CHAPTER 1
ENERGY

1. ENERGY

1.1 Overview

This chapter discusses inventory methods for emissions of SO_2 and direct and indirect greenhouse gases from energy sources, comprising CO_2, CH_4, N_2O, NO_x, CO and NMVOC. Energy systems are extremely complex and widespread components of national economies. The full range of greenhouse gases is emitted from the production, transformation, handling and consumption of energy commodities. Chapter 2, Industrial Processes, discusses emissions which arise jointly from fuel use in industrial processes and provides guidance on attributing the emissions to the energy or industrial process categories. The various emissions from energy systems are organised in two main categories: Emissions from Fuel Combustion and Fugitive Emissions.

Emissions from Fuel Combustion

CO_2 emissions from fuel combustion are discussed separately and in some depth because they can be calculated accurately at a highly aggregated level, unlike other gases. CO_2 emissions are primarily dependent on the carbon content of the fuel. The IPCC Reference Approach for CO_2 emissions is a simple, accurate and internationally transparent approach which takes advantage of this fact.

CO_2 from energy activities can be estimated from energy supply data, with a few adjustments such as for carbon non-oxidised. Supply data for all commercial fuels are available from international data bases covering individual countries of the world. These data, together with typical carbon content figures, provide a sound starting point for the estimation of CO_2 inventories, particularly for global or regional studies. However, because fuel qualities and emission factors may differ markedly between countries, sometimes by as much as ten percent for nominally similar fuels, national inventories should be prepared using local emission factors and energy data where possible.

Unlike CO_2, national inventories of CH_4, N_2O, NO_x, CO and NMVOCs require more detailed information. Accurate estimation of their emissions depends on knowledge of several interrelated factors, including combustion conditions, technology, and emission control policies, as well as fuel characteristics. The methods must, in general, be applied at a detailed activity/technology level. CO_2 emissions may also be calculated at the more detailed level required for other gases. Indeed, when calculating non-CO_2 emissions national experts are encouraged to calculate CO_2 emissions at the same time, as reconciliation of total CO_2 emissions estimated in this manner with those obtained from the Reference Approach provides a valuable verification process. Procedures for estimating CO_2 and non-CO_2 emissions at the detailed or more aggregated levels of activity are presented in this chapter. The methods for estimating the gases are divided in "Tiers" encompassing different levels of activity and technology detail. Tier 1 methods are generally very simple requiring less data and expertise than the most complicated Tier 3 methods.

Fugitive Emissions

In addition to the emission of greenhouse gases from fuel combustion, other emissions into the atmosphere occur in an unplanned or a deliberate manner. These are fugitive emissions. Fugitive emissions are intentional or unintentional releases of gases from anthropogenic activities. In particular, they may arise from the production, processing, transmission, storage and use of fuels, and include emissions from combustion only where it does not

support a productive activity (e.g., flaring of natural gases at oil and gas production facilities). The most significant greenhouse gas emissions in this category are methane emissions from coal mining and from oil and gas systems. There are also emissions of other gases, such as CO_2 and NMVOCs as fugitive or by-product emissions from energy systems.

1.1.1 Recent Developments

As part of Phase II of the IPCC/OECD/IEA Programme on National Greenhouse Gas (GHG) Inventories an expert group on GHG Emissions from Fuel Combustion was set up. The group included over forty experts from various geographical and professional backgrounds. The terms of reference of this group were to continue improving the estimation methodologies on emissions from fuel combustion which had been published in the *IPCC Guidelines for National Greenhouse Inventories* in March 1995.

The issues addressed by the group can be divided into several broad areas:

- harmonisation of international emission estimation methodologies and reporting;
- improvement and review of emission factors;
- development of a new Tier 1 method for estimating non-CO_2 GHG and SO_2 emissions based on fuel consumption;
- development of a new Tier 2 method for estimating emissions from aircraft.

In addition the group identified areas for further work. These are listed at the end of this chapter.

The results of the group's work on the final three items listed above are contained in the sections which follow. The experts' conclusions following a review and discussion of the harmonisation of methodologies are summarised in the following statement.

Harmonisation of International Emission Estimation Methodologies and Reporting

Two approaches to drawing up and presenting national emission inventories in comparable form are currently in use:

- The IPCC Guidelines for National Greenhouse Gas Inventories, and
- the joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook.

Countries which are Parties to both Conventions have to apply both reporting procedures to each Convention. The IPCC approach meets FCCC needs for calculating national totals (without further spatial resolution) and identifying sectors within which emissions occur, whereas the EMEP/CORINAIR approach is technology based and includes spatial allocation of emissions (point and area sources).

Both systems follow the same basic principles :

- complete coverage of anthropogenic emissions (CORINAIR also considers natural emissions);
- annual source category totals of national emissions;
- clear distinction between energy and non-energy related emissions;
- transparency and full documentation permitting detailed verification of activity data and emission factors.

To date, considerable progress has been made in the harmonisation of the IPCC and EMEP/CORINAIR approaches. The IPCC Expert Group on Fuel Combustion has made changes to the fuel list and to the source/sink categories to allow more direct comparison of the two approaches:

- Biomass fuels will be allocated to the various source categories (CO_2 from biomass will not be reported in national totals).
- In order to estimate the full emissions of the industry sector, emissions from autoproduction should be included with emissions from other fuel use within industry. At the same time the emissions from the autoproduction of electricity and heat should be excluded from the energy transformation source category to avoid double counting. This change brings the IPCC source categories for manufacturing and transformation industries into line with those used by CORINAIR.
- Treatment of evaporative emissions (NMVOC) from road transport in the IPCC Tier 2 method is consistent with CORINAIR. Combustion and evaporative emissions should be reported separately. In the IPCC Tier 1 method, all emissions from road transport are included together under fuel combustion.

