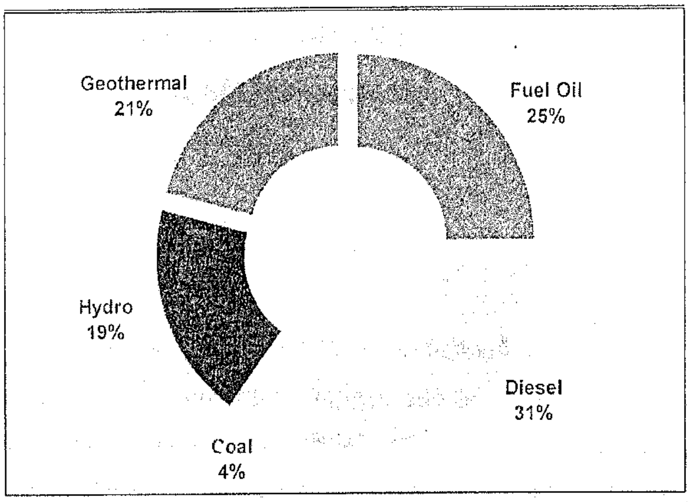


Fig. 1-1. Dominance of fossil fuel based energy in the 1994 Philippine energy mix. (Source: Department of Energy)

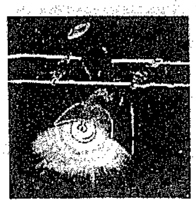
Fugitive GHG emissions from coal mining/handling and oil/gas production activities are mostly CH_4. These emissions, however, are insignificant compared to the GHGs released from fuel combustion. In the 1994 GHG inventory, 13% of the CH_4 emissions in the Energy sector are from fugitive emissions.

In this reference manual, GHG emissions from fossil fuel combustion are discussed in Sections 1.2 and 1.3. Fugitive emissions are explained in Section 1.4. Section 1.5 gives an overview of sulfur dioxide (SO_2) emissions from fuel combustion activities. The last section, Section 1.6, covers memo items such as CO_2 emissions not included in the national total but are still computed separately as recommended by the Revised 1996 IPCC Guidelines (henceforth, IPCC Guidelines) for completeness of the inventory. All the methods used in the computations are based on these IPCC Guidelines.

1.2 CO_2 Emissions From Fuel Combustion Activities

Fossil fuels are compounds that contain hydrocarbons, i.e. carbon and hydrogen atoms bonded together which, upon combustion, are broken down into their components, thus releasing energy in the process. The hydrogen and carbon molecules bond with oxygen to form H_2O and CO_2, respectively. This is illustrated schematically below:

$$\text{Hydrocarbon} + O_2 \xrightarrow[\text{Combustion}]{} H_2O,\ CO_2 + \text{Energy}$$



Estimating CO_2 emissions from fuel combustion can be done through either of two approaches, namely, the **top-down (or reference approach)**, and the **bottom-up (or sectoral approach)**. In the former, CO_2 emissions are accounted for by considering the overall supply of energy of the country in a particular year. In the bottom-up approach, CO_2 emissions are determined from the various subsectors that consume this supply of energy (hence, the sectoral approach). These two methods are discussed more extensively in the succeeding two subsections.

In both methods, the general formula used to compute for CO_2 emissions is:

$$\textit{Emissions } (t\ CO_2) = \Sigma\,[\textit{Fuel Consumption } (TJ) \times \textit{Carbon Emission Factor } (t\ C/TJ) - \textit{Carbon Stored } (t\ C)] \times \textit{Fraction Oxidized} \times 44/12 \qquad \text{Eq 1-1}$$

where:

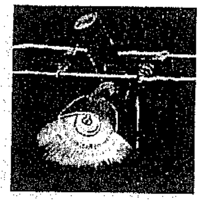
- $t\ CO_2$ = tons (or 1000 kg) of CO_2
- TJ = terajoules (10^{12} Joules)
- 44/12 = ratio of the molecular weight of CO_2 (i.e., 44) to the atomic weight of C (i.e., 12) which is used to convert mass from C to CO_2

The summation (Σ) is carried over all types of fuel involved in energy combustion activities. These fuel types are listed below in Table 1-1.

Table 1-1. 1994 Philippine local fuel classification

Solid Fossils	*Primary Fuel*	Coal
Liquid Fossils	*Primary Fuel*	Crude Oil
	Secondary Fuels	Gasoline Kerosene Diesel Fuel Oil LPG Avturbo Naptha Asphalt Avgas Lube/Grease
Biomass Fuels	*Solid Biomass*	Wood/Woodwaste Bagasse Agriwaste (Crop Residue) Charcoal Animal Waste Industrial Waste/Black Liquor

Source: Department of Energy



Fuel consumption data for both the top-down and bottom-up approaches may be obtained from the DOE. For 1994, the DOE issued an Overall Energy Balance (OEB) sheet containing the fuel supply and consumption data of the different subsectors per to fuel type. This balance sheet also contains all the information needed for the top-down approach such as fuel production, import, export, stock change, and international bunker (to be explained further below). The 1994 OEB sheet is attached as Appendix 1A.

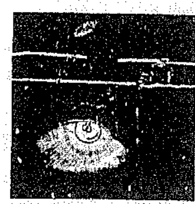
Note that in Eq 1-1, fuel consumption is expressed in terajoules (TJ), a unit of energy. In the OEB sheet, consumption data are expressed in ktoe or kilotons of oil equivalent, which is also an energy unit. (The conversion from ktoe to TJ is simply given by the relation: 1 ktoe = 41.868 TJ.) An energy unit such as TJ or ktoe provides consistency and uniformity when reporting energy utilization from various fuel types. Because raw fuel data can be expressed in different units, it is important to reduce all data into a common unit of energy. Liquid fuel can be expressed in barrels (bbl) and liters (li) and solid fuel in metric tons (MT). To convert these different fuel types to a common unit of energy, such as ktoe, the conversion factors are given in Appendix 1B. Other useful conversion factors (such as bbl to li) are also detailed here.

