



MODULE 1

ENERGY



1 ENERGY

1.1 Introduction

This module gives instructions for estimating the emissions of SO₂ 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

- CO₂ emissions
 - Reference Approach
 - By main source categories
- Non-CO₂ 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 SO₂ 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 CO₂ Emissions

The calculation of CO₂ 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-CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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: CO₂ 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 CO₂ 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.

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.

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.



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

$$\text{Apparent Consumption} = \text{Production} + \text{Imports} - \text{Exports} - \text{International Bunkers} - \text{Stock Change}$$

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)

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.

- 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.
- 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.

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.

Fuel	Carbon Emission Factor (t C/TJ)
LIQUID FOSSIL	
<i>Primary fuels</i>	
Crude oil	20.0
Orimulsion	22.0
Natural Gas Liquids	17.2
<i>Secondary fuels/products</i>	
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	
<i>Primary Fuels</i>	
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
<i>Secondary Fuels/Products</i>	
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 CO₂. The CO₂ 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.

	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 <i>Greenhouse Gas Inventory Reference Manual</i> 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 10³ 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 CO₂ EMISSIONS

- 1 Multiply Actual Carbon Emissions (Column O) by 44/12 to find Total Carbon Dioxide (CO₂) emitted from fuel combustion. Enter the results in Column P.
- 2 The sum is total national emissions of carbon dioxide from fuel combustion.

Coal ¹	0.98
Oil and Oil products	0.99
Gas	0.995
Peat for electricity generation ²	0.99
<ol style="list-style-type: none"> 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 CO₂ Emissions by Source Categories

Introduction

A sectoral breakdown of national CO₂ 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 CO₂ 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-CO₂ emissions from fuel combustion by sector (Worksheets 1-3 and 1-4) has been extended to CO₂ so that sectoral information can be obtained simply for this gas. However, the simplicity of CO₂ estimation and the special consideration given to CO₂ emissions from biofuels means that the methodology for CO₂ differs in a number of respects from that used for the non-CO₂ 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 (m³).

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.

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

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

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.

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.

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 CO₂.

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 CO₂ 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 CO₂ EMISSIONS

- 1 Multiply Actual Carbon Emissions (Column K) by 44/12 to find Actual Carbon Dioxide (CO₂) Emissions. Enter the results in Column L.

Worksheet 1-2: Overview

- 1 For each fuel for which you estimated sectoral CO₂ emissions, copy the Fuel Consumption in terajoules (from Column C in Worksheet 1-2: Step By Step Calculations) and the Actual CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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 CO₂ 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-CO₂ 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 CH₄, N₂O, NO_x, CO and NMVOC using energy statistics, and of SO₂ by using additional assumptions on the sulphur content of the fuels.

The Tier 1 methodology for non-CO₂ 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-ROM¹.

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-CO₂ 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 database², 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).

In the Tier 1 method for non-CO₂ 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.*

different countries. SO₂ 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 CH₄, N₂O, NO_x, CO, NMVOC

The calculation of non-CO₂ Greenhouse gases (CH₄, N₂O, 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 (CH₄, N₂O, NO_x, CO and NMVOC).

Completing the Worksheet

Use WORKSHEET 1-3: NON-CO₂ FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1) to enter the data for CH₄, N₂O, 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 A₁ to A₆. 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-CO₂ 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.

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 (CH₄, N₂O, NO_x, CO and NMVOC).

- 1 Enter the emission factors (in kg/TJ) for each fuel and activity in the Columns B₁ to B₆. 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 (CH₄, N₂O, 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 C₁ to C₆.

1.3.2 Methodology for SO₂

SO₂ 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 SO₂ emission factors

Step 3: Estimate the emissions

ENERGY INDUSTRIES

Manufacturing Industries and Construction

- **Transport**

Domestic Aviation

Road

Railways

National Navigation

- **Other Sectors**

Commercial/Institutional

Residential

Agriculture/ Forestry/ Fishing

Stationary

Mobile

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: SO₂ EMISSIONS FROM FUEL COMBUSTION BY SOURCE CATEGORIES (TIER 1) to enter the data for SO₂.

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 SO₂ 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/m³ 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 SO₂ emission factor as: 2 times [% sulphur content (Column B) / 100] times [1 / net calorific value (Column E)] times 10⁶ 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/m³ and not in per cent, calculate the SO₂ emission factor as: 2 times % sulphur content (Column B) times [1 / net calorific value (Column E)] times 10⁶ 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 SO₂ 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-CO₂ emissions vary significantly with operating mode and engine design. Reliable estimates of non-CO₂ 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.