The CORINAIR programme has now developed its approach further to include additional sectors and sub-divisions (e.g. the definition of civil aviation is now in line with the IPCC definition) so that a complete CORINAIR inventory, including emission estimates, can be used to produce reports in both the FCCC/IPCC or EMEP/CORINAIR reporting formats for submission to their respective Conventions. Minor adjustments based on additional local knowledge may be necessary to complete such reports for submission.

One difference between the approaches remains:

- Spatial allocation of road transport emissions: here CORINAIR, with a view to the input requirements of atmospheric dispersion models, applies the principle of territoriality (emission allocation according to fuel consumption) whereas the IPCC is bound to the principle of political responsibility (allocation according to fuel sale). For the IPCC, countries with a big disparity between emissions from fuel sales and fuel consumption have the option of estimating true consumption and reporting the emissions from consumption and trade separately. However, national totals must be on the basis of fuel sales.

1.1.2 Organisation of the Chapter

In addition to this introduction, this chapter is organised into four separate substantive sections covering fuel combustion and fugitive emissions:

- **Simple Methods (Tier 1)**: Emissions from all sources of combustion are estimated on the basis of the quantities of fuel consumed and average emission factors. The IPCC Reference Approach for CO_2 is presented together with new methods for the estimation of CO_2 and non-CO_2 emissions from the main source categories.
- **Detailed Methods (Tiers 2/3)**: Emission estimations are based on detailed fuel/technology information covering stationary and mobile sources.
- **Fugitive emissions from coal mining and handling**: Emissions are generated as a result of the mining and handling of coal, primarily methane emissions from coal mining. Other emissions of GHGs from coal mine and waste fires are briefly discussed.

- **Fugitive emissions from oil and natural gas activities**: Methane emissions from natural gas flaring and venting, and from natural gas production, transmission and distribution are the most important for this category. CO_2 emissions from venting and flaring are included as are NMVOC emissions from production, processing and distribution of oil and oil products. A new section briefly describes the estimation of emissions of ozone precursors and SO_2 from refineries.

1.2 Data

1.2.1 Data Sources

Activity Data

Subject to the requirements outlined below and intended to ensure the comparability of country inventories, the IPCC approach to the calculation of emission inventories encourages the use of fuel statistics collected by an officially recognised national body, as this is usually the most appropriate and accessible activity data. In some countries, however, those charged with the task of compiling inventory information may not have ready access to the entire range of data available within their country and may wish to use data specially provided by their country to the international organisations whose policy functions require knowledge of energy supply and use in the world.

There are, currently, two main sources of international energy statistics: the International Energy Agency of the Organisation for Economic Co-operation and Development (OECD/IEA), and the United Nations (UN). The primary energy data sources cited in this report include:

- From the OECD/IEA: Energy Statistics and Balances of Non-OECD Countries (OECD/IEA, 1996b); Energy Balances of OECD Countries (OECD/IEA, 1996a); and Energy Statistics of OECD Countries (OECD/IEA, 1996c).
- From the United Nations: Energy Statistics Yearbook (UN, 1996).

Both international organisations collect energy data from the national administrations of their member countries through systems of questionnaires. The data gathered are therefore "official" data. To avoid duplication of reporting, where countries are members of both organisations, the UN receives copies of the IEA questionnaires for the OECD member countries rather than requiring these countries to complete the UN questionnaires. When compiling its statistics of non-OECD member countries the IEA, for certain countries, uses UN data to which it may add additional information obtained from the national administration, consultants or energy companies operating within the countries. Statistics for other countries are obtained directly from national sources. The number of countries covered by the IEA publications is fewer than that of the UN. [1]

Emission Factors

Emissions of GHGs from fuel combustion and fuel supply activities are calculated by multiplying levels of activity by emission factors usually expressed as mass of pollutant per

[1] Approximately 130 countries (of about 170 UN Member countries) are included in the IEA data, but the countries it includes account for about 98 per cent of worldwide energy consumption and nearly all energy production.

energy unit of activity (e.g. kg N_2O/TJ). The most commonly used activity measure for energy-related emissions is the amount of fuel burned or, where fugitive emissions are concerned, the amount of fuel produced or distributed. In some cases other measures of activity are used, most notably in calculating emissions from the transport sector.

A number of international and national sources of energy activity data and industry emission factors exist largely as a result of international and national analyses of alternative control policies for SO_x, NO_x and NMVOC. A few sources have also recently emerged on various other GHGs. The more detailed factors (for gases other than CO_2) do not relate directly to national energy activity data described below, but require some additional information. The sources of emission factor data, and procedures for making these linkages are discussed in the context of specific gases and source types, in the relevant sections which follow.

1.2.2 Comparability of Reporting

In order to meet the objectives of the IPCC/OECD/IEA programme, inventories must be readily comparable. This requires a large measure of commonality of definitions of activities (source/sink categories) and fuel product groups and the use of a reporting discipline which makes evident the construction of the inventory from the activity data. Specific guidelines for reporting have been prepared. In order to reduce the uncertainty created by possibly different definitions, the IPCC *Reporting Instructions* have largely adopted definitions utilised by the IEA for the regular collection of energy data from OECD member countries. The active co-operation between the UN Statistical Division (New York), the UN ECE (Geneva), Eurostat and the IEA has ensured that there are now very few differences between the definitions employed by these organisations for the collection of their energy data. The IEA definitions may be found in the Glossary at the end of the *Reporting Instructions* (Volume 1).

Although common standards for the collection of data by international organisations exist the presentation of the data collected can be different. At least five aspects of energy data presentations need to be checked prior to using data for greenhouse gas inventories:

- Are the energy data expressed in terms of net calorific values (NCV) or gross calorific values (GCV)?[2] Since most of the world uses net calorific values, the IPCC *Guidelines* uses net calorific values.
- Are non-commercial fuels, including wood and other biomass fuels, included?[3]
- Are wood waste, agricultural wastes or waste-derived fuels included if combusted for energy production? These fuels should be accounted for in the IPCC methodology, but are included with biomass fuels.