The **carbon emission factor**, as its name implies, indicates the carbon content of the fuel with respect to its energy content (t C/TJ). Shown in Table 1-2 are the default emission factors recommended by the IPCC Guidelines as well as the correspondence between the IPCC and local fuel types.

Table 1-2. Local and IPCC fuel types and emission factors

Local Fuel Type	IPCC Equivalent	Carbon Emission Factor (t C/TJ)
Coal	Sub Bituminous Coal	26.2
Crude Oil	Crude Oil	20.0
Premium Gasoline	Gasoline	18.9
Regular Gasoline	Gasoline	18.9
Unleaded Gasoline	Gasoline	18.9
Kerosene	Other Kerosene	19.6
Diesel	Gas/Diesel Oil	20.2
Fuel Oil	Residual Fuel Oil	21.1
LPG	LPG	17.2
Avturbo	Jet Kerosene	21.1
Naptha	Naptha	20.0
Asphalt	Bitumen	22.0
Avgas	Other Oil	20.0
Lube/Grease	Lubricants	20.0

Source: IPCC, 1997



IPCC [1996] recommends the above emission factors (EFs) as default values in the absence of local data. The IPCC, however, encourages the use of local factors if available.

Carbon stored refers to the non-combusted carbon in fuels. Hence, this should be subtracted from the overall energy CO_2 emissions. The top-down and bottom-up approaches have different methods of getting this value.

Top-Down Approach for Carbon Stored

Although included in the Energy sector, some fuel types such as asphalt and coal are used in non-energy activities. Road paving for example uses asphalt extensively. In this case, the carbon content of asphalt is not oxidized or combusted and is said to be stored. The release of this carbon into the atmosphere occurs gradually and is no longer covered in the fuel combustion process of energy activities. This amount of carbon must be deducted from the calculated emissions.

Information on fuel quantities involved in non-energy use can also be obtained from the DOE. This is likewise contained in the 1994 OEB sheet. Another source of information is the *Philippine Statistical Yearbook* which contains data on Philippine non-fuel petroleum consumption specifically for asphalt, naptha, and lubricants (lube/grease). For these fuel types, an auxiliary worksheet in the Energy Workbook is provided to compute for the amount of carbon stored.

Bottom-Up or Sectoral Approach for Carbon Stored

In the 1994 inventory, it is assumed that no carbon is stored for all fuels types except for lube/grease. For this fuel type, the IPCC default value of 0.5, i.e. 50% of the lube/grease ktoe is assumed to be stored. IPCC, however, also recommends values for estimating the fraction of carbon stored for the following fuel types: bitumen and feedstock materials such as naptha, gas/diesel oil, LPG, and ethane.

In fuel combustion, not all of the fuel's carbon content will be completely burned or oxidized. Table 1-3 lists the default IPCC values for the **fraction of carbon oxidized per fuel type**. The applicability of these values to local fuel types, however, remains to be determined.

Table 1-3. Fraction of carbon oxidized in fuel combustion

Fuel Type	Fraction of Carbon Oxidized
Liquid Fossils	0.99
Solid Fossil or Coal	0.98
Biomass Fuels	0.88

Source: IPCC, 1997

1.2.1 TOP-DOWN OR REFERENCE APPROACH

The top-down approach calculates CO_2 emissions by looking at the primary level of energy supply and distribution. The basic data requirement is an overall inventory of the national fuel supply which includes information on fuel quantities for each of the fuel types listed in Table 1-1 that are utilized in the following activities:

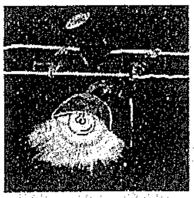
- production
- imports
- exports
- international bunkers, or the amount of fuel used for international aviation and marine transport
- stock change, or the variations in the quantity of fuel in stock.

Given these data, each fuel type's apparent consumption is computed thus:

$$\textit{Apparent Consumption} = \textit{Production} + \textit{Imports} - \textit{Exports} - \textit{International Bunkers} - \textit{Stock Change} \quad \text{Eq 1-2}$$

In Eq 1-2, fuels that are exported and fuels used for international bunkers (i.e., marine and aviation transport) are subtracted from the overall apparent consumption, hence are not included in the national GHG emissions inventory. CO_2 emissions from international bunkers are nonetheless computed as a separate memo item as recommended by IPCC [1996].

Stock change is the difference in fuel stocks between the previous year and the present inventory year. A negative stock change means a decrease in the fuel stock inventory which signifies an increase in the apparent consumption for the present



inventory year. A positive stock change, on the other hand, implies an increase in fuel stocks, hence, a decrease in the apparent consumption.

The apparent consumption given by Eq 1-2 is entered into Eq 1-1 to compute for CO_2 emissions using the top-down approach. Inventory results from this approach can be considered as an upperbound (or maximum) of the CO_2 emissions from fuel combustion activities. The approach provides an immediate, overall picture of the energy related emissions based on apparent fuel consumption based on the country's primary energy supply.

1.2.2. Bottom-Up or Sectoral Approach

The bottom-up approach is a more detailed method than the top-down approach. Computations are based on actual fuel consumption reported by six specific end-users of fuel: energy (or power generating) industries, transportation, manufacturing, residential, commercial, and agriculture.

