MODULE 1
ENERGY

1 ENERGY

1.1 Introduction

This module gives instructions for estimating the emissions of SO_2 and greenhouse gases from energy activities. It is divided into two main categories, fuel combustion and fugitive emissions. Within these categories the divisions are made pragmatically using methodological criteria:

- **Fuel Combustion**

  Tier 1 Methods

  - CO_2 emissions
    Reference Approach
    By main source categories
  - Non-CO_2 from fuel combustion by source categories

  Tier 2 Methods

  - Emissions from aircraft

- **Fugitive**

  - Methane Emissions from Coal Mining and Handling
  - Methane Emissions from Oil and Natural Gas Activities
  - Ozone Precursors and SO_2 from Oil Refining

Estimation of emissions for the activity/source categories used in the following methodologies must be done using the definitions for these categories given in the *Reporting Instructions*, Volume 1. These definitions have been carefully drafted to provide the maximum conformity with other international reporting systems and to minimise the risks of double counting.

FUEL COMBUSTION - TIER 1

1.2 CO_2 Emissions

The calculation of CO_2 emissions from fuel combustion may be done at three different levels referred to as Tiers 1, 2 and 3 in the IPCC Guidelines. Tier 1 methods, described here, concentrate on estimating the emissions from the carbon content of fuels supplied to the country as a whole (the Reference Approach) or to the main fuel combustion activities (source categories). This last method has been recently developed in parallel with its counterpart for estimating non-CO_2 emissions from fuel combustion and responds to the need for emissions figures by sector for monitoring and abatement policy formulation.

1.2.1 Reference Approach

Introduction

Carbon dioxide emissions are produced when carbon-based fuels are burned. National emissions estimates are made based on amounts of fuels used and the carbon content of fuels.

Fuel combustion is widely dispersed throughout most activities in national economies and a complete record of the quantities of each fuel type consumed in each "end use" activity is a considerable task, which some countries have not undertaken. Fortunately, it is possible to obtain an accurate estimate of national CO_2 emissions by accounting for the carbon in fuels supplied to the economy. The supply of fuels is simple to record and the statistics are more likely to be available in many countries.

In accounting for fuels supplied it is important to distinguish between *primary fuels* (i.e. fuels which are found in nature such as coal, crude oil, natural gas), and *secondary fuels* or fuel products, such as gasoline and lubricants, which are derived from primary fuels.

Accounting for carbon is based mainly on the supply of primary fuels and the net quantities of secondary fuels brought into the country.

To calculate supply of fuels to the country you require the following data for each fuel and year chosen:

- the amounts of primary fuels produced (production of secondary fuels is excluded)
- the amounts of primary and secondary fuels imported
- the amounts of primary and secondary fuels exported
- the amounts of fuel used for international marine and aviation bunkers
- the net increases or decreases in stocks of the fuels

For each fuel, the production (where appropriate) and imports are added together and the exports, bunkers, and stock changes are subtracted to calculate the apparent consumption of the fuels.

The manufacture of secondary fuels should be ignored in the main calculation, as the carbon in these fuels has already been accounted for in the supply of primary fuels from which they are derived. However, information on production of some secondary fuel products is required to adjust for carbon stored in these products.

The procedure calculates the supply of primary fuels to the economy with adjustments for net imports (imports - exports), bunkers and stock changes in secondary fuels. It is important to note that, in cases where exports of secondary fuels exceed imports or stock increases exceed net imports, negative numbers will result. This is correct, and should not give rise to concern.

Three other important points influence the accounting methodology:

- *Stored carbon*

  Not all fuel supplied to an economy is burned for heat energy. Some is used as a raw material (or feedstock) for manufacture of products such as plastics or in a non-energy use (e.g. bitumen for road construction), without oxidation (emissions) of the carbon. This is called *stored carbon*, and is deducted from the carbon emissions calculation. Estimation of the stored carbon requires data for fuel use by activities using the fuel as raw material. These requirements are explained later.

- *International Bunker fuels*

  The procedures given for calculating emissions ensure that emissions from the use of fuels for international marine and air transport are excluded from national emissions totals. However, for information purposes, the quantities and types of fuels delivered for international marine and aviation bunkers and the emissions should be separately reported.

- *Biomass fuels*

  Biomass fuels are included in the national energy and CO_2 emissions accounts for information only. Within the energy module biomass consumption is assumed to equal its regrowth. Any departures from this hypothesis are counted within the Land Use Change and Forestry module.

Data Sources

Locally available data should be used wherever possible. Energy data for a large number of countries are also published by the International Energy Agency and the United Nations Statistical Division. See *Reference Manual* Chapter 1, Section 1-2.

In addition to energy data, default emissions factors and other input assumptions are provided in the *Workbook* where available. In calculating national emissions, users of this method are free to override any of these assumptions or recommendations if other information is preferred. **Wherever information is used other than the values recommended in the *Workbook*, this should be noted and documentation should be provided on the sources of the information.**

Methodology

The IPCC methodology breaks the calculation of carbon dioxide emissions from fuel combustion into 6 steps:

Step 1: Estimate Apparent Fuel Consumption in Original Units

Step 2: Convert to a Common Energy Unit

Step 3: Multiply by Emission Factors to Compute the Carbon Content

Step 4: Compute Carbon Stored

Step 5: Correct for Carbon Unoxidised

Step 6: Convert Carbon Oxidised to CO_2 Emissions

Completing the Worksheet

USING THE WORKSHEET

- Copy the Worksheet at the end of this section to complete the inventory.
- Keep the original of the Worksheet blank so you can make further copies if necessary.

Use WORKSHEET 1-1: CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH) and AUXILIARY WORKSHEET 1-1: ESTIMATING CARBON STORED IN PRODUCTS at the end of this module to enter the data for this submodule.

This section provides step-by-step instructions for calculating emissions at the detailed fuels and fuel products level.

Note that the main worksheet allows CO_2 emissions from biomass fuels to be calculated but it does not include them in the national total.

STEP 1 ESTIMATING APPARENT FUEL CONSUMPTION

EXPORT DATA

In some data sources, Exports are shown as a negative number. For this method, all Export data should be entered as positive.

1 Apparent consumption is the basis for calculating the carbon supply to the country. To calculate apparent consumption (or total fuel supplied) for each fuel, enter the following data for primary fuels.

- Production (Column A)
- Imports (Column B)
- Exports (Column C)
- International Bunkers (Column D)
- Stock Change (Column E)

For secondary fuels and products, the only figures to be entered are:

- Imports (Column B)
- Exports (Column C)
- International Bunkers (Column D)
- Stock Change (Column E)

These allow the overall calculation to account for all consumption.

BUNKER FUEL

Where indicated in Worksheet 1-1, (Sheet 1), enter the amount of a particular fuel consumed as international bunker fuel (fuel used in international marine and aviation transportation). The calculation of Apparent Consumption automatically excludes these quantities. Bunker consumption data and related emissions are listed separately in Worksheet 1-1, Sheets 4 and 5, and follow the main steps as in the main Worksheet.

Amounts of all fuels can be expressed in joules (J), megajoules (MJ), gigajoules (GJ), terajoules (TJ), thousands of tonnes of oil equivalent (ktoe). Solid or liquid fuels can be expressed as thousands of tonnes (kt) and dry natural gas can be expressed as teracalories (Tcal) or cubic metres.

Note that the figure for production of natural gas, used in the Worksheet 1-1, must **not** include quantities of gas vented, flared or re-injected into the well.

If you report quantities of fuel expressed in energy units (terajoules, toe, etc.), you should ensure that the quantities have been calculated using the net calorific values (NCV) of the fuels concerned. NCV is sometimes referred to as the lower heating value (LHV). NCVs are approximately 95 per cent of the gross calorific value (GCV) for liquid fossil, solid fossil and biomass fuels, and 90 per cent of the GCV for natural gas. For other fuels, you should determine if the figures have been derived using the net or gross calorific values and make the conversion to NCV if necessary.

2 When you have entered data in Columns A to E, calculate Apparent Consumption for each fuel using this formula:

Apparent Consumption = Production + Imports - Exports - International Bunkers - Stock Change

Enter the result in Column F.

Particular attention should be given to the algebraic sign of "stock change" as it is entered in Column E. When more fuel is added to stock than is taken from it during the year there is a net stock build and the quantity is entered in Column E with a plus sign. In the converse case (a stock draw) the quantity should be entered in Column E with a minus sign. When calculating Apparent Consumption using the above formula the usual algebraic rules for combining signs should be used.

STOCK CHANGE DATA

An increase in stock is a positive stock change and, since it is subtracted, will decrease Apparent Consumption; a stock reduction (use of fuel from existing stocks) is a negative value and will increase Apparent Consumption.

STEP 2 CONVERTING TO A COMMON ENERGY UNIT (TJ)

TABLE 1-1
CONVERSION FACTORS

UNIT	CONVERSION FACTOR
J, MJ or GJ	Divide by the appropriate factor, 10^{12}, 10^{6} or 10^{3} respectively, to convert to TJ.
10^{6} toe units	Multiply by the conversion factor, 41868 TJ/10^{6} toe, to convert to TJ
Tcal units	Multiply by the conversion factor, 4.1868 TJ/Tcal.
10^{3} t	The Net Calorific Value of each fuel should be used. See box entitled "Net Calorific Values".

NOTE: When converting from 10^{3} t, for Anthracite, Coking Coal, other Bituminous Coal, Sub-bituminous Coal and Lignite, separately shown *Country Specific Net Calorific Values* in the *Reference Manual* provide different conversion values for Production (Column A), Imports (Column B), and Exports (Column C). For these fuels, the user should calculate Apparent Consumption by converting Production, Imports, Exports, and Stock Changes to TJ first. For International Bunkers (Column D) and Stock Change (Column E), use either a weighted average net calorific value or select a factor appropriate to the dominant source of supply.

NET CALORIFIC VALUES (NCV)

The calorific value of a fuel is a measure of its value for heating purposes. If NCVs are available for the fuels in your country, they should be used. Default NCVs for oil and coal products for many countries are provided in the *Reference Manual* (Volume 3). If NCVs for your country are not provided, select NCVs for a country that uses fuels similar to those used in your country.

NCVs for Refined Petroleum Products and some other products are shown in *Workbook* Table 1-3.

In all cases, you should report the net calorific values which you have used in Column G. If you use values other than those provided, please include a note explaining the source of the factors.

1 Enter the conversion factor used for each fuel in Column G.

Table 1-3 included here and other tables provided in the *Reference Manual* show net calorific values.

2 Multiply the Apparent Consumption by the relevant Conversion Factor (NCV or scaling factor) to give Apparent Consumption in terajoules. Enter the result in Column H.

TABLE 1-2
CARBON EMISSION FACTORS (CEF)

Fuel	Carbon Emission Factor (t C/TJ)
LIQUID FOSSIL	
Primary fuels	
Crude oil	20.0
Orimulsion	22.0
Natural Gas Liquids	17.2
Secondary fuels/products	
Gasoline	18.9
Jet Kerosene	19.5
Other Kerosene	19.6
Shale Oil	20.0
Gas/Diesel Oil	20.2
Residual Fuel Oil	21.1
LPG	17.2
Ethane	16.8
Naphtha	(20.0) (a)
Bitumen	22.0
Lubricants	(20.0) (a)
Petroleum Coke	27.5
Refinery Feedstocks	(20.0) (a)
Refinery Gas	18.2 (b)
Other Oil	(20.0) (a)
SOLID FOSSIL	
Primary Fuels	
Anthracite	26.8
Coking Coal	25.8
Other Bituminous Coal	25.8
Sub-bituminous Coal	26.2
Lignite	27.6
Oil Shale	29.1
Peat	28.9
Secondary Fuels/Products	
BKB & Patent Fuel	(25.8) (a)
Coke Oven / Gas Coke	29.5
Coke Oven Gas	13.0 (b)
Blast Furnace Gas	66.0 (b)
GASEOUS FOSSIL	
Natural Gas (Dry)	15.3
BIOMASS	
Solid Biomass	29.9
Liquid Biomass	(20.0) (a)
Gas Biomass	(30.6) (a)

(a) This value is a default value until a fuel specific CEF is determined. For Gas biomass, the CEF is based on the assumption that 50% of the carbon in the biomass is converted to methane and 50% is emitted as CO_2. The CO_2 emissions from biogas should not be included in national inventories. If biogas is released and not combusted 50% of the carbon content should be included as methane.
(b) For use in the sectoral calculations.