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[2] The IEA generally reports data in net calorific values. The difference between the net and the gross calorific value of a fuel is the heat of condensation of moisture in the fuel during combustion. The net calorific value excludes this. The IEA assumes that net calorific values are 5 per cent lower than gross calorific values for oil and coal, and 10 per cent lower for natural gas.

[3] While some of these fuels (such as wood) may be included in national or international data sets, it is likely that they are underestimated due to poor record-keeping and lack of statistical information for non-commercial fuels.

- Is non-energy fuel usage (if non-oxidised) accounted for?[4]
- How are international bunker fuels for air and ship transport treated?[5]

Given responses to these questions, several adjustments may need to be made to the energy data being used in order to formulate a complete inventory of greenhouse gases. If published IEA data are being used the following corrections must be made:

1 Consumption of vegetal fuels in non-OECD countries should be added to commercial fuel consumption. Estimates of the former are available in the IEA publication cited. Consumption of vegetal fuels, as declared by OECD countries in their reports to the IEA, are included as "Combustible Renewables and Wastes" in the IEA statistics for these countries.

2 International energy statistics show fuel consumption by industrial and commercial electricity generators (autoproducers) as an identified part of fuel use by the energy industries. In order to harmonise inventory preparation with the EMEP/CORINAIR methods, countries preparing IPCC inventories should include autoproducer fuel consumption in the industry and commercial sectors and remove it from energy industries. See *Recent Developments* above.

3 Care is required when estimating the amount of fuel used without oxidation in the manufacture of non-energy products. IEA data generally cover only deliveries to the industry sector manufacturing such products. Some of the fuels delivered will be oxidised by the user. See Chapter 2, Industrial Processes, Overview.

4 IEA data do not include deliveries of oil for international air transport as part of the International Bunkers data. Where data are available they are identified as part of the national transport sector fuel consumption. UN estimates are available for many countries.

1.2.3 Uncertainty

The *Reporting Instructions*, Volume 1, make explicit provision for the reporting of estimates from all source categories identified in the Standard Data Tables. Energy activity data and emission factors are both subject to wide variations through uncertainties in basic data, identification of fuel qualities, calorific values and measurements in emissions. Furthermore, the uncertainties in estimates of fugitive emissions can be larger than those from fuel combustion as wider ranges in natural resource conditions and operations practice exist for fuel extraction and processing. This topic is discussed further in Section 1.8.7. Managing and combining uncertainty estimates from several sources is discussed in Appendix 1 to the *Reporting Instructions*.

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[4] This is normally reported in primary energy requirements but is not combusted and therefore does not contribute directly to greenhouse gas emissions.

[5] International bunker fuels are combusted in ships at sea and by airplanes (both undertaking international movements) and therefore should be included in global greenhouse gas estimations. Following guidance from the INC, the IPCC recommends that every country estimate emissions from international bunker fuels sold within national boundaries, but that these emissions would be reported separately and, as far as possible, excluded from national totals.

1.3 Fuel Combustion: Overview

In the initial stages of the IPCC/OECD/IEA programme it was recognised that work on both methods development and national inventories needed to be prioritised, as it was not possible to deal with all of the gases and sources simultaneously. Priority was given to the direct GHGs in the order: carbon dioxide, methane and nitrous oxide (IPCC/OECD, 1991). In Phase II of the *Guidelines* development, an attempt has been made to identify default methods for a simplified Tier I method for estimating emissions of the GHGs and SO_2.

The purpose of a Tier 1 method is to assist countries that cannot access detailed fuel use and technology data to develop emission inventories. Consequently, the Tier 1 method should enable at least rough emission estimations of CO_2, 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 method should be used in cases where no detailed information is available on fuel type, technology and operating conditions. If countries have more exact national emission factors, these (and not the default factors) should be used.

Countries wanting to do more detailed emission estimations may use the Tier 2 method described in Section 1.5. 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[6].

1.4 Simple Methods (Tier 1) for Fuel Combustion

The Tier 1 method for CO_2 is fairly well established and is explained in Section 1.4.1. For non-CO_2 gases, a simplified methodology has been developed to estimate 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 method ignores these refinements (see Box 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[7], the CORINAIR 1990 database and scientific reports from 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. (1993a and 1993b), Delmas (1993), Smith et al. (1993), Delmas et al. (1995), Veldt and Berdowski (1995) and Brocard et al. (1996).

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

[7] 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 $1^o \times 1^o$ grid (Olivier et al., 1995).

For aircraft, the emission factors for the Tier 1 method 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)].

BOX 1
MAIN FUEL GROUPS

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 (includes dung, agricultural, municipal and industrial wastes, bagasse and agricultural residues).

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

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.

1.4.1 Carbon Dioxide (CO_2) Emissions

In this section the methodology for estimating CO_2 emissions from energy is discussed. Carbon dioxide (CO_2) is the most common greenhouse gas produced by anthropogenic activities, accounting for about 60 per cent of the increase in radiative forcing since pre-industrial times (IPCC, 1992). By far the largest source of CO_2 emissions is from the oxidation of carbon when fossil fuels are burned, which accounts for 70-90 per cent of total anthropogenic CO_2 emissions. When fuels are burned, most carbon is emitted as CO_2 immediately during the combustion process. Some carbon is released as CO, CH_4, or non-methane hydrocarbons, which oxidise to CO_2 in the atmosphere within a period from a few days to 10-11 years. The IPCC methodology accounts for all of the carbon from these emissions in the total for CO_2 emissions. The other carbon-containing gases are also estimated and reported separately (see following sections for methodologies for estimating CH_4, CO, and NMVOCs).[8]

[8] It is important to note that there is an intentional double counting of carbon emitted from combustion. This format treats the non-CO_2 gases as a subset of CO_2 emissions and ensures that the CO_2 emission estimates reported by each country represent the entire amount of carbon that would eventually be present in the atmosphere as CO_2. The

Fuel combustion is widely dispersed throughout most activities in national economies making assembly of a complete record of the quantities of each fuel type consumed in each "end use" activity a considerable task which some countries have not yet completed. Fortunately, it is possible to estimate national CO_2 emissions by accounting for the carbon in fuels supplied to the economy. This is the basis of the IPCC Reference Approach. The supply of fuels is simple to record and is more likely to be available in many countries than detailed end use consumption statistics.