The **energy industries** subsector consumes fuel through power plants that generate electricity. In 1994, power generation sources in the country can be categorized according to the following systems: Oil, Diesel, Coal, Gas Turbines, Hydropower, Geothermal, and NREs which refer to wind, solar, and biomass systems. By the year 2002, natural gas systems are scheduled to come on line. Of these eight power generating sources (including natural gas), five are dependent on fossil fuels: oil-based power plants, diesel and gas turbine plants, natural gas systems, and coal fired power plants. Hence, CO_2 emissions from this subsector may come mainly from the combustion of these four fuel types: fuel oil, diesel, coal, and natural gas (presumably by 2002).

The **transportation** subsector is made up of road, water, and air transport systems. Gasoline and diesel are the main fuel types used in road transport. In the Philippines, gasoline is further classified into premium, regular, and unleaded. The IPCC Guidelines, however, group these fuel types into one category which is gasoline. Other fuel types which are also used (in insignificant quantities) in road transportation are kerosene and fuel oil. Fuels for air transport are avturbo and avgas while for marine transport, diesel and fuel oil are the dominant fuel types.

Aside from the energy provided by power producers, **manufacturing industries** also buy raw fuel for other energy needs. The three dominant fuel types utilized in this subsector are coal, fuel oil, and diesel. About half of the total coal consumed in 1994 is from the cement industry. The biggest consumers of fuel oil are the food processing and cement industries.

The **residential** subsector is heavily dependent on LPG and kerosene for domestic activities such as cooking and lighting. Diesel and regular gasoline are used in relatively small quantities in this subsector.

In the **commercial** subsector, diesel, fuel oil, and LPG are the fuel types commonly used. This subsector also uses regular gasoline and kerosene for its energy requirements.

In **agriculture**, diesel is the dominant fuel type used to run tractors and other heavy agricultural machinery. Other fuel types used in this subsector are regular gasoline, kerosene, and fuel oil.

The total fuel consumption of these subsectors by fuel type is entered into Eq 1-1 to determine CO_2 emissions per subsector.

The bottom-up approach provides a more detailed inventory of the CO_2 emissions from fuel combustion. It identifies the specific sectoral consumers of fuel and thus the major emitters of energy related greenhouse gases. Compared to the top-down approach, however, it is more data and computation intensive. Also, the estimated CO_2 emissions may be underestimated since this approach relies heavily on data reported by fuel end-users which may not always be complete. The completeness of data submitted, if at all, to the DOE has always been a perennial problem.

It is recommended that both top-down and bottom-up calculations be done. Ideally, there should not be much of a difference in the emission results using the two methods. In the 1994 inventory, there is a relatively small difference of 2,665 kt CO_2 between the computed emissions using the top-down (49,999.51 kt CO_2) and bottom-up (47,335.37 kt CO_2) approaches.

1.3 NON-CO_2 EMISSIONS FROM FUEL COMBUSTION ACTIVITIES

The combustion of fuels also releases non-CO_2 GHGs such as methane (CH_4), and nitrous oxide (N_2O) as well as the GHG precursors carbon monoxide (CO), nitrogen oxides (NO_x), and non-methane volatile organic compounds (NMVOCs). This section discusses the contribution of these gases to the total energy related GHG emissions.

In order to compare the warming effect of the non-CO_2 gases, CH_4 and N_2O, global warming potential (GWP) coefficients are applied. The GWP takes into account the varying effectiveness of the different GHGs in warming the planet with respect to CO_2. The current IPCC [1996] recommendation for the GWPs of CH_4 and N_2O are 21 and 310, respectively. The CO_2 equivalents are computed by multiplying the actual emissions (of CH_4 and N_2O) with the respective global warming potentials. Hence, for example, 100 Gg of CH_4 is equivalent to 2100 Gg of CO_2.

To compute for these non-CO_2 emissions, the following equation is used:

Non-CO_2 Emissions (kg gas)
= Fuel Consumption (TJ) x *Emission Factor (kg gas/TJ)* Eq 1-3

In the next two sections (1.3.1 and 1.3.2), the two variables of the right hand side of this equation, namely fuel consumption data and the non-CO_2 emission factors, are explained further.

1.3.1 FUEL CONSUMPTION DATA FOR NON-CO_2 EMISSIONS

For fossil fuels such as coal and the oil derivatives, the data required are the same fuel consumption values contained in the OEB sheet. Non-CO_2 emissions, however, also include those emissions from the combustion of biomass fuels such as wood/woodwaste, charcoal, and other biomass/wastes (e.g., bagasse, agriwaste, animal wastes, industrial wastes, etc). The OEB sheet contains information on consumed biomass fuels only for the industry subsector. Unfortunately, the OEB does not contain data for the residential sector where this type of fuel is utilized the most.

Data on biomass fuel consumption in the residential subsector are obtained via interpolation. For the 1994 inventory, one basis is the data on biomass fuel consumption in the residential subsector found in the United Nations Development Programme/World

Bank Energy Sector Management Assistance Programme [UNDP-ESMAP, 1992] study on household energy consumption for 1989. The DOE started its own Household Energy Consumption Study (HECS) only in 1995. The ESMAP study made projections of household energy consumption patterns for the years 1995 and 2000 aside from the actual sampling that they carried out in 1989 based on a national annual population growth rate of 2.2%. The 1994 values are interpolated using the three sets of data points for 1989, 1995, and 2000.

To interpolate the values for biomass fuel consumption such as charcoal, for the year 1994, the available data points are first plotted. The values for charcoal are shown in Table 1-4.

Table 1-4. Charcoal consumption values for the year 1989 and projected values for the years 1995 and 2000

Year	Charcoal Consumption (kt)
1989	837
1995	966
2000	1,074

Source: UNDP-ESMAP, 1992

An exponential trend or regression line is drawn along these three points and the corresponding equation for the function is obtained. This is shown in Figure 1-3, where the broken lines represent the best fit line.