TABLE 1-3
SELECTED NET CALORIFIC VALUES

	Factors (TJ/10^3 tonnes)
Refined Petroleum Products	
Gasoline	44.80
Jet Kerosene	44.59
Other Kerosene	44.75
Shale Oil	36.00
Gas/Diesel Oil	43.33
Residual Fuel Oil	40.19
LPG	47.31
Ethane	47.49
Naphtha	45.01
Bitumen	40.19
Lubricants	40.19
Petroleum Coke	31.00
Refinery Feedstocks	44.80
Refinery Gas	48.15
Other Oil Products	40.19
Other Products	
Coal Oils and Tars derived from Coking Coals	28.00
Oil Shale	9.40
Orimulsion	27.50

See the *Greenhouse Gas Inventory Reference Manual* for sources.

STEP 3 MULTIPLYING BY CARBON EMISSION FACTORS

1 Enter the Carbon Emission Factor (CEF) which you are using to convert Apparent Consumption into Carbon Content in Column I.

Table 1-2 shows default values which you can use if there are no locally available data.

2 Multiply the Apparent Consumption in TJ (in Column H) by the Carbon Emission Factor (in Column I) to give the Carbon Content in tonnes of C. Enter the result in Column J.

4 Divide Carbon Content in tonnes C by 10^3 to give gigagrams of Carbon. Enter the result in Column K.

5 Calculate subtotals for Liquid, Solid, Gaseous, and Biomass Fuel categories, then add the subtotals for Solid Fossil, Liquid Fossil, and Gaseous Fossil Fuels to give the Total figure (Column K). This is for information purposes only.

STEP 4 CALCULATING CARBON STORED

Data, additional to those needed for calculating Apparent Consumption, are needed for this step (see box). Use AUXILIARY WORKSHEET 1-1: ESTIMATING CARBON STORED IN PRODUCTS.

1 Estimating Fuel Quantities

Bitumen and lubricants

Add Domestic Production for Bitumen and Lubricants to the Apparent Consumption (shown in Column F of the main Worksheet 1-1) for these products and enter the sum in Column A of the Auxiliary Worksheet 1-1.

Coal oils and tars

For coking coal, the default assumption is that 6 per cent of the carbon in coking coal consumed is converted to oils and tars. Multiply the Apparent Consumption for coking coal (from Worksheet 1-1, Column F) by 0.06. If better information on production of coal oils and tars is locally available, this should be used and the source of the data noted. Enter the result in Column A.

Natural gas, LPG, Ethane, Naphtha and Gas/Diesel oil

Estimate the amount of these fuels that is used as a feedstock for non-energy purposes and enter it in Column A.

2 Converting to TJ

Insert the appropriate Conversion Factors in Column B. Multiply Estimated Fuel Quantities (Column A) by the relevant Conversion Factor to give the Estimated Fuel Quantities in TJ. Enter the result in Column C of the Auxiliary Worksheet 1-1.

3 Calculating Carbon Content

Multiply the Estimated Fuel Quantities in TJ (Column C) by the Emission Factor (in tonnes of carbon per terajoule) (Column D) to give the Carbon Content in tonnes C (Column E). Divide the figures by 10^3 to express the amount as gigagrams of carbon. Enter the results in Column F of the Auxiliary Worksheet 1-1.

4 Calculating Actual Carbon Stored

Multiply the Carbon Content (Column F) by the Fraction of Carbon Stored (Column G) to give the Carbon Stored. Enter the result in Column H of the Auxiliary Worksheet 1-1.

When you have completed the Auxiliary Worksheet 1-1

5 Enter values for Carbon Stored for the relevant fuels/products in Column L of the main Worksheet 1-1.

CALCULATING CARBON STORED

To calculate carbon stored, it is necessary to work at a more detailed fuel product level. In order to carry out this calculation, the user will have to provide some additional information. If this information is not available or considered credible, you may choose not to calculate stored carbon. This should be noted in the documentation of the submitted results.

Use the Auxiliary Worksheet 1-1 at the end of this section for your calculations. The majority of stored carbon is accounted for using this list of fuels, but countries are encouraged to report carbon stored for any other fuels for which they have data.

IF YOU DO NOT WISH TO CALCULATE STORED CARBON

Skip Step 4, enter the values from Column K in Column M of Worksheet 1-1, and continue with Step 5.

6 Subtract the values for Carbon Stored (Column L) from Carbon Content (Column K) to give Net Carbon Emissions. Enter the results in Column M.

STEP 5 CORRECTING FOR CARBON UNOXIDISED

1 Enter values for Fraction of Carbon Oxidised in Column N of the Worksheet 1-1. Table 1-4 provides information on typical values measured from coal facilities and suggests global default values for solid, liquid and gaseous fuels. If more specific information is locally available, this should be used and documented.

2 Multiply Net Carbon Emissions (Column M) by Fraction of Carbon Oxidised (Column N) and enter the result in Column O, Actual Carbon Emissions.

STEP 6 CONVERTING TO CO_2 EMISSIONS

1 Multiply Actual Carbon Emissions (Column O) by 44/12 to find Total Carbon Dioxide (CO_2) emitted from fuel combustion. Enter the results in Column P.

2 The sum is total national emissions of carbon dioxide from fuel combustion.

TABLE 1-4
FRACTION OF CARBON OXIDISED

Coal[1]	0.98
Oil and Oil products	0.99
Gas	0.995
Peat for electricity generation[2]	0.99

1 This figure is a global average but varies for different types of coal, and can be as low as 0.91.

2 The fraction for peat used in households may be much lower.

1.2.2 CO_2 Emissions by Source Categories

Introduction

A sectoral breakdown of national CO_2 emissions using the defined IPCC source categories is needed for monitoring and abatement policy discussions. The IPCC Reference Approach provides a rapid estimate of the total CO_2 emissions from fuels supplied to the country but it does not break down the emissions by sector. The development of a Tier 1 method giving non-CO_2 emissions from fuel combustion by sector (Worksheets 1-3 and 1-4) has been extended to CO_2 so that sectoral information can be obtained simply for this gas. However, the simplicity of CO_2 estimation and the special consideration given to CO_2 emissions from biofuels means that the methodology for CO_2 differs in a number of respects from that used for the non-CO_2 gases.

The more detailed calculations used for this approach are essentially similar in content to those used for the Reference Approach.

Completing the Worksheets

Use WORKSHEET 1-2: STEP BY STEP CALCULATIONS, AUXILIARY WORKSHEET 1-2: ESTIMATING CARBON STORED IN PRODUCTS AND WORKSHEET 1-2: OVERVIEW at the end of this module to enter the data for this submodule.

This section provides step-by-step instructions for calculating emissions by fuels and for each of the main source categories. Furthermore, it provides instructions for the compilation of overview sheets.

For each source category a list of the most common fuels consumed is provided in the work sheets. Extra fuels can be added on the blank lines at the bottom of the list and at the end of the Overview sheets, if necessary.

Worksheet 1-2: Step by Step calculations

STEP 1 ESTIMATING SECTORAL FUEL CONSUMPTION

Enter the amount of each fuel consumed by sector in Column A.

If you report quantities of fuel expressed in energy units (terajoules, toe, etc.), you should ensure that the quantities have been calculated using the net calorific values (NCV) of the fuels concerned. NCV is sometimes referred to as the lower heating value (LHV). NCVs are approximately 95 per cent of the gross calorific value (GCV) for liquid fossil, solid fossil and biomass fuels, and 90 per cent of the GCV for natural gas. For other fuels, you should determine if the figures have been derived using the net or gross calorific values and make the conversion to NCV if necessary.

Units

Amounts of all fuels can be expressed in joules (J), megajoules (MJ), gigajoules (GJ), terajoules (TJ), thousands of tonnes of oil equivalent (ktoe). Solid or liquid fuels can be expressed as thousands of tonnes (kt) and dry natural gas can be expressed as teracalories (Tcal) or cubic metres (m^3).

Energy and Transformation Sector

Special care needs to be taken when considering the fuel use of the Energy and Transformation sector so that double counting is avoided.

Fuel use in the Energy and Transformation Sector can be divided into three groups:

Transformation Sector

1. Fuels transformed into secondary fuels by physical or chemical processes not involving combustion (e.g. crude oil to petroleum products in refineries, coal to coke and coke oven gas in coke ovens)
2. Fuels combusted to generate electricity and/or heat (excluding fuels used for autoproduction of electricity and heat, which are reported in the sector where they are used)

Energy Sector

3. Fuels combusted by the energy (energy extraction and transformation) industries for heating, pumping, traction and lighting purposes (e.g. refinery gas for heating distillation columns, use of colliery methane at mines for heating purposes).

In this worksheet only fuel use by Groups 2 and 3 (fuels that are combusted) are reported. However, see Step 4 for the reporting of lubricants used by the energy industries. For emissions resulting from fuel use by Group 1 no worksheets are available. They should be reported under the source/sink category 1B: Fugitive Emissions from Fuels. It is most important that this distinction be appreciated. The quantities of primary fuels reported in Column A will understate the quantities used for Group 1 activities. The reported quantities will cover only the combustion needs of these industries.

STEP 2 CONVERTING TO A COMMON ENERGY UNIT (TJ)

1 Enter the conversion factor to convert to terajoules in Column B.

Workbook Table 1-3 and *Reference Manual* Table 1-2 show conversion factors.

2 Multiply the Consumption by the relevant Conversion Factor (NCV or scaling factor) to give Consumption in terajoules. Enter the result in Column C.

NET CALORIFIC VALUES (NCV)

The calorific value of a fuel is a measure of its value for heating purposes. If NCVs are available for the fuels in your country, they should be used. Default NCVs for oil and coal products for many countries are provided in the *Reference Manual* (Volume 3). If NCVs for your country are not provided, select NCVs for a country that uses fuels similar to those used in your country.

NCVs for Refined Petroleum Products and some other products are shown in *Workbook* Table 1-3.

In all cases, you should report the conversion factors which you have used in Column B. If you use values other than those provided, please include a note explaining the source of the factors.

STEP 3 MULTIPLYING BY CARBON EMISSION FACTORS

1 Enter the Carbon Emission Factor which you are using to convert Consumption into Carbon Content in Column D.

Workbook Table 1-2 shows default values which you can use if there are no locally available data.

2 Multiply the Consumption in TJ (in Column C) by the Carbon Emission Factor (in Column D) to give the Carbon Content in tonnes of Carbon. Enter the result in Column E.

4 Divide Carbon Content in tonnes of Carbon by 10^3 to express as gigagrams of Carbon. Enter the result in Column F.

STEP 4 CALCULATING CARBON STORED

For the calculation of carbon stored, fuels are distinguished into four groups.

- Fuels used as feedstocks, such as naphtha, natural gas, gas/diesel oil, LPG or ethane
- Lubricants
- Bitumen and Coal Tars
- Fuels for which no carbon is stored

IF YOU DO NOT WISH TO CALCULATE STORED CARBON

Skip Step 4, enter the values from Column F of Worksheet 1-2, in Column I and continue with Step 5.

Fuels used as feedstocks, such as naphtha, natural gas, gas/diesel oil, LPG or ethane:

This subsection on feedstocks applies only to the Industry Source Category.

Additional data are needed for this step. Use AUXILIARY WORKSHEET 1-2: ESTIMATING CARBON STORED IN PRODUCTS.

1 **Estimating Fuel Quantities**

Estimate the amount of fuel that is used as a feedstock for non-energy purposes and enter it in Column A of the Auxiliary Worksheet 1-2.

2 **Converting to TJ**

Insert the appropriate Conversion Factors in Column B. Multiply Feedstock Use (Column A) by the relevant Conversion Factor to give

the Feedstock Use in TJ. Enter the result in Column C of the Auxiliary Worksheet 1-2.

3 **Calculating Carbon Content**

Multiply the Feedstock Use in TJ (Column C) by the Emission Factor (in tonnes of carbon per terajoule) (Column D) to give the Carbon Content in tonnes C (Column E). Divide the figures by 10^3 to express the amount as gigagrams of carbon. Enter the results in Column F of the Auxiliary Worksheet 1-2.