The Reference Approach requires statistics for production of fuels and their external trade as well as changes in their stocks. It also needs a limited number of figures for the consumption of fuels used for non-energy purposes where carbon may be stored. It uses a simple assumption: once carbon is brought into a national economy in fuel, it is either saved in some way (e.g., in increases of fuel stocks, stored in products, left unoxidised in ash) or it must be released to the atmosphere. In order to calculate the carbon released it is not necessary to know exactly how the fuel was used or what intermediate transformations it underwent. In this respect the methodology may be termed a "top-down" approach compared with the "bottom-up" methods used for other gases. As stated in the *Overview*, this does not mean that a "bottom-up" approach should not be followed for estimating CO_2 emissions but the total emissions must be compared with those obtained from the Reference Approach. A "bottom-up" method for CO_2 is briefly discussed later in this section.

When estimating CO_2 emissions from fuel combustion there are a number of points of a statistical, technical or procedural nature which affect several of the estimation methods.

- **Fuel Carbon and Energy Content:** There is considerable variation in the carbon and energy content by weight of fuels. However, expressing the carbon emission factor as the carbon content per unit of energy released reduces this variation because of the close link between the carbon content and energy value of the fuel. It is natural therefore that all fuel supply and consumption data for combustion emission calculations be expressed in energy units. Energy data expressed in other units should be converted to terajoules before use.
- **Unoxidised Carbon:** When energy is consumed not all of the carbon in the fuel oxidises to CO_2. Incomplete oxidation occurs due to inefficiencies in the combustion process that leave some of the carbon unburned or partly oxidised as soot or ash.
- **Stored Carbon:** Some of the fuel supplied to an economy is used as a raw material (or feedstock) for manufacture of products such as plastics, fertiliser, or in a non-energy use (e.g. bitumen for road construction, lubricants). In some cases, the carbon from the fuels is oxidised quickly to CO_2. In other cases the carbon is stored (or sequestered) in the product, sometimes for as long as centuries. The amounts stored for long periods are called *stored carbon* and should be deducted from the carbon emissions calculation. Estimation of stored carbon requires data on fuel used as feedstock and/or quantities of non-energy fuel products produced. The calculations are discussed within each of the alternative approaches presented in this section.
- **Bunker Fuels:** The IPCC methodology subtracts the quantities delivered to and consumed by ships or aircraft *for international transport* from the fuel supply to the country. In this manner, the CO_2 emissions arising from the use of international bunkers

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reasons for this double counting are discussed in the Overview of the IPCC Guidelines, General Notes on the Guidelines.

are not included in the national total. To simplify the preparation of global estimates, these emissions should be brought together in a separate table.

- **Biomass Fuels:** Biomass fuels are included in the national energy and emissions accounts for completeness. These emissions should not be included in national CO_2 emissions from fuel combustion. If energy use, or any other factor, is causing a long term decline in the total carbon embodied in standing biomass (e.g. forests), this net release of carbon should be evident in the calculation of CO_2 emissions described in the *Land Use Change and Forestry* chapter.

All of the above issues are addressed within the methods presented in the remainder of this section.

Approaches For Estimating CO_2 Emissions

The estimation process can be divided into six steps that lead to figures for CO_2 emissions from fuel combustion.

1 Estimate consumption of fuels by fuel/product type.

2 Convert the fuel data to a common energy unit (TJ), if necessary.

3 Select carbon emission factors for each fuel/product type and estimate the total carbon content of the fuels.

4 Estimate the amount of carbon stored in products for long periods of time.

5 Account for carbon not oxidised during combustion.

6 Convert emissions of carbon to full molecular weight of CO_2 .

1.4.1.1 IPCC REFERENCE APPROACH

Estimate Fuel Consumption

The first step of the IPCC Reference Approach is to estimate apparent consumption of fuels within the country. This requires a balance of primary fuels produced, plus imports, minus exports, minus international bunkers and minus net changes in stocks. In this way carbon is brought into the country from energy production and imports (adjusted for stock changes) and moved out of the country through exports and international bunkers. In order to avoid double counting it is important to distinguish between *primary fuels,* which are fuels found in nature such as coal, crude oil and natural gas, and *secondary fuels* or fuel products, such as gasoline and lubricants, which are derived from primary fuels.

To calculate the supply of fuels to the country, the following data are required for each fuel and inventory year:

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

The apparent consumption of *primary* fuels is, therefore, calculated from the above data as:

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

An increase in stocks is a positive stock change which withdraws supply from consumption. A stock reduction is a negative stock change which, when subtracted in the equation, causes an increase in apparent consumption.

Apparent consumption of secondary fuels should be added to primary apparent consumption. The production (or manufacture) of secondary fuels should be ignored in the calculations because the carbon in these fuels will already have been included in the supply of primary fuels from which they were derived; for instance, the estimate for apparent consumption of crude oil already contains the carbon from which gasoline would be refined. Apparent consumption of secondary fuels is calculated as follows:

Apparent Consumption = Imports - Exports - International Bunkers - Stock Change.

Note that this calculation can result in negative numbers for apparent consumption. This is a perfectly acceptable result for the purposes of this calculation since it indicates a net export or stock increase in the country.

Since carbon content typically varies by fuel type, data should be reported for detailed categories of fuel and product types as shown in Table 1-1. The table also illustrates the inputs and calculations recommended for the IPCC Reference Approach.