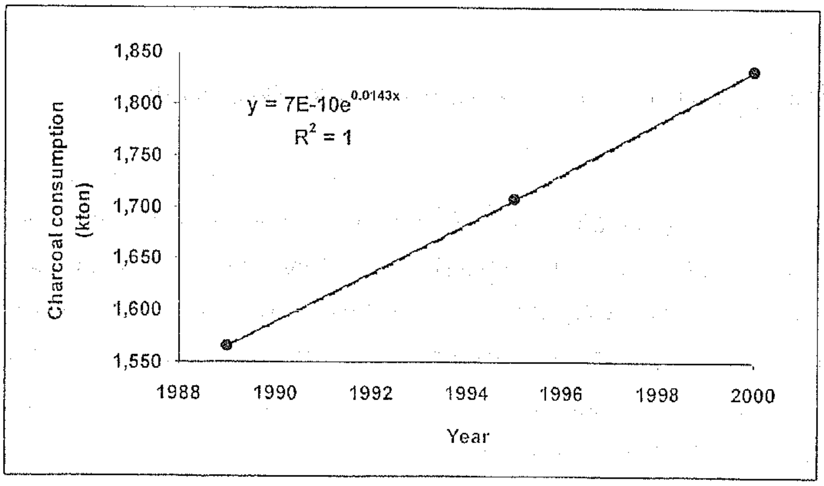
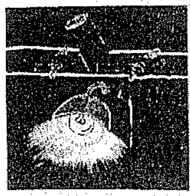


Figure 1-3. Charcoal consumption interpolation with the corresponding exponential fit equation.



The corresponding exponential function obtained is given by,

$$y = 7 \times 10^{-10} \exp(0.0143x)$$

where y is the unknown consumption variable for a particular year. For the year 1994 (x=1994), the charcoal consumption is found to be 1,693 kt (upon solving for y). The exponential trend line is chosen since it indicates the annual growth rate of the biomass fuel consumption. This annual growth rate is approximately equal to the coefficient of x which in the above equation is approximately 0.0143 or 1.43%. (Strictly speaking, the annual growth rate is equal to ($e^{0.0143}$ – 1) or 0.0144 or 1.44%.)

Table 1-5 shows the household consumption data for the three biomass fuels (charcoal, wood, and agriwaste) from the ESMAP study and the interpolated values for 1994. The corresponding trendline equations are also given.

Table 1-5. Consumption data for charcoal, wood and agriwaste including interpolated values with trendline equations

Year	Data Source	Charcoal (kt)	Wood (kt)	Agriwaste (kt)
1989	UNDP-ESMAP (actual)	1,564.93	18,316.90	2,570.45
1994	***Interpolated***	***1,681.44***	***19,270.44***	***2,702.00***
1995	UNDP-ESMAP (projection)	1,706.74	19,561.84	2,742.42
2000	UNDP-ESMAP (projection)	1,831.51	20,361.38	2,852.08
Interpolation Equations		$y=(7x10^{10}) \bullet \exp(0.0143x)$	$y=(8x10^{-05}) \bullet \exp(0.0097x)$	$y=(2x10^{-05}) \bullet \exp(0.0095x)$

1.3.2 EMISSION FACTORS FOR NON-CO_2 EMISSIONS

Non-CO_2 emissions depend not only on the type of fuel used but also on the specific end user and the particular trace gas. In the agriculture subsector, it is also important to know whether fuel combustion activities are mobile or stationary. In the 1994 inventory, diesel is the major fuel type for agricultural transport equipment like tractors and thus falls under the mobile category.

Methane (CH_4)

Methane emissions come from the incomplete combustion of hydrocarbons in fuels. For mobile sources, the amount of CH_4 emitted is also a function of the methane content of the fuel, the amount of hydrocarbons unburnt in the engine, the engine type, and any

post-combustion controls [IPCC, 1997]. CH_4 emissions from fuel combustion are relatively small on a global scale and the uncertainty is high.

In the 1994 inventory, most of the CH_4 emissions come from the incomplete burning of biomass fuels such as wood/woodwaste, charcoal, and other biomass/waste. This in itself is 97% of the total CH_4 emissions from fuel combustion activities. Table 1-6 shows the default IPCC CH_4 EFs for each subsector and fuel type.

Table 1-6. CH_4 default emission factors (kg CH_4/TJ)

			Coal	Oil		Wood/ Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries			1	3		30	200	30
Manufacturing Industries			10	2		30	200	30
Transport	Aviation			0.5				
	Road			Gasoline	Diesel			
				20	5			
	Navigation		10	5				
Other	Commercial/Institutional		10	10		300	200	300
Sectors	Residential		300	10		300	200	300
	Agriculture/	Stationary	300	10		300	200	300
	Fishing	Mobile		5				

Source: IPCC, 1997

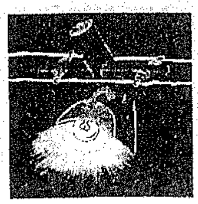
Nitrous Oxide (N_2O)

The combustion of fossil fuels also releases nitrous oxide, N_2O. As with CH_4, the contribution of fuel combustion to global N_2O emissions is minor and the uncertainty is high [IPCC, 1997]. Table 1-7 shows the default IPCC EFs for N_2O per subsector and fuel type.

Table 1-7. N_2O default emission factors (kg N_2O/TJ)

			Coal	Oil		Wood/ Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries			1.4	0.6		4	4	4
Manufacturing Industries			1.4	0.6		4	4	4
Transport	Aviation			2				
	Road			Gasoline	Diesel			
				0.6	0.6			
	Navigation		1.4	0.6				
Other	Commercial/Institutional		1.4	0.6		4	1	4
Sectors	Residential		1.4	0.6		4	1	4
	Agriculture/	Stationary	1.4	0.6		4	1	4
	Fishing	Mobile		0.6				

Source: IPCC, 1997



Nitrogen Oxides (NO_x)

Most of the emissions of NO_x from fuel combustion activities (about 48% in 1994) are from mobile sources. Even if it is not a GHG, NO_x plays a role in the formation of tropospheric ozone, O_3, as well as in the formation of acid rain. Table 1-8 shows the default IPCC emission factors for NO_x per subsector and fuel type.