4 **Calculating Actual Carbon Stored**

Multiply the Carbon Content (Column F) by the Fraction of Carbon Stored (Column G) to give the Carbon Stored. Enter the result in Column H of the Auxiliary Worksheet 1-2.

When you have completed the Auxiliary Worksheet 1-2

5 Do not fill in Column G of main Worksheet 1-2. Enter the amount of Carbon Stored for the relevant fuel/product in Column H of Worksheet 1-2 for the Industry Source Category, in the cells marked with (b). Fill in any other cells in Column H for products for which you have information on carbon storage.

6 Subtract the amount of Carbon Stored (Column H) from the Carbon Content (Column F) to give Net Carbon Emissions. Enter the results in Column I.

Lubricants:

It has been estimated that during the first use, recycling and final disappearance of lubricants, approximately half of the production is oxidised as CO_2.

1 For each sector where lubricants are used, enter the Fraction of Carbon Stored for lubricants in Column G. If better information is not available use 0.5 as a default value.

2 Multiply the Carbon Content (Column F) by the Fraction of Carbon Stored (Column G) to obtain the amount of Carbon Stored. Enter the result in Column H.

3 Subtract the amount of Carbon Stored (Column H) from the Carbon Content (Column F) to obtain the Net Carbon Emissions. Enter the result in Column I.

Bitumen and Coal Tars:

Bitumen and coal tars are usually not combusted but used in a manner that stores almost all of the carbon. Therefore, in contrast to the IPCC Reference Approach, bitumen and coal tars do not figure in the list of CO_2 emitting fuels. Emissions of NMVOCs from the use of bitumen for road paving are estimated in the Industrial Processes Chapter.

Fuels for which no carbon is stored:

Skip Step 4, enter the values from Column F in Column I, and continue with Step 5.

STEP 5 CORRECTING FOR CARBON UNOXIDISED

1 Enter values for Fraction of Carbon Oxidised in Column J of the Worksheet 1-2. *Workbook* Table 1-4 provides information on typical values measured from coal facilities and suggests global default values for solid, liquid and gaseous fuels. If more specific information is locally available, this should be used and documented.

2 Multiply Net Carbon Emissions (Column I) by Fraction of Carbon Oxidised (Column J) and enter the result in Column K, Actual Carbon Emissions.

STEP 6 CONVERTING TO CO_2 EMISSIONS

1 Multiply Actual Carbon Emissions (Column K) by 44/12 to find Actual Carbon Dioxide (CO_2) Emissions. Enter the results in Column L.

Worksheet 1-2: Overview

1 For each fuel for which you estimated sectoral CO_2 emissions, copy the Fuel Consumption in terajoules (from Column C in Worksheet 1-2: Step By Step Calculations) and the Actual CO_2 emissions (from Column L in Worksheet 1-2: Step By Step Calculations) into the corresponding column and row of Worksheet 1-2: Overview.

2 Calculate the total Fuel Consumption and CO_2 Emissions of Liquid Fossil Fuels by adding horizontally the numbers from Column A: Crude Oil to Column O: Refinery Gas in Worksheet 1-2: Overview. If you supplied any additional Liquid Fossil Fuels to Worksheet 1-2: Overview in any of the Columns AG to AK, add these as well. Enter the result in Column AL.

3 Calculate the total Fuel Consumption and CO_2 Emissions of Solid Fossil Fuels (or from fuels derived from solid fuels) by adding horizontally the numbers from Column P: Anthracite to Column AC: Blast Furnace Gas in Worksheet 1-2: Overview. If you supplied any additional Solid Fossil Fuels to Worksheet 1-2: Overview in any of the Columns AG to AK, add these as well. Enter the result in Column AM.

4 Calculate the total Fuel Consumption and CO_2 Emissions of Gaseous Fossil Fuels by copying the numbers from Column AD: Natural Gas in Worksheet 1-2: Overview. Enter the result in Column AN.

5 Calculate the total Fuel Consumption and CO_2 Emissions of Other Fuels by adding horizontally the numbers from Column AE: Municipal Solid Waste and from Column AF: Industrial Waste in Worksheet 1-2: Overview. Enter the result in Column AO.

6 Calculate the total Fuel Consumption and CO_2 Emissions of Fuels by adding horizontally the numbers from Column AL: Total Liquid Fossil to Column AO: Total Other Fuels in Worksheet 1-2: Overview. Enter the result in Column AP.

7. Calculate the total Fuel Consumption and CO_2 Emissions of Biomass by adding horizontally the numbers from Column AQ: Wood/Wood Waste to Column AU: Gaseous Biomass. Enter the result in Column AV: Total Biomass.

1.3 Non-CO_2 from Fuel Combustion by Source Categories

Introduction

The purpose of a Tier 1 approach is to assist countries that can not access detailed fuel use and technology data in developing emission inventories. Consequently, the Tier 1 approach should enable at least rough emission estimations of CH_4, N_2O, NO_x, CO and NMVOC using energy statistics, and of SO_2 by using additional assumptions on the sulphur content of the fuels.

The Tier 1 methodology for non-CO_2 gases estimates emissions by applying emission factors to fuel statistics which are organised by sector. In reality, emissions of these gases depend on the fuel type used, combustion technology, operating conditions, control technology, and on maintenance and age of the equipment. However, since it is unlikely that many countries will have this detailed data, the Tier 1 methodology ignores these refinements.

Countries wishing to make more detailed emission estimations may use the Tier 2 method described in Section 1.4.2 of the *Reference Manual*. A third option which may be used (Tier 3) is the CORINAIR 94 methodology which is described in the EEA TF Emission Inventory Guidebook and is available on CD-ROM[1].

In the Tier 1 method for non-CO_2 gases, the fuels are aggregated into the following main groups:

- **coal**
- **natural gas**
- **oil**
  - gasoline for transport
  - diesel oil for transport
  - other oil products
- **biomass**
  - wood/wood waste
  - charcoal
  - other biomass and wastes*

Note: Refer to Section 1.2 Common Reporting Framework in the Reporting Instructions for details on which products are included in each of the main groups.

* *Includes dung, agricultural, municipal and industrial wastes, bagasse and agricultural residues.*

Data sources

Locally available data should be used wherever possible. Energy data for a large number of countries are published by the International Energy Agency and the United Nations Statistical Division. See Section 1.2 of the *Reference Manual*. However, users of international statistics should bear in mind that the recent changes to the definitions of the manufacturing sector and energy transformation sector mean that the figures given within the international compendia no longer correspond to the activities covered in these sectors according to the IPCC and CORINAIR definitions. See *Reference Manual* Section 1.1.1.

Section 1.4.2 provides average non-CO_2 emission factors for the agreed IPCC source categories together with additional information on the range of these factors and their use. The proposed values are based on emission factors included in Radian Corporation (1990), US EPA (1995), the EDGAR database[2], the CORINAIR 1990 database and scientific reports from

[1] The CD-ROM may be obtained by contacting the European Environment Agency, Kongens Nytorv 6, 1050 Copenhagen, Denmark.

[2] EDGAR Version 2.0 was developed by TNO and RIVM and is a set of global emission inventories of greenhouse gases and ozone-depleting substances for all anthropogenic and most natural sources on a per country basis and on 1° x 1° grid (Olivier et al., 1995).

different countries. SO_2 emission factors are estimated using a formula based on sulphur content in the fuel. The compilation of default factors for biomass fuels in the "Other Sectors" has been based on measurement data reported by Smith and Ramakrishna (1990), Berdowski et al. (1993), Delmas (1993), Smith et al. (1993), Delmas et al. (1995), Veldt and Berdowski (1995) and Brocard et al. (1996). For aircraft, the emission factors for the Tier 1 approach are based on the fleet average values of NO_X, CO and NMVOC of the global inventories compiled by NASA, ECAC/ANCAT, WSL and NLR [Wuebbles et al. (1993); Olivier (1995); Brok (1995)].

The default emission factors are internally consistent and it is essential to preserve this consistency when replacing the default by local values so that total emissions of carbon (for example) do not exceed the carbon available in the fuel.

When information is used that differs from values recommended in the *Workbook/Reference Manual*, this should be noted and documentation should be provided on the sources of the information.

1.3.1 Methodology for CH_4, N_2O, NO_X, CO, NMVOC

The calculation of non-CO_2 Greenhouse gases (CH_4, N_2O, NO_x, CO, NMVOC) is broken into 3 steps:

Step 1: Estimate annual fuel consumption per sector in energy units

Step 2: Estimate emission factors for each fuel per sector

Step 3: Estimate the emissions

Repeat Steps 2 and 3 for each gas (CH_4, N_2O, NO_x, CO and NMVOC).

Completing the Worksheet

Use WORKSHEET 1-3: NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1) to enter the data for CH_4, N_2O, NO_x, CO and NMVOC.

STEP 1 ESTIMATE ANNUAL FUEL CONSUMPTION PER SECTOR IN ENERGY UNITS

1 Enter the fuel consumption (in TJ) in Columns A_1 to A_6. All fuels combusted in the country should be included in the calculation. As far as possible, the fuels used for international aviation bunkers and international marine bunkers are to be reported separately as memo items.

In national statistics, annual consumption of fuels can be expressed in energy units or mass units. Gaseous fuels may be expressed in volume units. The fuel consumption should be converted to energy units using the net calorific value (or lower heating value). These

conversions are described in Section 1.2.1 Reference Approach in the *Workbook*.

It is highly recommended that fuel consumption be split by main activities (see box) because emissions of non-CO_2 GHGs vary strongly with combustion technology and operating conditions.

2 Calculate total fuel consumption for each fuel by summing the sectors in Column A. International bunkers should not be included in the totals.

ENERGY INDUSTRIES

Manufacturing Industries and Construction

- **Transport**
  - Domestic Aviation
  - Road
  - Railways
  - National Navigation
- **Other Sectors**
  - Commercial/Institutional
  - Residential
  - Agriculture/ Forestry/ Fishing
    - *Stationary*
    - *Mobile*

STEP 2 ESTIMATE EMISSION FACTORS FOR EACH FUEL PER SECTOR

Photocopy the worksheet with Step 2 five times and fill it out for each of the gases (CH_4, N_2O, NO_x, CO and NMVOC).

1 Enter the emission factors (in kg/TJ) for each fuel and activity in the Columns B_1 to B_6. Default values have been provided in Section 1.4.2 of the *Reference Manual*.

The default values for international bunkers are the emission factors that are proposed for Aviation and Navigation. For activities in "Other (not elsewhere specified)", use emission factors according to the type of activity.

STEP 3 ESTIMATE THE EMISSIONS FOR EACH GAS

Photocopy the worksheet with Step 3 five times and fill it out for each of the gases (CH_4, N_2O, NO_x, CO and NMVOC).

1 Multiply fuel consumption (Column A, Sheet 1) by the emission factors (Column B, Sheet 2). Enter the results in Column C, Sheet 3. The calculation is $C_i = A_i \times B_i$.

2 Calculate total emissions for each fuel by summing the sectors in Column C. Emissions from international bunkers should not be included in the totals.

3 Calculate the total emissions (Column D) as the sum of Columns C_1 to C_6.

1.3.2 Methodology for SO_2

SO_2 emissions are related to the composition of fuels, not to combustion technologies. The IPCC Tier 1 methodology proposes to split the fuels according to the sulphur content of the fuels and breaks the calculation down into 3 steps:

Step 1: Estimate annual fuel consumption in energy units

Step 2: Estimate the SO_2 emission factors

Step 3: Estimate the emissions

This method can be applied once for total fuel consumption or can be repeated for each sector. Photocopy the sheets as many times as there are sectors to be calculated. If the calculations are done by sector, care must be taken to account for all national fuel consumption.

Completing the Worksheet

Use WORKSHEET 1-4: SO_2 EMISSIONS FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1) to enter the data for SO_2.

STEP 1 ESTIMATE ANNUAL FUEL CONSUMPTION IN ENERGY UNITS

1 Enter the fuel consumption by fuel type (in TJ) in Column A. All fuels combusted in the country should be included in the calculation. The fuels used for international aviation bunkers and international marine bunkers are to be reported separately as memo items.