TABLE 1-1
IPCC REFERENCE APPROACH
ENTRIES AND CALCULATIONS FOR STEPS (1) AND (2)

Fuel	(1) Production	(2) Imports	(3) Exports	(4) International Bunkers	(5) Stock Change	(6) Apparent Consumption[a]	(7) Conversion Factor	(8) Apparent Consumption (TJ)
A) Liquid Fossil						sum[b]		sum
Primary Fuels								
1) Crude Oil	input	input	input	NA	input	calc	input	calc
2) Orimulsion	input	input	input	NA	input	calc	input	calc
3) N. Gas Liquids	input	input	input	NA	input	calc	input	calc
Secondary Fuels / Products								
4) Gasoline	NA	input	input	input	input	calc	input	calc
5) Jet Kerosene	NA	input	input	input	input	calc	input	calc
6) Other Kerosene	NA	input	input	NA	input	calc	input	calc
7) Shale Oil	NA	input	input	NA	input	calc	input	calc
8) Gas / Diesel Oil	NA	input	input	input	input	calc	input	calc
9) Residual Fuel Oil	NA	input	input	input	input	calc	input	calc
10) LPG	NA	input	input	NA	input	calc	input	calc
11) Ethane	NA	input	input	NA	input	calc	input	calc
12) Naphtha	NA	input	input	NA	input	calc	input	calc
13) Bitumen	NA	input	input	NA	input	calc	input	calc
14) Lubricants	NA	input	input	input	input	calc	input	calc
15) Petroleum Coke	NA	input	input	NA	input	calc	input	calc
16) Refinery Feedstocks	NA	input	input	NA	input	calc	input	calc
17) Other Oil	NA	input	input	NA	input	calc	input	calc
B) Solid Fossil						sum		sum
Primary Fuels								
18) Anthracite[c]	input	input	input	NA	input	calc	input	calc
19) Coking Coal	input	input	input	NA	input	calc	input[d]	calc
20) Other Bit. Coal	input	input	input	input	input	calc	input[d]	calc
21) Sub-bit. Coal	input	input	input	input	input	calc	input[d]	calc
22) Lignite	input	input	input	NA	input	calc	input[d]	calc
23) Oil Shale	input	input	input	NA	input	calc	input	calc
24) Peat	input	input	input	NA	input	calc	input	calc
Secondary Fuels								
25) BKB & Patent Fuel	NA	input	input	NA	input	calc	input	calc
26) Coke Oven/Gas Coke	NA	input	input	NA	input	calc	input	calc
C) Gaseous Fossil						sum		sum
27) Natural Gas (Dry)	input	input	input	NA	input	calc	input	calc
Total[e]						**sum**		**sum**
Information Entries								
Biomass Total						sum		sum
28) Solid Biomass	input	input	input	NA	input	calc	input	calc
29) Liquid Biomass	input	input	input	NA	input	calc	input	calc
30) Gas Biomass	input	input	input	NA	input	calc	input	calc

TABLE 1-1 (CONTINUED)
IPCC REFERENCE APPROACH
ENTRIES AND CALCULATIONS FOR STEPS (3) TO (6)

Fuel	(8) Apparent Consumption (TJ)	(9) Carbon Emission Factor[f] (t C/TJ)	(10) Carbon Content (Gg C)	(11) Carbon Stored (Gg C)	(12) Net Carbon Emissions (Gg C)	(13) Actual Carbon Emissions (Gg C)	(14) Actual CO_2 Emissions (Gg CO_2)
A) Liquid Fossil	sum		sum	sum	sum	sum	sum
Primary Fuels							
1) Crude Oil	calc	20.0	calc		calc	calc	calc
2) Orimulsion	calc	22.0	calc		calc	calc	calc
3) N. Gas Liquids	calc	17.2	calc		calc	calc	calc
Secondary Fuels / Products							
4) Gasoline	calc	18.9	calc		calc	calc	calc
5) Jet Kerosene	calc	19.5	calc		calc	calc	calc
6) Other Kerosene	calc	19.6	calc		calc	calc	calc
7) Shale Oil	calc	20.0	calc		calc	calc	calc
8) Gas / Diesel Oil	calc	20.2	calc	Table 1-5	calc	calc	calc
9) Residual Fuel Oil	calc	21.1	calc		calc	calc	calc
10) LPG	calc	17.2	calc	Table 1-5	calc	calc	calc
11) Ethane	calc	16.8	calc	Table 1-5	calc	calc	calc
12) Naphtha	calc	(20.0)	calc	Table 1-5	calc	calc	calc
13) Bitumen	calc	22.0	calc	Table 1-5	calc	calc	calc
14) Lubricants	calc	(20.0)	calc	Table 1-5	calc	calc	calc
15) Petroleum Coke	calc	27.5	calc		calc	calc	calc
16) Refinery Feedstocks	calc	(20.0)	calc		calc	calc	calc
17) Other Oil	calc	(20.0)	calc		calc	calc	calc
B) Solid Fossil	sum		sum	sum	sum	sum	sum
Primary Fuels							
18) Anthracite[c]	calc	26.8	calc		calc	calc	calc
19) Coking Coal	calc	25.8	calc	Table 1-5	calc	calc	calc
20) Other Bit. Coal	calc	25.8	calc		calc	calc	calc
21) Sub-bit. Coal	calc	26.2	calc		calc	calc	calc
22) Lignite	calc	27.6	calc		calc	calc	calc
23) Oil Shale	calc	29.1	calc		calc	calc	calc
24) Peat	calc	28.9	calc		calc	calc	calc
Secondary Fuels							
25) BKB & Patent Fuel	calc	(25.8)	calc		calc	calc	calc
26) Coke Oven/Gas Coke	calc	29.5	calc		calc	calc	calc
C) Gaseous Fossil	sum		sum	sum	sum	sum	sum
27) Natural Gas (Dry)	calc	15.3	calc	Table 1-5	calc	calc	calc
Total[e]	**sum**		**sum**	**sum**	**sum**	**sum**	**sum**
Information Entries							
Biomass Total	sum		sum		sum	sum	sum
28) Solid Biomass	calc	29.9	calc		calc	calc	calc
29) Liquid Biomass	calc	(20.0)	calc		calc	calc	calc
30) Gas Biomass	calc	(30.6)[g]	calc		calc	calc	calc