Table 1-8. NO_x default emission factors (kg NO_x/TJ)

			Coal	Oil	Wood/ Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries			300	200	100	100	100
Manufacturing Industries			300	200	100	100	100
Transport	Aviation			300			
	Road			Gasoline: 600 / Diesel: 800			
	Navigation		300	1500			
Other Sectors	Commercial/Institutional		100	100	100	100	100
	Residential		100	100	100	100	100
	Agriculture/ Fishing	Stationary	100	100	100	100	100
		Mobile		1200			

Source: IPCC, 1997

Carbon Monoxide (CO)

In general, the release of CO from the Energy sector comes from the incomplete combustion of fuel in motor vehicles. Note, however, the large EFs for biomass fuels in the commercial, residential, and agriculture subsectors shown in **Table 1-9** which lists the default IPCC values. This indicates that high CO emissions may also come from these fuel end users specially if biomass consumption is large. The residential sector, in particular, is a potential major CO emitter because of its intensive use of biomass (e.g. fuelwood and charcoal) for domestic cooking. In 1994, this sector accounts for 66% of the total CO emissions. Transportation contributes only about 23%.

Table 1-9. CO default emission factors (kg CO/TJ)

			Coal	Oil	Wood/ Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries			20	15	1000	1000	1000
Manufacturing Industries			150	10	2000	4000	4000
Transport	Aviation			100			
	Road			Gasoline: 8000 / Diesel: 1000			
	Navigation		150	1000			
Other Sectors	Commercial/Institutional		2000	20	5000	7000	5000
	Residential		2000	20	5000	7000	5000
	Agriculture/ Fishing	Stationary	2000	20	5000	7000	5000
		Mobile		1000			

Source: IPCC, 1997

Non-methane Volatile Organic Compounds (NMVOCs)

Transportation and residential combustion of biomass fuels are the more important sources of NMVOCs. These two subsectors contribute 97% of the total NMVOC emissions from fuel combustion in 1994. Table 1-10 shows the default IPCC EFs for NMVOCs per subsector and per fuel type.

Table 1-10. NMVOC default emission factors (kg NMVOC/TJ)

			Coal	Oil		Wood/ Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries			5	5		50	100	50
Manufacturing Industries			20	5		50	100	50
Transport	Aviation			50				
	Road			Gasoline	Diesel			
				1500	200			
	Navigation		20	200				
Other Sectors	Commercial/Institutional		200	5		600	100	600
	Residential		200	5		600	100	600
	Agriculture/ Fishing	Stationary	200	5		600	100	600
		Mobile		200				

Source: IPCC, 1997

1.4 Fugitive Emissions

The release of GHGs into the atmosphere occurs not only during the combustion of fuels. The extraction of fuels and related activities such as fuel transport, processing, and storage, also result in GHG emissions of which CH_4 is the most notable. This section takes into account fugitive emissions from two main processes: a) coal mining and handling, and b) oil activities such as production, transport, refining and storage.

It is noted that there are other sources of fugitive CH_4 emissions and these are: venting/flaring in oil and gas production and activities involved in (natural) gas production/exploration. In the 1994 inventory, however, no information is available for these two processes. Data on venting and flaring are not regularly submitted by oil company contractors to the DOE and natural gas systems are expected to come on line only in 2002, as previously mentioned.

1.4.1 CH_4 Emissions from Coal Mining and Handling

Methane is inherently generated when coal is formed over millions of years. The extent of this coal formation determines how much CH_4 is generated. Once generated, the

amount of CH_4 in coal is controlled by the pressure and temperature of the coal seam [IPCC, 1997]. When coal is extracted or mined, the layers above the coal seam are removed, thus reducing the pressure and causing the release of CH_4 into the atmosphere.

The three main sources of CH_4 in these subsectors are underground mines, surface mines, and post-mining activities. It is important to distinguish underground mines from surface mines because depth affects the quantity of CH_4 stored in coal. Coal at greater depths will have higher concentrations of CH_4 since the pressure is greater. Hence, the emission factors are lower for surface mines and CH_4 emissions are generally also lower.

Coal processing, transport, and use are post-mining activities that also release CH_4. Desorption (or release) of CH_4 from the coal may occur while in transit or when the coal is crushed, broken and left to dry.

The emissions in all these processes are computed using the equation:

$$\begin{aligned}&\mathit{Emissions}(Gg\ CH_4) = \\ &\quad \mathit{Emission\ Factor}\ (m^3\ CH_4/ton) \times \mathit{Tons\ of\ Coal\ produced} \\ &\quad \times \mathit{Conversion\ Factor}\ (Gg/10^6\ m^3)\end{aligned} \qquad \text{Eq 1-4}$$

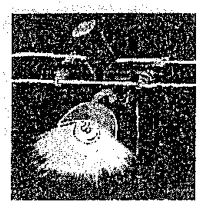
where the conversion factor converts the volume of CH_4 to a weight measure and is simply the density of methane at 20°C and 1 atm, 0.67 $Gg/10^6 m^3$. Table 1-11 shows the range of EFs for mining activities.