2 Calculate total fuel consumption by summing the fuel types in Column A. International bunkers should not be included in the totals.

STEP 2 ESTIMATE THE SO_2 EMISSION FACTORS

Default values for the following items are available in Section 1.4.2.6 of the *Reference Manual*.

1 Estimate the sulphur content of each fuel (expressed as a percentage for all fuels except natural gas) in Column B. The sulphur content of natural gas should be expressed in g/m^3 and not in per cent.

2 Estimate the sulphur retention in ash (in %) in Column C.

3 Estimate the abatement efficiency (in %) in Column D.

4 Estimate the net calorific value (expressed in TJ/kt for all fuels except natural gas) in Column E. The net calorific value of natural gas should be expressed in kJ/m3.

5 For all fuels except natural gas, calculate the SO_2 emission factor as: 2 times [% sulphur content (Column B) / 100] times [1 / net calorific value (Column E)] times 10^6 times [[100 - % sulphur retention in ash (Column C)] / 100] times [[100 - % abatement efficiency (Column D)] / 100]. Enter the results in Column F.

Since the sulphur content of natural gas is expressed in g/m^3 and not in per cent, calculate the SO_2 emission factor as: 2 times % sulphur content (Column B) times [1 / net calorific value (Column E)] times 10^6 times [[100 - % sulphur retention in ash (Column C)] / 100] times [[100 - % abatement efficiency (Column D)] / 100].

STEP 3 ESTIMATE THE EMISSIONS

1 For each fuel, multiply the fuel consumption (Column A) by the calculated SO_2 emission factor (Column F). Enter the results in Column G.

2 Calculate the total emissions by summing the fuel types in Column G. Emissions from international bunkers should not be included in the totals.

FUEL COMBUSTION - TIER 2

1.4 Emissions from Aircraft

Introduction

Emissions from aircraft come from jet kerosene and aviation gasoline which are used as fuel for the aircraft. Non-CO_2 emissions vary significantly with operating mode and engine design. Reliable estimates of non-CO_2 gases from aircraft require a detailed consideration of the characteristics of the fleet, type and amount of fuel consumed and the Time-in-Modes (or TIM) of specific aircraft fleet using national airports.

This Tier 2 methodology is applicable only for jet fuel used in jet engines. Aviation gasoline is used only in very small aircraft and generally represents less than 1 per cent of fuel consumption for aviation.

For the purposes of the emissions inventory a distinction is made between domestic and international flights.

- *Domestic aviation* (1 A 3 a ii) includes all civil domestic passenger and freight traffic inside a country. All flight stages between two airports in one country are considered domestic no matter the nationality of the carrier or the subsequent destination of the aircraft.[3]
- *International aviation* (1 A 3 a i) includes all civil air traffic coming to or leaving a country. It is assumed that the number of out-bound flights equals the number of in-bound flights.
- *LTOs* take the classification (domestic or international) of the flight stage to which they belong. As most flights are regarded as return flights, fuel used during landing and take-off will be regarded as equal to a take-off and landing.

[3] If an aircraft goes from one airport in one country to another in the same country and then leaves for a third airport in another country, the first flight stage is considered a domestic trip while the second is considered an international trip. It is not important whether the airport is a domestic or an international airport. In addition, the type of activity (LTO, cruise, domestic, international) is independent of the nationality of the carrier. This treatment of domestic and international differs from that recommended to States by the International Civil Aviation Organisation (ICAO,1994). ICAO defines as domestic all flight stages flown between domestic points by an airline registered in that State and therefore excludes flights between domestic points by foreign airlines.

Operations of aircraft are divided into two parts:

- *The Landing/Take-Off (LTO) cycle*[4] which includes all activities near the airport that take place under the altitude of 914 metres (3000 feet). This includes taxi-in and out, climbing and descending.
- *Cruise* is defined as all activities that take place at altitudes above 914 metres (3000 feet). No upper limit is given.

Data sources

Locally available data should be used whenever possible. The fuel consumption and LTO information can be obtained from the national airports. Total number of aircraft per type and engines types can be obtained from the airline companies. Some emission factors are in the *Reference Manual* tables. At the Tier 2 level, emission factors are based on the specific national aircraft fleet and typical airport TIM (ICAO Engine Exhaust Emissions Databank, International Civil Aviation Organization). Another possibility is US EPA (1985): *Compilation of air pollutant emission factors,* Vol. II: Mobile sources, 4th edition, or US Office of Environment and Energy (1991) *FAA Aircraft Emission Database User's Manual.*

Methodology

To use the Tier 2 method, the aircraft types used for both domestic and international flights, as well as the number of LTO's carried out by the various aircraft types, must be known. If this information on a per aircraft type basis is not available, it is recommended that the Tier 1 method be used.

The Tier 2 Approach breaks the calculation of emissions from aviation into 4 steps:

Step 1: Estimate the total fuel consumption for domestic and international aviation

Step 2: Estimate the fuel consumption for LTO activities by aircraft type

Step 3: Estimate the fuel consumption for cruise activities by aircraft type

Step 4: Estimate the emissions for each gas

Completing the Worksheet

Use WORKSHEET 1-5: EMISSIONS FROM AIRCRAFT (TIER 2) to enter the data for this submodule.

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[4] Some statistics count either a landing or a take-off as one operation. **However it is *both* one take-off and one landing, that together define one LTO-operation.**

STEP 1 ESTIMATE THE FUEL CONSUMPTION FOR DOMESTIC AND INTERNATIONAL AVIATION

1 Enter the total amount of fuel sold for all flights (in kt) in Column A.

2 Enter the total amount of fuel sold for domestic flights (in kt) in Column B.

3 Calculate the total amount of fuel sold for international flights by subtracting the total amount of fuel sold for domestic flights (Column B) from the total fuel sold (Column A) and enter in Column C.

STEP 2 ESTIMATE THE FUEL CONSUMPTION FOR LTO CYCLES BY AIRCRAFT TYPE

Do the following calculations for domestic aviation and international aviation separately.

1 Enter the total number of LTO's carried out per aircraft type ($a_1..a_n$) and ($b_1..b_n$) in Column D.

2 Enter the appropriate fuel consumption per LTO (in t/LTO) in Column E (see *Reference Manual*, Section 1.5.3.5 for default values).

3 Calculate the fuel consumption for LTO activity per aircraft type ($a_1..a_n$) and ($b_1..b_n$) in tonnes by multiplying the fuel use per LTO (Column E) by the number of LTO's carried out for that specific aircraft type (Column D) and enter the results in Column F.

4 Calculate the total fuel use for LTO activities by summing the results of the individual aircraft type in Column F and enter the results in the $Total_a$ and $Total_b$ rows of Column F.

STEP 3 ESTIMATE THE FUEL CONSUMPTION FOR CRUISE ACTIVITIES BY AIRCRAFT TYPE

Do the following calculations for domestic aviation and international aviation separately.[5]

1 Enter the total amount of fuel sold for domestic flights in tonnes (Column B multiplied by 1000) and the total amount of fuel sold for international aviation in tonnes (Column C multiplied by 1000) in Column G.

---

[5] This method assumes that the share in fuel consumption in the cruise mode by a type of aircraft will by and large be proportional to the number of LTO cycles of that type of aircraft. It is recognised that by using this method the contribution from larger aircraft may be underestimated. However, this simplifying assumption has been made in order to minimise the amount of aircraft specific data required for the Tier 2 method.

2 Calculate the total fuel consumption for *cruise* by subtracting the total amount of fuel for LTO activities (total from Column F) from the total fuel sold (Column G) and enter the results in Column H.

3 Calculate the fuel consumption for *cruise activities* for each aircraft type as: total fuel used for cruise activities (total in Column H) x (number of LTO's carried out by aircraft type (Column D) / total number of LTO's (total in Column D)) and enter in Column I.

STEP 4 ESTIMATE THE EMISSIONS FOR EACH GAS

Photocopy Sheet 3 seven times and do the following calculations for each gas (CO_2, CH_4, N_2O, NO_x, CO, NMVOC and SO_2). The calculations for domestic aviation and international aviation should be done separately.

1 Enter the emission factors per LTO for each aircraft type (in kg/LTO) in Column J. Default emission factors are available in Section 1.5.3.5 in the *Reference Manual*.

2 Calculate the emissions from LTO's for each aircraft type (in tonnes) by multiplying the total number of LTO's per aircraft type (Column D) by the emission factors per LTO (Column J) and then dividing by 1000. Enter the results in Column K.

3 Enter the emission factors per fuel consumption for cruise activities for various engine types (in kg/t) in Column L. Default emission factors are available in the *Reference Manual*, Section 1.5.3.5.

4 Calculate the emissions from cruise activities for each aircraft type (in tonnes) by multiplying the fuel used for cruise activities (Column I) by the emission factors per fuel consumption for cruise activities (Column L) and then dividing by 1000. Enter the results in Column M.

5 Calculate the total emissions by type of aircraft (in Gigagrams) by adding the emissions from LTO activities (Column K) and the emissions from cruise activities (Column M) and dividing by 1000. Enter the results in Column N.

6 Calculate total emissions from aircraft by summing the results of the individual aircraft type in Column N and enter the results in the $Total_a$ and $Total_b$ rows of Column N.

FUGITIVE SOURCES

1.5 Methane Emissions from Coal Mining and Handling

Introduction

The process of coal formation, commonly called coalification, inherently generates methane and other by-products. The degree of coalification (defined by the rank of the coal) determines the quantity of methane generated and, once generated, the amount of methane stored in coal is controlled by the pressure and temperature of the coal seam and by other, less well-defined characteristics of the coal. The methane will remain stored in the coal until the pressure on the coal is reduced, which can occur through the erosion of overlying strata or the process of coal mining. Once the methane has been released, it flows through the coal toward a region of lower pressure (such as a coal mine) and into the atmosphere.

The amount of CH_4 generated during coal mining is primarily a function of coal rank and depth, as well as other factors such as moisture. If two coal seams have the same rank, the deeper seam will hold larger amounts of CH_4 because the pressure is greater at lower depths, all other things being equal. As a result, most methane released to the atmosphere from coal mining is assumed to come from underground rather than surface mining. As a result, the methane emission factors for surface-mined coal are assumed to be lower than for underground mining.

Methane is also emitted from post-mining activities such as coal processing, transportation, and utilisation. Methane is released mainly because the increased surface area allows more CH_4 to desorb from the coal. Transportation of the coal contributes to CH_4 emissions, because CH_4 desorbs directly from the coal to the atmosphere while in transit (e.g., in railroad cars). Coal may also release methane during its preparation for final use. For instance, in steel production coal is crushed to a particle size of less than 5 mm, vastly increasing the surface area of the coal and allowing more CH_4 to desorb.

Data Sources

The basic data necessary to perform these calculations are, at a minimum, quantity of coal mined by type of mine (underground or surface). Use locally available data where these are reliable.

Country statistics on underground and surface coal production are available from the OECD/IEA (for certain OECD Member countries). Data on coal production by type (hard coal and lignite) are also available for most countries in the world.

Methodology

On the advice of an expert group (see the Section 1.7 in the *Reference Manual*), calculations have been organised around a single formula which relates tonnes of coal production to total CH_4 emissions from *mining* and *post-mining* activities.

The *Workbook* enables the user to operate at several different levels of detail or "tiers" (discussed in more detail in the *Reference Manual*).

Tier 1 is the least accurate and is based upon global average emission factors.

Tier 2 is possible when a country has enough information to develop average emission factors of its own. More detailed calculations can be accommodated by making extra copies of the worksheet and breaking the calculations into sub-national components for which more specific emissions factors may be available.

Tier 3 is based on mine-specific measurement of emissions from mine ventilation and degasification. This method is recommended if data are available as it should provide much more accurate country-based estimates.

The equation for calculating CH_4 emissions from mining activities is:

CH_4 Emissions	**=**	**Coal Production**	**x**	**Emission Factor**	**x**	**Conversion Factor**
(Gg)		**(10^6 t)**		**(m^3 CH_4 / tonne coal)**		**(Gg CH_4 / 10^6 m^3 CH_4)**

ALTERNATIVE LEVELS OF DETAIL - TIERS

The information provided in this *Workbook*, including global default emission factors, allows for calculation at the *Tier 1* level. *Tier 2* calculations follow the same structure, but would use country or basin-specific emission factors if available locally. If a country is capable of *Tier 3* estimates this would indicate that the emissions estimates are already available (having been directly measured) and the *Workbook* methodology for calculating emissions is not needed. Countries with *Tier 3* estimates can move directly to the *Reporting Instructions* volume of these *Guidelines* for guidance on reporting and documenting emissions estimates.