TABLE 1-1 (CONTINUED)
IPCC REFERENCE APPROACH
EMISSIONS FROM INTERNATIONAL BUNKERS
(INTERNATIONAL MARINE AND AIR TRANSPORT)[h]

Fuel	(15) Quantities delivered[i]	(16) Conversion Factor (TJ/units)	(17) Quantities Delivered (TJ)	(18) Carbon Emission Factor (t C/TJ)	(19) Carbon Content (t C)	(20) Carbon Content (Gg C)
A) Solid Fossil						
Primary Fuels						
1) Other Bituminous Coal	input	input	calc	25.8	calc	calc
2) Sub-Bituminous Coal	input	input	calc	26.2	calc	calc
Liquid Fossil						
Secondary Fuels						
3) Gasoline	input	input	calc	18.9	calc	calc
4) Jet Kerosene	input	input	calc	19.5	calc	calc
5) Gas / Diesel Oil	input	input	calc	20.2	calc	calc
6) Residual Fuel Oil	input	input	calc	21.1	calc	calc
7) Lubricants	input	input	calc	(20.0)	calc	calc
Total			**sum**			

TABLE 1-1 (CONTINUED)
IPCC REFERENCE APPROACH
EMISSIONS FROM INTERNATIONAL BUNKERS
(INTERNATIONAL MARINE AND AIR TRANSPORT)

Fuel	(21) Fraction of Carbon Stored	(22) Carbon Stored (Gg C)	(23) Net Carbon Emissions	(24) Actual Carbon Emissions (Gg C)	(25) Actual CO_2 Emissions (Gg CO_2)
A) Solid Fossil					
Primary Fuels					
1) Other Bituminous Coal	NA	calc	calc	calc	calc
2) Sub-Bituminous Coal	NA	calc	calc	calc	calc
Liquid Fossil					
Secondary Fuels					
3) Gasoline	NA	calc	calc	calc	calc
4) Jet Kerosene	NA	calc	calc	calc	calc
5) Gas / Diesel Oil	NA	calc	calc	calc	calc
6) Residual Fuel Oil	NA	calc	calc	calc	calc
7) Lubricants	0.5	calc	calc	calc	calc
Total					**sum**

TABLE 1-1 (CONTINUED)
EXPLANATORY NOTES

calc = value to be calculated, NA = not applicable

(a) Apparent Consumption = Production + Imports - Exports - International Bunkers - Stock Changes. A stock build is positive; a stock draw is negative.

(b) Apparent Consumption for the aggregate categories of Liquid Fossil, Solid Fossil, Gaseous Fossil, and Biomass Fuels equal the sum of Apparent Consumption over the fuel types within the appropriate categories.

(c) If anthracite is not separately identifiable, include it with Other Bituminous Coal.

(d) If data are in 10^3t, separate conversion factors are available for Production, Imports and Exports in Table 1-2. Each of these entries should be multiplied by the appropriate conversion factor. Then, the results should be summed to find Apparent Consumption in TJ (Column 8).

(e) Total should include Liquid, Solid, and Gaseous Fossil Fuel subtotals only. Biomass subtotals are for reference purposes only and should not be included in the totals.

(f) If value is in parenthesis it is a default value until a fuel-specific CEF is determined.

(g) Based on the assumption that 50 per cent of the carbon in the biomass is converted to methane.

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

(i) See Column 4, "International Bunkers".

Convert Fuel Data to a Common Energy Unit (if necessary)

In the OECD/IEA *Energy Statistics*, and other energy data compilations, production and consumption of solid and liquid fuels are specified in 10^3 tonnes. To convert tonnes to terajoules, net calorific values (NCV) must be applied. The values to convert from 10^3 tonnes to terajoules are in Table 1-2. In some cases, particularly for coal, different NCVs are given for production, imports and exports in a given country and are used to convert each category separately when calculating apparent consumption. For international bunkers and stock changes national experts can use a weighted average of the different NCVs, or use the one for the coal type which meets the largest share of total apparent consumption. For refined products the NCVs from 10^3 tonnes to terajoules do not normally vary greatly by country and global default values are provided in Table 1-3.[9]

National experts may use more detailed locally available NCVs. In this case, the values used should also be reported and documented. If original data are expressed in other energy units such as British thermal units (Btu's) or million tons of oil equivalent (Mtoe), they should be converted to terajoules using standard conversion factors. If energy data are already available in terajoules on a net calorific value basis, no conversion is necessary and Column 7 of Table 1-1 can be ignored.

[9] Throughout the *Guidelines* net calorific values are used and expressed in SI units or multiples of SI units (for example TJ/kt). The term *Conversion Factor* has two uses. First, as net calorific value, to convert quantities expressed in natural units to energy units, and second as a scaling factor to convert one form of energy unit to another (e.g., Btu's to GJ).