Table 1-11. Emission Factors for Mining Activities (Gg CH_4/ million ton of coal)

	Type of Mine/Activity	
	Underground	*Surface*
Mining	6.7-16.75	0.201-1.34
Post-mining	0.603-2.68	0-0.134

Source: IPCC, 1997

In the 1994 inventory, underground and surface mines produced 0.73 and 0.72 million tons of coal, respectively. Note that the amount of coal produced for mining and post-mining activities will be the same since the same quantity of coal is involved in both processes. Getting the average of the range of EFs listed in Table 1-11 and multiplying it by the corresponding production values, coal mining and handling activities in 1994 emitted a total of 10.32 Gg of CH_4.



1.4.2 Fugitive Emissions from Oil Activities

CH_4 is released when crude oil is produced, transported, and stored. In 1994, 10.69 PJ (peta or 10^{15} Joules) of oil were produced, 506.11 PJ loaded in tankers (or transported), and 497.75 PJ of oil refined and stored afterwards. These data were obtained from the DOE. To compute for CH_4 emissions, the following relation is applied

$$CH_4\ Emissions\ from\ Oil\ Activities = \sum A_i \times EF_i \qquad \text{Eq 1-5}$$

where A is the amount of oil in PJ involved in activity i, EF is the corresponding emission factor for activity i, and the summation is carried over each of the oil activities. Using the EFs listed in Table 1-12, oil activities in 1994 released 0.47 Gg of CH_4.

Table 1-12. Emission factors for oil production, transport, and storage activities

Category	Activity (PJ)	Emission Factor (kg CH_4/PJ)
Production	PJ of Oil Produced	2650
Transport	PJ of Oil Loaded in Tankers	745
Stored	PJ of Oil Refined	135

Source: IPCC, 1997

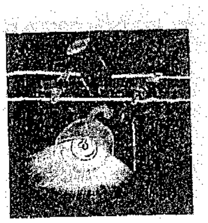
Note that there are no CH_4 emissions from oil refining. Gas emissions in this particular oil activity are sulfur dioxide (SO_2) and the GHG precursors CO, NOx, and NMVOC. To compute for these non-CO_2 emissions, the main information required is the crude oil throughput in kilotons from oil refining and catalytic cracking. These values, which can be obtained from the oil refining companies, are then multiplied to the emission factors given in Tables 1-13 and 1-14.

Table 1-13. Emission factors for GHG precursors and SO_2 from oil refining

Pollutant	Emission Factor (kg gas/t)
CO	0.09
NOx	0.06
NMVOC	0.62
SO_2	0.93

Source: IPCC, 1997

The GHG precursor, NMVOC, is also released through evaporation during oil storage. The emissions depend on the type and condition of the storage tanks. Table 1-



15 lists the emission factors from storage and handling for each type of storage tank. The emission factor is multiplied with the crude oil throughput from catalytic cracking to get the NMVOC emissions.

Table 1-14. Emission factors for GHG precursors and SO_2 from catalytic cracking

Pollutant	Emission Factor (kg gas/t)
CO	42.60
NOx	0.20
NMVOC	0.60
SO_2	1.50

Source: IPCC, 1997

Table 1-15. Emission factors for NMVOC emissions from oil storage and handling

Type of Handling Facility	Emission Factor (kg NMVOC/t)
Secondary Seals	0.20
Primary Seals	0.70
Fixed roof	4.90

If no information is available on the type of handling facility, the highest emission factor is used. Furthermore, countries with warm climate may have higher emissions. The 1994 inventory used the value for the fixed roof storage type which is also the highest emission factor listed in the Table 1-15.

1.5 SO_2 Emissions from Fuel Combustion Activities

Even if sulfur dioxide (SO_2) is not a greenhouse gas, it has the potential to alter local or regional climate as an aerosol precursor.

SO_2 emissions are computed using the relation

$$SO_2\ Emissions\ (kg) = \sum \left(EF_{ij} (kg\ SO_2/TJ) \times A_{ij} (TJ) \right) \qquad \text{Eq 1-6}$$

where the summation is carried over all fuel types *i*, and sector activities *j*, *EF* is the emission factor, and *A* is activity data on energy consumption.

The emission factor depends on the fuel's sulfur content, sulfur retention in ash, abatement efficiency (if existing), and net calorific value. Given the above information, the emission factor is given by:

$$SO_2\ Emission\ Factor = 2\times\left(\frac{s}{100}\right)\times\left(\frac{1}{Q}\right)\times 10^6\times\left(\frac{100-r}{100}\right)\times\left(\frac{100-n}{100}\right) \quad \text{Eq 1-7}$$

where the factor 2 in the right hand side of the equation is the molecular weight ratio of SO_2 to S, s is the % sulfur content, r is the % retention of sulfur in ash, Q is the net calorific value (TJ/kt), the factor 10^6 is the (unit) conversion factor, and n is % efficiency of abatement technology and/or reduction efficiency.

Local data on the sulfur content of fuels exist for some fuel types, as provided by the DOE. For other fuel types, IPCC default values are used. Table 1-16 shows the sulfur content (%) of the different fuel types. Table 1-17 shows the net calorific values for the different fuel types.

Table 1-16. Sulfur content of the different fuel types

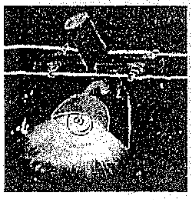
Fuel Type	% Sulfur Content in Fuel
Coal	3*
Fuel Oil	3
Diesel (road)	0.8*
Gasoline (road)	0.1*
Avturbo	0.05
Industrial Waste/Black Liquor	0.2
Fuelwood	0.2
Other Biomass	
Bagasse	0.02
Agriwaste	0.02
Animal Waste	0.02

Sources: *DOE; IPCC, 1997

Table 1-17. Net calorific values for the different fuel types

Fuel Type	Net Calorific Value (TJ/kt)
Coal	42.58
Fuel Oil	40.19
Diesel (road)	43.33
Gasoline (road)	44.80
Avturbo	44.59
Industrial Waste/Black Liquor	11.00
Fuelwood	15.00
Other Biomass	
Bagasse	8.00
Agriwaste	15.00
Animal Waste	11.00

Source: IPCC, 1997



1.6 MEMO ITEMS

1.6.1 CO_2 FROM BIOMASS FUEL

CO_2 emissions from the combustion of biomass fuels are covered as a memo item for completeness in the inventory process, as recommended by the IPCC [1996]. The computed CO_2 emissions, however, are not included in the inventory total since it is assumed that CO_2 released from the consumed biomass is absorbed in biomass regrowth [IPCC, 1997] and is thus taken up in the next growing cycle. Irretrievable net CO_2 emissions from biomass sources are accounted for in the Land Use Change/Forestry sector.