The highest tier of estimation methodology possible should be used for each component of mining activity. It is acceptable to provide estimates using different tiers for various components, provided that the level of calculation is clearly identified in each component. For example, even if *Tier 3* is used to estimate underground emissions, *Tier 1* or *2* can be used to estimate emissions from other components of mining activity.

Completing the Worksheet

Use WORKSHEET 1-6: METHANE EMISSIONS FROM COAL MINING AND HANDLING to enter your data for this submodule.

STEP 1 ESTIMATING METHANE EMISSIONS FROM COAL MINING AND HANDLING

1 Enter the amount of coal produced by each type of mining activity, in millions of tonnes, in Column A.

The total amount of coal should be consistent with that used in the CO_2 from Energy submodule (Worksheet 1-1, Sheet 1, Column A).

2 Select an Emission Factor using Table 1-5 below. Do this for each type of mining activity involved in your inventory. Select a point within the possible range of values which is appropriate to your country. If you do not have the information to select a point, use an average value. Enter the value in Column B.

USING THE WORKSHEET

- Copy the worksheet at the end of this section to complete the inventory.
- Keep the original of the worksheet blank so you can make further copies if necessary

TABLE 1-5
HIGH AND LOW EMISSION FACTORS FOR MINING ACTIVITIES (M^3/TONNE)

	Type of Mine/Activity	
Emission Factor	*Underground*	*Surface*
Mining	10 - 25	0.3 - 2.0
Post-mining	0.9 - 4.0	0 - 0.2

Source: Compiled from various country studies as summarised in Reference Manual

3 Multiply the Amount of Coal Produced (Column A) by the Emission Factor (Column B) to give Methane Emissions (in millions of cubic metres) for each type of mining activity. Enter the result in Column C.

STEP 2 CONVERTING METHANE EMISSIONS IN M^3 TO METHANE EMISSIONS IN GIGAGRAMS

1 Enter a Conversion Factor in Column D.

The conversion factor converts volume of CH_4 to a weight measure (gigagrams) using the density of methane at 20^oC and at a pressure of 1 atmosphere. This conversion factor, expressed in a form suitable for this *Workbook*, is 0.67 $Gg/10^6$ m^3.

2 Multiply the Methane Emissions in millions of m^3 by the Conversion Factor to give the Methane Emissions in gigagrams. Enter the result in Column E. Sum the figures and enter the total in the Total box at the bottom of the column.

1.6 Methane Emissions from Oil and Natural Gas Activities

Introduction

Fugitive emissions of methane from oil and gas activities probably account for about 30 to 70 teragrams per year of global methane emissions. The category includes all emissions from the production, processing, transport and use of oil and natural gas, and from non-productive combustion. It excludes use of oil and gas or derived fuel products to provide energy for internal use, in energy production processing and transport. The latter are considered fuel combustion and treated in an earlier section of this chapter. Fugitive emissions do include, however, emissions which result from the combustion of natural gas during flaring operations. Sources of emissions within oil and gas systems include:

- emissions during normal operation, such as emissions associated with venting and flaring during oil and gas production, chronic leaks or discharges from process vents;
- emissions during repair and maintenance, ; and
- emissions during system upsets and accidents.

To calculate methane emissions from oil and gas activities in your country, you require the following energy data:

Oil	**Gas**
Number of wells drilled	Quantity of gas produced
Quantity of oil produced	Quantity of gas consumed
Quantity of oil refined	

In addition, emission factors will be required as discussed below.

Data sources

Locally available data should be used wherever possible. Energy data for a large number of countries are also published by the International Energy Agency and the United Nations Statistical Division. See *Reference Manual* Sections 1.8.2 and 1.8.3.

In addition to energy data, default emissions factors and other input assumptions, are provided in the *Workbook* methodology where available. In calculating national emissions, users of this method are free to override any of these assumptions or recommendations if other information is preferred. Wherever information is used other than the values recommended in the *Workbook*, this should be noted and documentation should be provided on the sources of the information.

Users should ensure that data used in this section are consistent with those entered in the *CO_2 from Energy* calculations. Countries which have significant emissions from oil and natural gas should consult the discussion in the *Reference*

Manual and look for locally available data which will allow the development of more country-specific factors.

Methodology

Three different *tiers* or levels of detail for calculating these emissions are presented in the *Reference Manual*.

- Tier 1 Production-Based Average Emission Factors Approach
- Tier 2 Mass Balance Approach
- Tier 3 Rigorous Source-Specific Approach

Only Tier 1 is presented in this *Workbook*.

This requires assembling activity data (production etc.) for the country, selecting emission factors based on information in the tables of typical regional values (or from locally available data), and multiplying through to produce emissions estimates by major subcategory. Explanations of the regions used are provided below.

Regional Definitions

Regions have been defined recognising the limitations in data on emissions factors and activity levels, and key differences in oil and gas activities throughout the world. The following five regions have been chosen:

- **USA and Canada**:
- **Former USSR and Eastern Europe**: This region includes the former USSR (which is by far the largest oil and gas producer in the region), Albania, Bulgaria, Czech & Slovak Republics, Hungary, Poland, Romania, and the former Yugoslav republics.
- **Western Europe**: This region includes: Austria, Belgium, Denmark, Faroe Islands, Finland, France, Germany, Gibraltar, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom.
- **Other Oil Exporting Countries**: This region includes the world's other major oil producing countries: the 11 OPEC members (Algeria, Libya, Nigeria, Venezuela, Indonesia, Iran, Iraq, Kuwait, Qatar, Saudi Arabia and the United Arab Emirates) Gabon, Ecuador and Mexico.
- **Rest of the World**: This region includes the remaining countries of Asia, Africa, Middle East, Oceania and Latin America.

Completing the Worksheet

Use WORKSHEET 1-7: METHANE EMISSIONS FROM OIL AND GAS ACTIVITIES (TIER 1) to enter your data for this submodule.

ESTIMATING THE AMOUNT OF METHANE EMITTED BY OIL AND GAS ACTIVITIES

1 Enter data for each type of oil and gas production activity in Column A.

Data sources are discussed above. Ensure that the data you use are consistent with the activity data used to calculate CO_2 from Energy Sources in the first submodule of this module.

2 For each type of activity enter an Emission Factor in Column B.

Use locally available data or the data in Table 1-6 below. Note that these tables provide a range of values to account for the uncertainty implicit in this method. You should use your judgement to select a single value from this range. You are also encouraged to provide an estimate of uncertainty with the values (see the *Greenhouse Gas Inventory Reporting Instructions*).

3 Multiply the amounts of oil and gas for each Activity (Column A) by the Emission Factor (Column B) to give the amount of CH_4 emitted in kilograms CH_4. Enter the results in kilograms in Column C.

4 Divide the emissions of CH_4 in kilograms (Column C) by 10^6 to convert to gigagrams. Enter the results, in gigagrams CH_4, in Column D and complete the "total" boxes.

EXPLORATION AND DRILLING

A category of exploration and drilling is included on the worksheet. However, no sources of activity data or default emissions are provided. If you have locally available data for these values, enter this. If you are working from default sources you should ignore this category which is only expected to be a small component of emissions.

TABLE 1-6
REVISED REGIONAL EMISSION FACTORS FOR METHANE FROM OIL AND GAS ACTIVITIES SYSTEMS (kg/PJ)

Source Type	Basis	Western Europe	USA & Canada	Former USSR, Central & Eastern Europe	Other Oil Exporting Countries	Rest of the World
OIL & GAS PRODUCTION						
Fugitive and Other Routine Maintenance Emissions from Oil Production	Oil Produced	300 - 5 000	300 - 5 000	300 - 5 000	300 - 5 000	300 - 5 000
Fugitive and Other Routine Maintenance Emissions from Gas Production	Gas Produced	15 000 - 27 000	46 000 - 84 000	140 000 - 314 000	46 000 - 96 000	46 000 - 96 000
Venting & Flaring from Oil and Gas Production	Oil & Gas Produced[a]	-	3 000 - 14 000	-	-	-
	Oil Produced	1 000 - 3 000	-	-	-	-
	Gas Produced	-	-	6 000 - 30 000	758 000 - 1 046 000	175 000 - 209 000
CRUDE OIL TRANSPORTATION, STORAGE AND REFINING						
Transportation	Oil Tankered	745	745	745	745	745
Refining	Oil Refined	90 - 1 400	90 - 1 400	90 - 1 400	90 - 1 400	90 - 1 400
Storage Tanks	Oil Refined	20 - 250	20 - 250	20 - 250	20 - 250	20 - 250
NATURAL GAS PROCESSING, TRANSPORT AND DISTRIBUTION						
Emissions from Processing, Transmission and Distribution	Gas Produced	-	-	288 000 - 628 000	288 000 (high)[b]	288 000 (high) [b]
	Gas Consumed	72 000 - 133 000	57 000 - 118 000	-	118 000 (low) [c]	118 000 (low) [c]
Leakage at industrial plants and power stations	Non-residential Gas Consumed[d]	-	-	175 000 - 384 000	0 - 175 000	0 - 175 000
Leakage in the residential and commercial sectors	Residential Gas Consumed[e]	-	-	87 000 - 192 000	0 - 87 000	0 - 87 000

(a) In the United States and Canada, the emissions are based on total production of both oil and gas produced.

(b) The emission factor of 288 000 kg/PJ of gas produced is used only for the high emissions estimate.

(c) The emission factor of 118 000 kg/PJ of gas consumed is used only for the low emissions estimate.

(d) Gas consumption by utilities and industries.

(e) Gas consumption by the residential and commercial sectors.

Source: Constructed from the literature summarised in the *Reference Manual*

1.7 Ozone Precursors and SO_2 Emissions from Oil Refining

Introduction

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.

Data Sources

Data on crude oil throughput, required for the simplified Tier 1 approach, is usually readily available from national sources or international compendia of energy statistics. The Tier 2 methods require data on internal refinery operations which can be obtained only locally either through a national industry association including refiners or by direct contact with the refiners. These contacts also provide the opportunity to obtain local emission factors for use in place of the default factors provided below.

Completing the Worksheet

Use WORKSHEET 1-8 OZONE PRECURSORS AND SO_2 EMISSIONS FROM OIL REFINING to enter your data for this submodule.

ESTIMATING EMISSIONS OF CO, NO_x, NMVOC AND SO_2

Tier 1 - Using Crude Oil Throughput

A simple estimation method uses average default emission factors for all four pollutants based on the crude oil throughput of the refineries. Local emission factors should be used wherever possible as values, particularly for NMVOCs, can vary widely.

Using Worksheet 1-8, Sheet 1

1 Enter the crude oil throughput of the refinery(ies) in Column A expressed in 1000 tonnes.

2 In Column C, overwrite the default emission factors with local values if available.

3 Multiply, in turn, the figure in Column A by each of the emission factors entered in Column C and place the results in the corresponding rows of Column D.

4 Divide the figures in Column D by 1000 to convert to gigagrams and place the results in Column E.

Tier 2 Methods

Separate methods for the estimation of the four pollutants from catalytic cracking, SO_2 from desulphurisation and NMVOCs from oil storage are presented below.

The discussion in Section 1.8.9 of the *Reference Manual* makes clear that the default emission factors for SO_2 and NO_x are subject to wide ranges. Efforts should be made to use local values for these pollutants and for NMVOCs.

ESTIMATING EMISSIONS OF OZONE PRECURSORS AND SO_2 FROM CATALYTIC CRACKING

Using Worksheet 1-8, Sheet 2

1 Enter the oil throughput of the catalytic cracker units in Column A expressed in 1000 tonnes.

2 In Column C, overwrite the default emission factors with local values if available.

3 Multiply, in turn, the figure in Column A by each of the emission factors entered in Column C and place the results in the corresponding rows of Column D.