TABLE 1-2
1990 COUNTRY-SPECIFIC NET CALORIFIC VALUES FOR SELECTED NON-OECD COUNTRIES

(Terajoule per kilotonne)

	Albania	Algeria	Angola Cabinda	Argentina	Armenia	Azer-baijan	Bahrain	Bangla-desh	Bela-russia	Benin	Bolivia
OIL											
Crude Oil	41.45	43.29	42.75	42.29	-	42.08	42.71	42.16	42.08	42.58	43.33
NGL	-	43.29	-	42.50	-	-	42.71	42.71	-	-	43.33
COAL											
Hard Coal											
Production	-	25.75	-	24.70	-	-	-	-	-	-	-
Imports	27.21	25.75	-	30.14	18.58	18.58	-	20.93	25.54	-	-
Exports	-	-	-	24.70	18.58	18.58	-	-	25.54	-	-
Lignite and Sub-Bituminous Coal											
Production	9.84	-	-	-	-	-	-	-	-	-	-
Imports	-	-	-	-	14.65	14.65	-	-	14.65	-	-
Exports	9.84	-	-	-	14.65	14.65	-	-	14.65	-	-
Coal Products											
Patent Fuel/BKB	-	-	-	-	29.31	29.31	-	-	29.31	-	-
Coke Oven/Gas Coke	27.21	27.21	-	28.46	25.12	25.12	-	-	25.12	-	-

	Brazil	Brunei	Bulgaria	Came-roon	Chile	China	Colombia	Congo	Cuba	Cyprus	Czech Republic
OIL											
Crude Oil	42.54	42.75	42.62	42.45	42.91	42.62	42.24	42.91	41.16	42.48	41.78
NGL	45.22	42.75	-	-	42.87	-	41.87	-	-	-	-
COAL											
Hard Coal											
Production	18.42	-	24.70	-	28.43	20.52	27.21	-	-	-	24.40
Imports	30.56	-	24.70	-	28.43	20.52	-	-	25.75	25.75	23.92
Exports	-	-	-	-	-	20.52	27.21	-	-	-	27.98
Lignite and Sub-Bituminous Coal											
Production	-	-	7.03	-	17.17	-	-	-	-	-	12.26
Imports	-	-	-	-	-	-	-	-	-	-	-
Exports	-	-	-	-	-	-	-	-	-	-	15.26
Coal Products											
Patent Fuel/BKB	-	-	20.10	-	-	-	-	-	-	-	21.28
Coke Oven/Gas Coke	28.30	-	27.21	-	28.43	28.47	20.10	-	27.21	-	27.01

Note: A few of these countries have become OECD members subsequent to the production of this table.

Crude oil conversion factors are based on weighted average production data.

The conversion factors are those used by the IEA in the construction of energy balances.

Source: OECD/IEA, 1993b.

TABLE 1-2 (CONTINUED)
1990 COUNTRY-SPECIFIC NET CALORIFIC VALUES FOR SELECTED NON-OECD COUNTRIES

(Terajoule per kilotonne)

	Ecuador	Egypt	Estonia	Ethiopia	Gabon	Georgia	Ghana	Guate-mala	Hong Kong	Hungary	India
OIL											
Crude Oil	42.45	42.54	-	42.62	42.62	42.08	42.62	42.45	-	40.36	42.79
NGL	42.45	42.54	-	-	-	-	-	-	-	45.18	43.00
COAL											
Hard Coal											
Production	-	-	-	-	-	18.58	-	-	-	16.42	19.98
Imports	-	25.75	18.58	-	-	18.58	25.75	-	25.75	26.33	25.75
Exports	-	-	18.58	-	-	18.58	-	-	-	24.15	19.98
Lignite and Sub-Bituminous Coal											
Production	-	-	14.65	-	-	-	-	-	-	10.55	9.80
Imports	-	-	14.65	-	-	14.65	-	-	-	9.91	-
Exports	-	-	14.65	-	-	14.65	-	-	-	-	-
Coal Products											
Patent Fuel/BKB	-	-	20.10	-	-	29.31	-	-	-	21.44	20.10
Coke Oven/Gas Coke	-	27.21	25.12	-	-	25.12	-	-	27.21	30.11	-

	Indonesia	Iran	Iraq	Israel	Ivory Coast	Jamaica	Jordan	Kazakh-stan	Kenya	Kuwait	Kyrgy-zstan
OIL											
Crude Oil	42.66	42.66	42.83	42.54	42.62	42.16	42.58	42.08	42.08	42.54	42.08
NGL	42.77	42.54	42.83	-	-	-	-	-	-	42.62	-
COAL											
Hard Coal											
Production	25.75	25.75	-	-	-	-	-	18.58	-	-	18.58
Imports	25.75	25.75	-	26.63	-	25.75	-	18.58	25.75	-	18.58
Exports	25.75	-	-	-	-	-	-	18.58	-	-	18.58
Lignite and Sub-Bituminous Coal											
Production	-	-	-	-	-	-	-	14.65	-	-	14.65
Imports	-	-	-	-	-	-	-	14.65	-	-	14.65
Exports	-	-	-	-	-	-	-	14.65	-	-	14.65
Coal Products											
Patent Fuel/BKB	-	-	-	-	-	-	-	29.31	-	-	29.31
Coke Oven/Gas Coke	27.21	-	-	-	-	-	-	25.12	-	-	25.12

Note: A few of these countries have become OECD members subsequent to the production of this table.

Crude oil NCVs are based on weighted average production data.

The NCVs are those used by the IEA in the construction of energy balances.

Source: OECD/IEA, 1993b.

TABLE 1-2 (CONTINUED)
1990 COUNTRY-SPECIFIC NET CALORIFIC VALUES FOR SELECTED NON-OECD COUNTRIES

(Terajoule per kilotonne)

	Latvia	Leb-anon	Libya	Lithu-ania	Malaysia	Malta	Mexico	Moldova	Mor-occo	Mozam-bique	Myan-mar
OIL											
Crude Oil	-	42.16	43.00	42.08	42.71	-	42.35	-	43.00	-	42.24
NGL	-	-	-	-	43.12	-	46.81	-	-	-	42.71
COAL											
Hard Coal											
Production	-	-	-	-	25.75	-	24.72	-	23.45	25.75	25.75
Imports	18.58	-	-	18.59	25.75	25.75	30.18	18.58	27.63	25.75	25.75
Exports	18.58	-	-	18.59	25.75	-	22.41	18.58	-	-	-
Lignite and Sub-Bituminous Coal											
Production	-	-	-	-	-	-	-	-	-	-	8.37
Imports	14.65	-	-	14.65	-	-	-	14.65	-	-	-
Exports	14.65	-	-	14.65	-	-	-	14.65	-	-	-
Coal Products											
Patent Fuel/BKB	29.31	-	-	29.31	-	-	-	29.31	-	-	-
Coke Oven/Gas Coke	25.12	-	-	25.12	27.21	-	27.96	25.12	27.21	-	27.21