However, non-CO_2 emissions from biomass fuels such as wood/woodwaste, charcoal, and other biomass/wastes, are not memo items and are therefore included in the inventory.

1.6.2 CO_2 FROM INTERNATIONAL BUNKERS

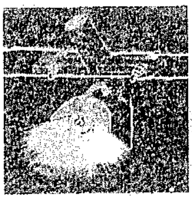
CO_2 emissions from fuel combustion in international marine and aviation are computed separately. As recommended by the IPCC Guidelines, these emissions are not to be included in the inventory total.

1.6.3 CO_2 FROM FUEL COMBUSTION IN INDUSTRY

The industry subsector can be categorized further into specific industries such as cement, sugar, paper processing, etc. This section is included if a more detailed inventory is desired to quantify the CO_2 emissions from the fuel consumption of each of these industries. Major industries that emit the most CO_2 as well as other GHGs can be readily identified if this detailed inventory is undertaken.

1.7 CONCLUSION

Fuel combustion activities and fugitive emissions are the two main sources of GHGs in the Energy sector. Majority of the emissions, however, come from the former. The combustion of conventional fossil fuel such as coal and oil, contributes substantially to GHG emissions, especially CO_2. Future emissions will have to account for natural gas based power, which is scheduled to come online in the country by 2002.



Fugitive emissions, on the other hand, are mostly composed of CH_4 coming from activities associated with coal mining/handling and oil production, transport, and refining. Although CH_4 has a high GWP, the net amount of CH_4 emitted is much smaller than the net CO_2 emissions coming from fuel combustion activities. A summary of the 1994 GHG emissions from the Energy sector is shown in **Figure 1-4**.

Sub Sector	CO_2 Emissions (Gg)
Energy Industries	15,508
Residential	4,359
Industries	9,497
Agriculture	1,189
Transport	15,888
Commercial	3,370
Fugitive Emissions	227
TOTAL	50,038

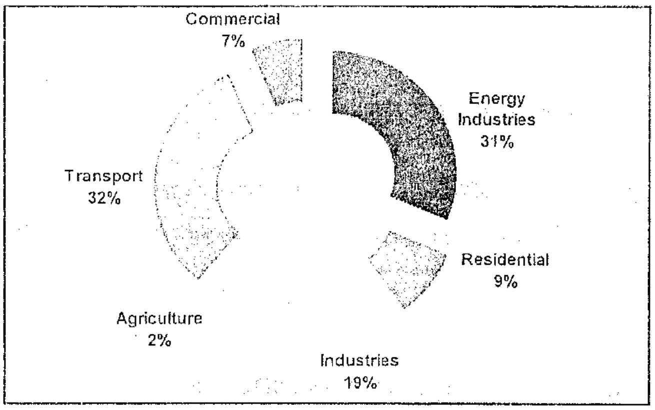
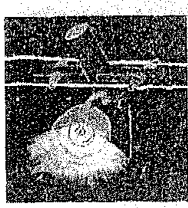


Figure 1-4. 1994 GHG emissions from Energy.

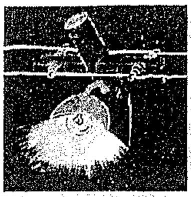


APPENDIX 1A

1994 OVERALL ENERGY BALANCE SHEET

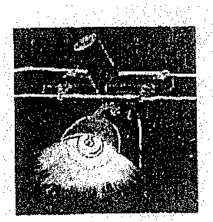
FUELS		PETROLEUM PRODUCTS					
	Coal	Crude	Premium	Regular	Kerosene	Diesel	Fuel Oil
Conversion Factors	0.00048	0.1344	0.1245	0.1223	0.127	0.1347	0.1444
Indigenous Production	695.60	256.38					
Imports (+)	534.35	11,884.58	378.80		83.48	1,976.35	1,069.05
Exports (-)		-176.50	0.00	-23.82			-47.65
Marine Bunkers (-)			0.00			-30.65	-62.00
Stock Change (+/-)	24.64	-149.16	11.45	6.60	5.92	142.54	53.40
PRIMARY ENERGY SUPPLY	1,254.59	11,815.30	390.25	-17.21	89.40	2,088.24	1,012.79
Refinery		-11,780.61	1,069.97	437.06	497.29	3,547.76	4,271.64
Power Generation						0.00	
Fuel Input (-)	-603.35					-1,476.69	-2,660.06
Electricity Gen.(GWh)	0.65					1,259.04	1,094.84
Gas Manufacture							
Transmission/Dist. Loss (-)							
Energy Sector Use & Loss (-)		-438.40					
NET DOMESTIC SUPPLY	651.89	-403.72	1,460.23	419.85	586.70	4,159.30	2,624.37
Statistical Difference	*-135.39*	*-403.72*	*31.19*	*-20.58*	*42.75*	*-37.50*	*386.13*
NET DOMESTIC CONSUMPTION	787.28	0.00	1,429.04	440.43	543.95	4,196.80	2,238.24
Industry	*639.66*				*29.00*	*439.39*	*1,560.84*
Manufacturing							
Beverages					0.00	0.00	0.00
Tobacco					0.00	3.34	13.41
Coco/Vegetable Oil					0.01	9.26	91.35
Sugar	2.87				0.01	35.92	86.58
Other Food Processing					1.25	59.21	254.02
Textile/Apparel					1.21	5.98	146.37
Wood Prod/Furniture					0.03	33.66	12.57
Paper Prod/ Printing					0.05	1.61	171.33
Chemicals Except Fertilizer	8.56				15.65	17.32	61.39
Fertilizer	5.72				0.00	1.48	17.44
Rubber/Rubber Prod					0.13	2.25	27.53
Glass/Glass Products					0.03	10.99	74.86
Cement	614.22				0.01	15.11	226.24
Lube Refining					0.15	83.08	82.69
Other Non-Metallic Minerals					5.23	4.98	18.35
Basic Metal	8.29				3.85	19.40	144.08
Machinery/ Equipment					0.00	0.00	0.00
Mining					0.00	55.65	119.06
Construction					1.38	80.17	13.57
Transport			1,429.04	338.87	2.93	2,997.01	283.82
Railway							
Road Transport			1,429.04	338.34	1.72	2,886.93	5.68
Water Transport				0.54	1.21	110.08	278.13
Air Transport							
Residential				6.08	469.90	15.38	
Commercial				18.46	39.52	437.44	390.02
Agriculture				77.01	2.59	307.58	3.56
Others, Non-Energy Use	147.62						