4 Divide the figures in Column D by 1000 to convert to gigagrams and place the results in Column E.

ESTIMATING EMISSIONS OF SO_2 FROM DESULPHURISATION

Using Worksheet 1-8, Sheet 3

1 Enter the quantity of sulphur recovered in tonnes in Column A.

2 Multiply this figure by 139 (the default emission factor in kg/t) and place the result in Column C.

3 Divide the figure in kg in Column C by 10^6 to convert to gigagrams and put the result in Column D.

ESTIMATING EMISSIONS OF NMVOCS FROM OIL STORAGE

Using Worksheet 1-8, Sheet 4

1 For each refinery in the country, identify the major storage type. Sum the crude oil throughputs for each storage type and enter the result in Column A expressed in 1000 tonnes.

2 Multiply the emission factor by the crude oil throughput in Column A and place the result in the appropriate row in Column D.

3 Divide the figure in Column D by 1000 and put the result in gigagrams in Column E.

MODULE	ENERGY
SUBMODULE	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)
WORKSHEET	1-1
SHEET	1 OF 5

			STEP 1					
			A Production	B Imports	C Exports	D International Bunkers	E Stock Change	F Apparent Consumption
FUEL TYPES								F=(A+B -C-D-E)
Liquid Fossil	Primary Fuels	Crude Oil						
		Orimulsion						
		Natural Gas Liquids						
	Secondary Fuels	Gasoline						
		Jet Kerosene						
		Other Kerosene						
		Shale Oil						
		Gas / Diesel Oil						
		Residual Fuel Oil						
		LPG						
		Ethane						
		Naphtha						
		Bitumen						
		Lubricants						
		Petroleum Coke						
		Refinery Feedstocks						
		Other Oil						
Liquid Fossil Totals								
Solid Fossil	Primary Fuels	Anthracite[(a)]						
		Coking Coal						
		Other Bit. Coal						
		Sub-bit. Coal						
		Lignite						
		Oil Shale						
		Peat						
	Secondary Fuels	BKB & Patent Fuel						
		Coke Oven/Gas Coke						
Solid Fossil Totals								
Gaseous Fossil		Natural Gas (Dry)						
Total								
Biomass Total								
		Solid biomass						
		Liquid biomass						
		Gas biomass						

(a) If anthracite is not separately available, include with Other Bituminous Coal.

MODULE	ENERGY
SUBMODULE	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)
WORKSHEET	1-1
SHEET	2 OF 5

			STEP 2		STEP 3		
			G[a] Conversion Factor (TJ/Unit)	H Apparent Consumption (TJ)	I Carbon Emission Factor (t C/TJ)	J Carbon Content (t C)	K Carbon Content (Gg C)
FUEL TYPES				H=(FxG)		J=(HxI)	K=(Jx10^{-3})
Liquid Fossil	Primary Fuels	Crude Oil					
		Orimulsion					
		Natural Gas Liquids					
	Secondary Fuels	Gasoline					
		Jet Kerosene					
		Other Kerosene					
		Shale Oil					
		Gas / Diesel Oil					
		Residual Fuel Oil					
		LPG					
		Ethane					
		Naphtha					
		Bitumen					
		Lubricants					
		Petroleum Coke					
		Refinery Feedstocks					
		Other Oil					
Liquid Fossil Totals							
Solid Fossil	Primary Fuels	Anthracite					
		Coking Coal					
		Other Bit. Coal[b]					
		Sub-bit. Coal					
		Lignite					
		Oil Shale					
		Peat					
	Secondary Fuels	BKB & Patent Fuel					
		Coke Oven/Gas Coke					
Solid Fossil Totals							
Gaseous Fossil		Natural Gas (Dry)					
Total							
Biomass Total							
		Solid biomass					
		Liquid biomass					
		Gas biomass					

(a) Please specify units.
(b) If anthracite is not separately available, include with Other Bituminous Coal.

MODULE	ENERGY					
SUBMODULE	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)					
WORKSHEET	1-1					
SHEET	3 OF 5					
			STEP 4		STEP 5		STEP 6
			L Carbon Stored (Gg C)	M Net Carbon Emissions (Gg C)	N Fraction of Carbon Oxidised	O Actual Carbon Emissions (Gg C)	P Actual CO_2 Emissions (Gg CO_2)
FUEL TYPES				M=(K-L)		O=(MxN)	P=(Ox[44/12])
Liquid Fossil	Primary Fuels	Crude Oil					
		Orimulsion					
		Natural Gas Liquids					
	Secondary Fuels	Gasoline					
		Jet Kerosene					
		Other Kerosene					
		Shale Oil					
		Gas / Diesel Oil					
		Residual Fuel Oil					
		LPG					
		Ethane					
		Naphtha					
		Bitumen					
		Lubricants					
		Petroleum Coke					
		Refinery Feedstocks					
		Other Oil					
Liquid Fossil Totals							
Solid Fossil	Primary Fuels	Anthracite					
		Coking Coal					
		Other Bit. Coal[(a)]					
		Sub-bit. Coal					
		Lignite					
		Oil Shale					
		Peat					
	Secondary Fuels	BKB & Patent Fuel					
		Coke Oven/Gas Coke					
Solid Fossil Totals							
Gaseous Fossil		Natural Gas (Dry)					
Total							
Biomass Total							
		Solid biomass					
		Liquid biomass					
		Gas biomass					

(a) If anthracite is not separately available, include with Other Bituminous Coal.

MODULE	ENERGY
SUBMODULE	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)
WORKSHEET	1-1
SHEET	4 OF 5 EMISSIONS FROM INTERNATIONAL BUNKERS (INTERNATIONAL MARINE AND AIR TRANSPORT)

		STEP 1	STEP 2		STEP 3		
		A Quantities Delivered[a]	B Conversion Factor (TJ/unit)	C Quantities Delivered (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
FUEL TYPES				C=(AxB)		E=(CxD)	F=(E x 10^{-3})
Solid Fossil	Other Bituminous Coal						
	Sub-Bituminous Coal						
Liquid Fossil	Gasoline						
	Jet Kerosene						
	Gas/Diesel Oil						
	Residual Fuel Oil						
	Lubricants						
			Total				

(a) Enter the quantities from Table 1-1, Sheet 1, Column D: "International Bunkers".

MODULE	ENERGY
SUBMODULE	CO_2 FROM ENERGY SOURCES (REFERENCE APPROACH)
WORKSHEET	1-1
SHEET	5 OF 5 EMISSIONS FROM INTERNATIONAL BUNKERS (INTERNATIONAL MARINE AND AIR TRANSPORT)

		STEP 4			STEP 5		STEP 6
		G Fraction of Carbon Stored	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	L Actual CO_2 Emissions (Gg CO_2)
FUEL TYPES			H=(FxG)	I=(F-H)		K=(IxJ)	L=(Kx44/12)
Solid Fossil	Other Bituminous Coal	0	0				
	Sub-Bituminous Coal	0	0				
Liquid Fossil	Gasoline	0	0				
	Jet Kerosene	0	0				
	Gas/Diesel Oil	0	0				
	Residual Fuel Oil	0	0				
	Lubricants	0.5					
						Total[a]	

(a) The bunker emissions are not to be added to national totals.

MODULE	**ENERGY**
SUBMODULE	**CO_2 FROM ENERGY**
WORKSHEET	**AUXILIARY WORKSHEET 1-1: ESTIMATING CARBON STORED IN PRODUCTS**
SHEET	**1 OF 1**

	A	B	C	D	E	F	G	H
	Estimated Fuel Quantities	Conversion Factor (TJ/Units)	Estimated Fuel Quantities (TJ)	Carbon Emission Factor (t C/TJ)	Carbon Content (t C)	Carbon Content (Gg C)	Fraction of Carbon Stored	Carbon Stored (Gg C)
FUEL TYPES			C=(AxB)		E=(CxD)	F=(Ex10^{-3})		H=(FxG)
Naphtha[a]							0.80	
Lubricants							0.50	
Bitumen							1.0	
Coal Oils and Tars (from Coking Coal)							0.75	
Natural Gas[a]							0.33	
Gas/Diesel Oil[a]							0.50	
LPG[a]							0.80	
Ethane[a]							0.80	
Other fuels[b]								

(a) Enter these fuels when they are used as feedstocks.

(b) Use the Other fuels rows to enter any other products in which carbon may be stored

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	1 OF 16 ENERGY INDUSTRIES

	STEP 1	STEP 2		STEP 3		
Energy Industries	A Consumption	B Conversion Factor (TJ/unit)	C Consumption (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
			C=(AxB)		E=(CxD)	F=(E x 10^{-3})
Crude Oil	(a)					
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Gas						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Peat						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Coke						
Gas Works Gas						
Coke Oven Gas						
Blast Furnace Gas						
Natural Gas						
Municipal Solid Waste						
Industrial Waste						
		Total				
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
		Total Biomass				

(a) Include only consumption of crude oil that is burned, not crude oil which is refined into petroleum products.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	2 OF 16 ENERGY INDUSTRIES

	STEP 4			STEP 5		STEP 6
Energy Industries	G Fraction of Carbon Stored	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	L Actual CO_2 Emissions (Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(K x [44/12])
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Ethane						
Naphtha						
Lubricants	(a)					
Petroleum Coke						
Refinery Gas						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Peat						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Coke						
Gas Works Gas						
Coke Oven Gas						
Blast Furnace Gas						
Natural Gas						
Municipal Solid Waste						
Industrial Waste						
					Total	
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
					Total Biomass	

(a) Use a value of 0.5 for lubricants.

MODULE	**ENERGY**
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)**
WORKSHEET	**1-2 STEP BY STEP CALCULATIONS**
SHEET	**3 OF 16 MANUFACTURING INDUSTRIES AND CONSTRUCTION**

	STEP 1	STEP 2		STEP 3		
	A	B	C	D	E	F
Manufacturing Industries and Construction	Consumption	Conversion Factor (TJ/unit)	Consumption (TJ)	Carbon Emission Factor (t C/TJ)	Carbon Content (t C)	Carbon Content (Gg C)
			C=(AxB)		E=(CxD)	F=(E x 10^{-3})
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Gas						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Peat						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Coke						
Gas Works Gas						
Coke Oven Gas						
Blast Furnace Gas						
Natural Gas						
Municipal Solid Waste						
Industrial Waste						
		Total				
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
		Total Biomass				

Note: To separately identify emissions associated with autogeneration from those associated with process heat, photocopy sheets 3 and 4, clearly indicating the source of the emissions.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 OVERVIEW
SHEET	2 OF 8

			G Shale Oil	H Gas/Diesel Oil	I Residual Fuel Oil	J LPG	K Ethane	L Naphtha
FUEL CONSUMPTION (TJ)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								
CO_2 EMISSIONS (Gg)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes International Bunkers.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 OVERVIEW
SHEET	3 OF 8

			M Lubricants	N Petroleum Coke	O Refinery Gas	P Anthracite	Q Coking Coal	R Other Bituminous Coal
FUEL CONSUMPTION (TJ)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[a]							
	Road							
	Railways							
	National Navigation[a]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[a]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								
CO_2 EMISSIONS (Gg)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[a]							
	Road							
	Railways							
	National Navigation[a]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[a]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes International Bunkers.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 OVERVIEW
SHEET	4 OF 8

			S Sub-Bituminous Coal	T Lignite	U Oil Shale	V Peat	W Patent Fuel	X Brown Coal Briquettes
FUEL CONSUMPTION (TJ)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								
CO_2 EMISSIONS (Gg)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes International Bunkers.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 OVERVIEW
SHEET	5 OF 8

			Y Coke Oven Coke	Z Gas Coke	AA Gas Works Gas	AB Coke Oven Gas	AC Blast Furnace Gas	AD Natural Gas
FUEL CONSUMPTION (TJ)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other	Commercial/Institutional							
Sectors	Residential							
	Agriculture/Forestry/	Stationary						
	Fishing	Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								
CO_2 EMISSIONS (Gg)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other	Commercial/Institutional							
Sectors	Residential							
	Agriculture/Forestry/	Stationary						
	Fishing	Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes International Bunkers.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 OVERVIEW
SHEET	6 OF 8

			AE Municipal Solid Waste	AF Industrial Waste	AG	AH	AI	AJ
FUEL CONSUMPTION (TJ)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								
CO_2 EMISSIONS (Gg)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes International Bunkers.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 OVERVIEW
SHEET	7 OF 8

			AK	AL Total Liquid Fossil	AM Total Solid Fossil	AN Total Gaseous Fossil	AO Total Other Fuels	AP Total[b]
FUEL CONSUMPTION (TJ)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[a]							
	Road							
	Railways							
	National Navigation[a]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[a]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								
CO_2 EMISSIONS (Gg)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[a]							
	Road							
	Railways							
	National Navigation[a]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[a]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes International Bunkers.