	Nepal	Neth. Antilles	Neutral Zone	Nigeria	North Korea	Oman	Paki-stan	Panama	Para-guay	Peru	Philip-pines
OIL											
Crude Oil	-	42.16	42.12	42.75	42.16	42.71	42.87	42.16	42.54	42.75	42.58
NGL	-	-	-	-	-	-	-	-	-	42.75	-
COAL											
Hard Coal											
Production	-	-	-	25.75	25.75	-	18.73	-	-	29.31	20.10
Imports	25.12	-	-	-	25.75	-	27.54	25.75	-	29.31	20.52
Exports	-	-	-	25.75	25.75	-	-	-	-	-	-
Lignite and Sub-Bituminous Coal											
Production	-	-	-	-	17.58	-	-	-	-	-	8.37
Imports	-	-	-	-	-	-	-	-	-	-	-
Exports	-	-	-	-	-	-	-	-	-	-	-
Coal Products											
Patent Fuel/BKB	-	-	-	-	-	-	-	-	-	-	-
Coke Oven/Gas Coke	-	-	-	27.21	27.21	-	-	-	-	27.21	27.21

Note: A few of these countries have become OECD members subsequent to the production of this table.

Crude oil NCVs are based on weighted average production data.

The NCVs are those used by the IEA in the construction of energy balances.

Source: OECD/IEA, 1993b.

TABLE 1-2 (CONTINUED)
1990 COUNTRY-SPECIFIC NET CALORIFIC VALUES FOR SELECTED NON-OECD COUNTRIES

(Terajoule per kilotonne)

	Poland	Qatar	Romania	Russia	Saudi Arabia	Senegal	Sing-apore	South Africa	South Korea	Slovak Republic	Sri Lanka
OIL											
Crude Oil	41.27	42.87	40.65	42.08	42.54	42.62	42.71	44.13	42.71	41.78	42.16
NGL	-	43.00	-	-	42.62	-	-	-	-	-	-
COAL											
Hard Coal											
Production	22.95	-	16.33	18.58	-	-	-	25.09	19.26	-	-
Imports	29.41	-	25.12	18.58	-	-	-	-	27.21	23.92	25.75
Exports	25.09	-	-	18.58	-	-	-	25.09	-	-	-
Lignite and Sub-Bituminous Coal											
Production	8.36	-	7.24	14.65	-	-	-	-	-	12.26	-
Imports	-	-	7.24	14.65	-	-	-	-	-	-	-
Exports	9.00	-	-	14.65	-	-	-	-	-	15.26	-
Coal Products											
Patent Fuel/BKB	20.93	-	14.65	29.31	-	-	-	-	-	21.28	-
Coke Oven/Gas Coke	27.76	-	20.81	25.12	-	-	27.21	-	-	27.01	-

	Sudan	Syria	Chinese Taipei	Tajik-istan	Tanz-ania	Thai-land	Trini-dad / Tobago	Tunisia	Turk-meni-stan	Ukraine	Utd Arab Emir-ates
OIL											
Crude Oil	42.62	42.04	41.41	42.08	42.62	42.62	42.24	43.12	42.08	42.08	42.62
NGL	-	-	-	-	-	46.85	-	43.12	-	-	-
COAL											
Hard Coal											
Production	-	-	25.96	18.58	25.75	-	-	-	-	21.59	-
Imports	-	-	27.42	18.58	-	26.38	-	25.75	18.58	25.54	-
Exports	-	-	-	18.58	-	-	-	-	18.58	21.59	-
Lignite and Sub-Bituminous Coal											
Production	-	-	-	-	-	12.14	-	-	-	14.65	-
Imports	-	-	-	14.65	-	-	-	-	14.65	14.65	-
Exports	-	-	-	14.65	-	-	-	-	14.65	14.65	-
Coal Products											
Patent Fuel/BKB	-	-	-	29.31	-	-	-	-	29.31	29.31	-
Coke Oven/Gas Coke	-	-	-	25.12	27.21	27.21	-	27.21	25.12	25.12	-

Note: A few of these countries have become OECD members subsequent to the production of this table.

Crude NCVs are based on weighted average production data.

The NCVs are those used by the IEA in the construction of energy balances.

Source: OECD/IEA, 1993b.

TABLE 1-2 (CONTINUED)
1990 COUNTRY-SPECIFIC NET CALORIFIC VALUES FOR SELECTED NON-OECD COUNTRIES

(Terajoule per kilotonne)

	Uruguay	Uzbek-istan	Venez-uela	Viet Nam	Yemen	Former Yugo-slavia	Zaire	Zambia	Zim-babwe
OIL									
Crude Oil	42.71	42.08	42.06	42.61	43.00	42.75	42.16	42.16	-
NGL	-	-	41.99	-	-	-	-	-	-
COAL									
Hard Coal									
Production	-	18.58	25.75	20.91	-	23.55	25.23	24.71	25.75
Imports	-	18.58	-	-	-	30.69	25.23	-	25.75
Exports	-	18.58	25.75	20.91	-	-	-	24.71	25.75
Lignite and Sub-Bituminous Coal									
Production	-	-	-	-	-	8.89	-	-	-
Imports	-	14.65	-	-	-	16.91	-	-	-
Exports	-	14.65	-	-	-	16.90	-	-	-
Coal Products									
Patent Fuel/BKB	-	29.31	-	-	-	20.10	29.31	-	-
Coke Oven/Gas Coke	-	25.12	27.21	27.21	-	26.90	27.21	-	27.21

Note: A few of these countries have become OECD members subsequent to the production of this table.
Crude oil NCVs are based on weighted average production data.
The NCVs are those used by the IEA in the construction of energy balances.
Source: OECD/IEA, 1993b.