Department of Energy, 1999



FUELS	PETROLEUM PRODUCTS					
	LPG	AVTurbo	Naphtha	Asphalt	AVGas	Others
Conversion Factors	0.0922	0.127	0.1238	0.1521	0.1224	0.1412
Indigenous Production						
Imports (+)	397.83	30.04			2.89	17.44
Exports (-)			-548.85			
Marine Bunkers (-)		-450.93				-0.17
Stock Change (+/-)	-7.70		8.52	3.22	0.98	16.72
PRIMARY ENERGY SUPPLY	390.14	-420.89	-540.33	3.22	3.87	33.99
Refinery	258.68	552.66	540.25	34.59	0.00	90.25
Power Generation						
Fuel Input (-)		-0.12	-1.75	0.00	0.00	-6.85
Electricity Gen.(GWh)						
Gas Manufacture						
Transmission/Dist. Loss (-)						
Energy Sector Use & Loss (-)						
NET DOMESTIC SUPPLY	648.81	131.65	-1.83	37.81	3.87	117.38
Statistical Difference	*-8.70*	*-50.57*	*-0.08*	*2.33*	*-2.51*	*-72.14*
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Industry	*6.96*		*0.00*			
Manufacturing						
Beverages	0.00				0.00	
Tobacco	0.08				0.00	
Coco/Vegetable Oil	0.00				0.01	
Sugar	0.00				0.00	
Other Food Processing	3.00				0.00	
Textile/Apparel	0.51				0.00	
Wood Prod/Furniture	0.00				0.00	
Paper Prod/ Printing	0.19				0.02	
Chemicals Except Fertilizer	0.01				0.00	
Fertilizer	0.00				0.00	
Rubber/Rubber Prod	0.00				0.00	
Glass/Glass Products	0.00				0.00	
Cement	0.00				0.00	
Lube Refining	0.00				0.00	
Other Non-Metallic Minerals	1.02				0.00	
Basic Metal	2.15				0.00	
Machinery/ Equipment	0.00				0.00	
Mining	0.00				0.01	
Construction	0.00				0.00	
Transport	0.00	182.22	0.00		6.38	
Railway						
Road Transport						
Water Transport						
Air Transport		182.22			6.38	
Residential	419.79					
Commercial	230.76	0.00				
Agriculture						
Others, Non-Energy Use				35.49		189.53

Department of Energy, 1999



FUELS	HYDRO	GEO	ELECTRICITY	BIOMASS FUELS			
	0.086	0.86		Bagasse	Fuelwood	Rice hull	Coconut
Conversion Factors	0.086	0.086	0.086	0.00023	0.00022	0.0003333	0.0004453
Indigenous Production	504.13	543.52		1,495	135	3,495	789
Imports (+)							
Exports (-)							
Marine Bunkers (-)							
Stock Change (+/-)							
PRIMARY ENERGY SUPPLY	**504.13**	**543.52**	**0.00**	**1,495.00**	**134.92**	**3,495.43**	**789.21**
Refinery							
Power Generation							
Fuel Input (-)							
Electricity Gen.(GWh)	504.13	543.52	2,619.47				
Gas Manufacture							
Transmission/Dist. Loss (-)			-407.12				
Energy Sector Use & Loss (-)			-97.35				
NET DOMESTIC SUPPLY	**504.13**	**543.52**	**2,115.00**	**1,495.00**	**134.92**	**3,495.43**	**789.21**
Statistical Difference			*0.00*	*0*	*0*	*0*	*0*
NET DOMESTIC CONSUMPTION			2,115.00				
Industry			918.82				
Manufacturing							
Beverages							
Tobacco							
Coco/Vegetable Oil							
Sugar							
Other Food Processing							
Textile/Apparel							
Wood Prod/Furniture							
Paper Prod/ Printing							
Chemicals Except Fertilizer							
Fertilizer							
Rubber/Rubber Prod							
Glass/Glass Products							
Cement							
Lube Refining							
Other Non-Metallic Minerals							
Basic Metal							
Machinery/ Equipment							
Mining							
Construction							
Transport	**0.00**	**0.00**	65.53				
Railway							
Road Transport							
Water Transport							
Air Transport							
Residential			626.25				
Commercial			504.39				
Agriculture							
Others, Non-Energy Use							

Department of Energy, 1999