(b) Excluding biomass.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 OVERVIEW
SHEET	8 OF 8

Memo Items: Biomass			AQ Wood/Wood Waste	AR Charcoal	AS Other Solid Biomass	AT Liquid Biomass	AU Gaseous Biomass	AV Total Biomass
FUEL CONSUMPTION (TJ)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								
CO_2 EMISSIONS (Gg)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes International Bunkers.

MODULE	ENERGY
SUBMODULE	NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)
WORKSHEET	1-3
SHEET	1 OF 3

			STEP 1					
			A Fuel Consumption (TJ)					
			A_1	A_2	A_3	A_4	A_5	A_6
Activity			Coal	Natural Gas	Oil	Wood/ Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road				Gasoline / Diesel			
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/ Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes international bunkers.

MODULE	ENERGY
SUBMODULE	NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)
WORKSHEET	1-3
SHEET	2 OF 3 GAS [(a)]_____

			STEP 2					
			B					
			Emission Factors (kg/TJ)					
			B_1	B_2	B_3	B_4	B_5	B_6
Activity			Coal	Natural Gas	Oil	Wood/ Wood Waste	Charcoal	Other Biomass and Wastes
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(b)]							
	Road				Gasoline / Diesel			
	Railways							
	National Navigation[(b)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/ Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Make 5 photocopies of this sheet and fill it out for CH_4, N_2O, NO_x, CO and NMVOC.

(b) Excludes international bunkers.

MODULE	ENERGY
SUBMODULE	NON-CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)
WORKSHEET	1-3
SHEET	3 OF 3 GAS [(a)]_____

			STEP 3						
			C Emissions by Fuel (kg)						D Total Emissions (Gg)
			C=(AxB)						$D=(\Sigma C_{1..6})/10^6$
			C_1	C_2	C_3	C_4	C_5	C_6	
Activity			Coal	Natural Gas	Oil	Wood/ Wood Waste	Charcoal	Other Biomass and Wastes	
Energy Industries									
Manufacturing Industries and Construction									
Transport	Domestic Aviation[(b)]								
	Road				Gasoline	Diesel			
	Railways								
	National Navigation[(b)]								
Other Sectors	Commercial/Institutional								
	Residential								
	Agriculture/ Forestry/ Fishing	Stationary							
		Mobile							
Other (not elsewhere specified)									
Total[(b)]									
Memo: International Marine Bunkers									
Memo: International Aviation Bunkers									

(a) Make 5 photocopies of this sheet and fill it out for CH_4, N_2O, NO_x, CO and NMVOC.

(b) Excludes international bunkers.

MODULE	ENERGY
SUBMODULE	SO_2 EMISSIONS FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1)
WORKSHEET	1-4
SHEET	1 OF 1 SECTOR[a]_____

		STEP 1	STEP 2					STEP 3
		A Fuel Consumption (TJ)	B Sulphur content of fuel[b] (%)	C Sulphur retention in ash (%)	D Abatement Efficiency (%)	E Net Calorific Value[b] (TJ/kt)	F SO_2 Emission factor[b] (kg/TJ)	G Emissions (t)
FUEL TYPE							$F = 2x\frac{B}{100} x \frac{1}{E} x10^6 x \frac{100 - C}{100} x \frac{100 - D}{100}$	G=(AxF)/1000
Coal	low							
	medium							
	high							
Heavy Fuel Oil	low							
	medium							
	high							
Light Fuel Oil/ diesel	low							
	high							
Diesel (road)								
Gasoline (road)								
Jet Kerosene								
Oil Shale								
Other Oil								
Natural Gas[b]								
Municipal Waste								
Industrial Waste								
Black Liquor								
Fuelwood								
Other Biomass								
Total								
Memo: Fuels for International Marine Bunkers								
Memo: Fuels for International Aviation Bunkers								

(a) This method can be applied once for total fuel consumption or can be repeated for each sector. Photocopy the sheets as many times as there are sectors to be calculated. If the calculations are done by sector, care must be taken to account for all national fuel consumption.

(b) The sulphur content of natural gas is expressed in g/m^3 and the net calorific value should be expressed in kJ/m^3. The sulphur content for natural gas (in Column B) should not be divided by 100 when calculating the emission factor in Column F.

MODULE	ENERGY		
SUBMODULE	EMISSIONS FROM AIRCRAFT (TIER 2)		
WORKSHEET	1-5		
SHEET	1 OF 3 FUEL CONSUMPTION FOR DOMESTIC AND INTERNATIONAL AVIATION		
		STEP 1	
	A Total Amount of Fuel Sold for All Aviation (kt)	B Total Amount of Fuel Sold for Domestic Aviation (kt)	C Total amount of Fuel Sold for International Aviation (kt)
			C=(A-B)
Fuel Sold			

MODULE	ENERGY					
SUBMODULE	EMISSIONS FROM AIRCRAFT (TIER 2)					
WORKSHEET	1-5					
SHEET	2 OF 3 FUEL CONSUMPTION FOR LTO AND CRUISE ACTIVITIES					
	STEP 2			STEP 3		
	D Total Number of LTO's per Aircraft type	E Fuel Consumption per LTO (t/LTO)	F Fuel Consumption for LTO Activities (t)	G Total Fuel Sold (t)	H Total Fuel Consumption for Cruise Activities (t)	I Fuel Consumption for Cruise Activities (t)
DOMESTIC AIRCRAFT TYPE			F=DxE		H=G-F	$I=Hx(D_a/D_{Total_a})$
a_1						
.						
.						
.						
.						
.						
.						
.						
.						
.						
.						
.						
a_n						
$Total_a$		$Total_a$		G=Bx1000		
INTERNATIONAL AIRCRAFT TYPE						$I=Hx(D_b/D_{Total_b})$
b_1						
.						
.						
.						
.						
.						
.						
.						
.						
.						
.						
.						
b_n						
$Total_b$		$Total_b$		G=Cx1000		

MODULE	ENERGY				
SUBMODULE	EMISSIONS FROM AIRCRAFT (TIER 2)				
WORKSHEET	1-5				
SHEET	3 OF 3 EMISSIONS FOR GAS[(a)] _____				
	STEP 4				
	J Emission Factor per LTO (kg/LTO)	K Emissions from LTO Activities (t)	L Emission Factor per Fuel Cons. for Cruise Activities (kg/t)	M Emissions from Cruise Activities (t)	N Total Emissions from Aircraft (Gg)
DOMESTIC AIRCRAFT TYPE		K=(DxJ)/1000		M=(IxL)/1000	N=(K+M)/1000
a_1					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
a_n					
	$Total_a$		$Total_a$		
INTERNATIONAL AIRCRAFT TYPE					
b_1					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
.					
b_n					
	$Total_b$		$Total_b$		

(a) Make 7 photocopies of this sheet and fill it out for CO_2, CH_4, N_2O, NO_x, CO, NMVOC and SO_2.

MODULE		**ENERGY**				
SUBMODULE		**METHANE EMISSIONS FROM COAL MINING AND HANDLING**				
WORKSHEET		**1-6**				
SHEET		**1 OF 1**				
		STEP 1			**STEP 2**	
		A Amount of Coal Produced (million t)	B Emission Factor (m^3 CH_4/t)	C Methane Emissions (million m^3)	D Conversion Factors (0.67 Gg CH_4/10^6 m^3)	E Methane Emissions (Gg CH_4)
				C=(AxB)		E=(CxD)
Underground Mines	Mining				0.67	
	Post-Mining				0.67	
Surface Mines	Mining				0.67	
	Post-Mining				0.67	
					Total	

MODULE	ENERGY
SUBMODULE	METHANE EMISSIONS FROM OIL AND GAS ACTIVITIES (TIER 1)
WORKSHEET	1-7
SHEET	1 OF 1

Category	A Activity	B Emission Factor	C CH_4 Emissions ($kg\ CH_4$)	D Emissions CH_4 ($Gg\ CH_4$)
			C=(AxB)	D=(C/10^6)
OIL				
Exploration *(Optional if data is locally available)* [a]	*number of wells drilled*	*kg CH_4/well drilled*		
Production[b]	*PJ oil produced*	*kg CH_4/PJ*		
Transport	*PJ oil loaded in tankers*	*kg CH_4/PJ*		
Refining	*PJ oil refined*	*kg CH_4/PJ refined*		
Storage	*PJ oil refined*	*kg CH_4/PJ refined*		
			TOTAL CH_4 FROM OIL	
GAS				
Production[b] / Processing	*PJ gas produced*	*kg CH_4/PJ*		
Transmission and Distribution	*PJ gas consumed*	*kg CH_4/PJ*		
Other Leakage	*PJ gas consumed* - *non-residential gas consumed (PJ)* - *Residential gas consumed*			
			TOTAL CH_4 FROM GAS	
VENTING AND FLARING FROM OIL/GAS PRODUCTION[c]	*PJ oil and gas produced* - *Oil* - *Gas* - *Combined*	*kg CH_4/PJ*		
			TOTAL CH_4 EMISSIONS FROM OIL AND GAS	

(a) Emission Factors are not provided.

(b) If using default emission factors these categories will include emissions from production other than venting and flaring.

(c) If using default emission factors, emissions from venting and flaring from all oil and production should be accounted for here.

MODULE	ENERGY
SUBMODULE	OZONE PRECURSORS AND SO_2 FROM OIL REFINING
WORKSHEET	1-8 OZONE PRECURSORS AND SO_2 FROM REFINING
SHEET	1 OF 4

A Crude Oil Throughput (kt)	B Pollutant	C Emission Factor[a] (kg/t)	D Emissions (t)	E Emissions (Gg)
			D=(AxC)	E = D/1000
	CO	0.09		
	NO_x	0.06		
	NMVOC	0.62		
	SO_2	0.93		

(a) Default values. Use local values where possible, particularly for NMVOCs for which emission factors vary widely. The default values shown have been derived from the values given in the *Reference Manual* using an average crude oil density of 860 kg/m^3 (33° API).

MODULE	ENERGY
SUBMODULE	OZONE PRECURSORS AND SO_2 FROM OIL REFINING
WORKSHEET	1-8 OZONE PRECURSORS AND SO_2 FROM CATALYTIC CRACKING
SHEET	2 OF 4

A Catalytic Cracker Throughput (kt)	B Pollutant	C Emission Factor[a] (kg/t)	D Emissions (t)	E Emissions (Gg)
			D=(AxC)	E = D/1000
	CO	42.6		
	NO_x	0.2		
	NMVOC	0.6		
	SO_2	1.5		

(a) Default values. Use local values where possible. The default values shown have been derived from the values given in the *Reference Manual* using an average oil density of 920 kg/m^3 (22° API).

MODULE	ENERGY
SUBMODULE	OZONE PRECURSORS AND SO_2 FROM OIL REFINING
WORKSHEET	1-8 SO_2 FROM SULPHUR RECOVERY PLANTS
SHEET	3 OF 4

A Quantity of Sulphur Recovered (t)	B Emission Factor (kg/t)	C Emissions (kg)	D Emissions (Gg)
		C=AxB	D=(C/10^6)
	139		

MODULE	ENERGY
SUBMODULE	OZONE PRECURSORS AND SO_2 FROM OIL REFINING
WORKSHEET	1-8 NMVOC EMISSIONS FROM STORAGE AND HANDLING
SHEET	4 OF 4

A Crude Oil Throughput (kt)	B Storage Type	C Emission Factor (kg/t)	D Emissions (t)	E Emissions (Gg)
			D=(AxC)	E = D/1000
	Secondary Seals	0.2		
	Primary Seals	0.7		
	Fixed Roof	4.9		

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	4 OF 16 MANUFACTURING INDUSTRIES AND CONSTRUCTION

	STEP 4			STEP 5		STEP 6
	G	H	I	J	K	L
Manufacturing Industries and Construction	Fraction of Carbon Stored[a]	Carbon Stored (Gg C)[a]	Net Carbon Emissions (Gg C)	Fraction of Carbon Oxidised	Actual Carbon Emissions (Gg C)	Actual CO_2 Emissions (Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(K x [44/12])
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil		(b)				
Residual Fuel Oil						
LPG		(b)				
Ethane		(b)				
Naphtha		(b)				
Lubricants	(c)					
Petroleum Coke						
Refinery Gas						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Peat						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Coke						
Gas Works Gas						
Coke Oven Gas						
Blast Furnace Gas						
Natural Gas		(b)				
Municipal Solid Waste						
Industrial Waste						
					Total	
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
					Total Biomass	

(a) For naphtha, natural gas, gas/diesel oil, LPG and any other fuels used as feedstocks, do not fill out Column G. Complete Column H, using Auxiliary Worksheet 1-2.

(b) Use Auxiliary Worksheet 1-2 to fill out the cells for these products.

(c) Use a value of 0.5 for lubricants.

MODULE	ENERGY					
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)					
WORKSHEET	1-2 STEP BY STEP CALCULATIONS					
SHEET	5 OF 16 TRANSPORT					
	STEP 1	STEP 2		STEP 3		
Transport	A Consumption	B Conversion Factor (TJ/unit)	C Consumption (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
			C=(AxB)		E=(CxD)	F=(E x 10^{-3})
Domestic Aviation[(a)]						
Gasoline						
Jet Kerosene						
		Subtotal				
Road Transport						
Natural Gas						
LPG						
Gasoline						
Gas/Diesel Oil						
		Subtotal				
Rail Transport						
Gas/Diesel Oil						
Residual Fuel Oil						
Anthracite						
Other Bituminous Coal						
Coke Oven Coke						
		Subtotal				
National Navigation[(a)]						
Gasoline						
Gas/Diesel Oil						
Residual Fuel Oil						
Lubricants						
Sub-Bituminous Coal						
		Subtotal				
Pipeline Transport						
Natural Gas						
		Subtotal				
		Total Transport[(a)]				
Memo items:						
Liquid Biomass						
		Total Biomass				

(a) Excluding international bunkers.

MODULE	ENERGY					
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)					
WORKSHEET	1-2 STEP BY STEP CALCULATIONS					
SHEET	6 OF 16 TRANSPORT					
	STEP 4			STEP 5		STEP 6
Transport	G Fraction of Carbon Stored	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	L Actual CO_2 Emissions (Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(K x [44/12])
Domestic Aviation						
Gasoline						
Jet Kerosene						
					Subtotal	
Road Transport						
Natural Gas						
LPG						
Gasoline						
Gas/Diesel Oil						
					Subtotal	
Rail Transport						
Gas/Diesel Oil						
Residual Fuel Oil						
Anthracite						
Other Bituminous Coal						
Coke Oven Coke						
					Subtotal	
National Navigation						
Gasoline						
Gas/Diesel Oil						
Residual Fuel Oil						
Lubricants	(a)					
Sub-Bituminous Coal						
					Subtotal	
Pipeline Transport						
Natural Gas						
Subtotal						
					Total Transport	
Memo items:						
Liquid Biomass						
					Total Biomass	

(a) Use a value of 0.5 for lubricants.

MODULE	ENERGY					
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)					
WORKSHEET	1-2 STEP BY STEP CALCULATIONS					
SHEET	7 OF 16 MEMO ITEMS: INTERNATIONAL BUNKERS					
	STEP 1	**STEP 2**		**STEP 3**		
Memo Items: International Bunkers	A Consumption	B Conversion Factor (TJ/unit)	C Consumption (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
			C=(AxB)		E=(CxD)	F=(E x 10^{-3})
Intl. Marine Bunkers						
Gasoline						
Gas/Diesel Oil						
Residual Fuel Oil						
Lubricants						
Sub-Bituminous Coal						
		Total				
Intl. Aviation Bunkers						
Gasoline						
Jet Kerosene						
		Total				

Note: Emissions of international bunkers are excluded from national totals and are reported for informational purposes only.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	8 OF 16 MEMO ITEMS: INTERNATIONAL BUNKERS

	STEP 4			STEP 5		STEP 6
Memo Items: International Bunkers	G Fraction of Carbon Stored	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	L Actual CO_2 Emissions (Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(K x [44/12])
Intl. Marine Bunkers						
Gasoline						
Gas/Diesel Oil						
Residual Fuel Oil						
Lubricants	(a)					
Sub-Bituminous Coal						
					Total	
Intl. Aviation Bunkers						
Gasoline						
Jet Kerosene						
					Total	

(a) Use a value of 0.5 for lubricants.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	9 OF 16 COMMERCIAL / INSTITUTIONAL SECTOR

	STEP 1	STEP 2		STEP 3		
Commercial/ Institutional Sector	A Consumption	B Conversion Factor (TJ/unit)	C Consumption (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
			C=(AxB)		E=(CxD)	F=(E x 10^{-3})
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Anthracite						
Other Bituminous Coal						
Lignite						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Works Gas						
Coke Oven Gas						
Natural Gas						
		Total				
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
		Total Biomass				

Note: To separately identify emissions associated with autogeneration from those associated with process heat, photocopy Sheets 9 and 10, clearly indicating the source of the emissions.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	10 OF 16 COMMERCIAL / INSTITUTIONAL SECTOR

	STEP 4			STEP 5		STEP 6
Commercial/ Institutional Sector	G Fraction of Carbon Stored	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	L Actual CO_2 Emissions (Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(K x [44/12])
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Anthracite						
Other Bituminous Coal						
Lignite						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Works Gas						
Coke Oven Gas						
Natural Gas						
					Total	
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
					Total Biomass	

MODULE	ENERGY					
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)					
WORKSHEET	1-2 STEP BY STEP CALCULATIONS					
SHEET	11 OF 16 RESIDENTIAL SECTOR					
	STEP 1	STEP 2		STEP 3		
Residential Sector	A Consumption	B Conversion Factor (TJ/unit)	C Consumption (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
			C=(AxB)		E=(CxD)	$F=(E \times 10^{-3})$
Gasoline						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Anthracite						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Peat						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Works Gas						
Coke Oven Gas						
Natural Gas						
		Total				
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
		Total Biomass				

MODULE	ENERGY					
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)					
WORKSHEET	1-2 STEP BY STEP CALCULATIONS					
SHEET	12 OF 16 RESIDENTIAL SECTOR					
	STEP 4			STEP 5		STEP 6
Residential Sector	G Fraction of Carbon Stored	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	L Actual CO_2 Emissions (Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(K x [44/12])
Gasoline						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Anthracite						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Peat						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Works Gas						
Coke Oven Gas						
Natural Gas						
					Total	
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
					Total Biomass	

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	13 OF 16 AGRICULTURE / FORESTRY / FISHING

	STEP 1	STEP 2		STEP 3		
Agriculture/Forestry/ Fishing	A Consumption	B Conversion Factor (TJ/unit)	C Consumption (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
			C=(AxB)		E=(CxD)	F=(E x 10^{-3})
Mobile						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
		Total				
Stationary						
Gasoline						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
Liquefied Petroleum Gas						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Lignite						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Works Gas						
Natural Gas						
		Total				
Memo items:						
Mobile						
Liquid Biomass						
Stationary						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
		Total Biomass				

Note: To separately identify emissions associated with autogeneration from those associated with process heat, photocopy Sheets 13 and 14, clearly indicating the source of the emissions.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	14 OF 16 AGRICULTURE / FORESTRY / FISHING

	STEP 4			STEP 5		STEP 6
Agriculture/Forestry/ Fishing	G Fraction of Carbon Stored[a]	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	L Actual CO_2 Emissions (Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(K x [44/12])
Mobile						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
					Total	
Stationary						
Gasoline						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
Liquefied Petroleum Gas						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Lignite						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Works Gas						
Natural Gas						
					Total	
Memo items:						
Mobile						
Liquid Biomass						
Stationary						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
					Total Biomass	

(a) Use a value of 0.5 for lubricants.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	15 OF 16 OTHER (NOT ELSEWHERE SPECIFIED)

	STEP 1	STEP 2		STEP 3		
Other (not elsewhere specified)	A Consumption	B Conversion Factor (TJ/unit)	C Consumption (TJ)	D Carbon Emission Factor (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)
			C=(AxB)		E=(CxD)	F=(E x 10^{-3})
Crude Oil	(a)					
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Ethane						
Naphtha						
Lubricants						
Petroleum Coke						
Refinery Gas						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Peat						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Coke						
Gas Works Gas						
Coke Oven Gas						
Blast Furnace Gas						
Natural Gas						
Municipal Solid Waste						
Industrial Waste						
		Total				
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
		Total Biomass				

Note: To separately identify emissions associated with autogeneration from those associated with process heat, photocopy Sheets 15 and 16, clearly indicating the source of the emissions.

(a) Include only consumption of crude oil that is burned, not crude oil which is refined into petroleum products.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 STEP BY STEP CALCULATIONS
SHEET	16 OF 16 OTHER (NOT ELSEWHERE SPECIFIED)

	STEP 4			STEP 5		STEP 6
Other (not elsewhere specified)	G Fraction of Carbon Stored	H Carbon Stored (Gg C)	I Net Carbon Emissions (Gg C)	J Fraction of Carbon Oxidised	K Actual Carbon Emissions (Gg C)	L Actual CO_2 Emissions (Gg CO_2)
		H=(FxG)	I=(F-H)		K=(IxJ)	L=(K x [44/12])
Crude Oil						
Natural Gas Liquids						
Gasoline						
Jet Kerosene						
Other Kerosene						
Gas/Diesel Oil						
Residual Fuel Oil						
LPG						
Ethane						
Naphtha						
Lubricants	(a)					
Petroleum Coke						
Refinery Gas						
Anthracite						
Coking Coal						
Other Bituminous Coal						
Sub-Bituminous Coal						
Lignite						
Peat						
Patent Fuel						
Brown Coal Briquettes						
Coke Oven Coke						
Gas Coke						
Gas Works Gas						
Coke Oven Gas						
Blast Furnace Gas						
Natural Gas						
Municipal Solid Waste						
Industrial Waste						
					Total	
Memo items:						
Wood/Wood Waste						
Charcoal						
Other Solid Biomass						
Liquid Biomass						
Gaseous Biomass						
					Total Biomass	

(a) Use a value of 0.5 for lubricants.

MODULE	**ENERGY**
SUBMODULE	**CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)**
WORKSHEET	**AUXILIARY WORKSHEET 1-2: ESTIMATING CARBON STORED IN PRODUCTS**
SHEET	**1**

	A	B	C	D	E	F	G	H
	Feedstock Use	Conversion Factor (TJ/Units)	Feedstock Use (TJ)	Carbon Emission Factor (t C/TJ)	Carbon Content (t C)	Carbon Content (Gg C)	Fraction of Carbon Stored	Carbon Stored[a] (Gg C)
FUEL TYPES			C=(AxB)		E=(CxD)	F=(Ex10^{-3})		H=(FxG)
Gas/Diesel Oil							0.5	
LPG							0.8	
Ethane							0.8	
Naphtha							0.8	
Natural Gas							0.33	
Other Fuels[b]								

(a) Enter the result of this calculation in Worksheet 1-2 Step by Step Calculation, Sheet 4, in the cells marked with (b).

(b) Please specify.

MODULE	ENERGY
SUBMODULE	CO_2 FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER I)
WORKSHEET	1-2 OVERVIEW
SHEET	1 OF 8

			A Crude Oil	B Orimulsion	C Natural Gas Liquids	D Gasoline	E Jet Kerosene	F Other Kerosene
FUEL CONSUMPTION (TJ)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								
CO_2 EMISSIONS (Gg)								
Energy Industries								
Manufacturing Industries and Construction								
Transport	Domestic Aviation[(a)]							
	Road							
	Railways							
	National Navigation[(a)]							
Other Sectors	Commercial/Institutional							
	Residential							
	Agriculture/Forestry/ Fishing	Stationary						
		Mobile						
Other (not elsewhere specified)								
Total[(a)]								
Memo: International Marine Bunkers								
Memo: International Aviation Bunkers								

(a) Excludes International Bunkers.