# CHAPTER 1

# INTRODUCTION

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# 1 INTRODUCTION

## 1.1 INTRODUCTION

Energy systems are for most economies largely driven by the combustion of fossil fuels. During combustion the carbon and hydrogen of the fossil fuels are converted mainly into carbon dioxide ($CO_2$) and water ($H_2O$), releasing the chemical energy in the fuel as heat. This heat is generally either used directly or used (with some conversion losses) to produce mechanical energy, often to generate electricity or for transportation. The energy sector is usually the most important sector in greenhouse gas emission inventories, and typically contributes over 90 percent of the $CO_2$ emissions and 75 percent of the total greenhouse gas emissions in developed countries. $CO_2$ accounts typically for 95 percent of energy sector emissions with methane and nitrous oxide responsible for the balance. Stationary combustion is usually responsible for about 70 percent of the greenhouse gas emissions from the energy sector. About half of these emissions are associated with combustion in energy industries mainly power plants and refineries. Mobile combustion (road and other traffic) causes about one quarter of the emissions in the energy sector.

## 1.2 SOURCE CATEGORIES

The energy sector mainly comprises:

- exploration and exploitation of primary energy sources,
- conversion of primary energy sources into more useable energy forms in refineries and power plants
- transmission and distribution of fuels
- use of fuels in stationary and mobile applications.

Emissions arise from these activities by combustion and as fugitive emissions, or escape without combustion.

For inventory purposes, *fuel combustion* may be defined as *the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus.* This definition aims to separate the combustion of fuels for distinct and productive energy use from the heat released from the use of hydrocarbons in chemical reactions in industrial processes, or from the use of hydrocarbons as industrial products. It is *good practice* to apply this definition as fully as possible but there are cases where demarcation with the industrial processes and product use (IPPU) sector is needed. The following principle has been adopted for this:

*Combustion emissions from fuels obtained directly or indirectly from the feedstock for an IPPU process will normally be allocated to the part of the source category in which the process occurs. These source categories are normally 2B and 2C. However, if the derived fuels are transferred for combustion in another source category, the emissions should be reported in the appropriate part of Energy Sector source categories (normally 1A1 or 1A2).* Please refer to Box 1.1 and section 1.3.2 in chapter 1 of the IPPU Volume for examples and further details.

When the total emissions from the gases are calculated, the quantity transferred to the energy sector should be noted as an information item under IPPU source category and reported in the relevant energy sector source category to avoid double counting.

Typically, only a few percent of the emissions in the energy sector arise as *fugitive emissions* from extraction, transformation and transportation of primary energy carriers. Examples are leakage of natural gas and the emissions of methane during coal mining and flaring during oil/gas extraction and refining[1]. In some cases where countries produce or transport significant quantities of fossil fuels, fugitive emissions can make a much larger contribution to the national total. Combustion and fugitive emissions from production, processing and handling of oil and gas should be allocated according to the national territory of the facilities including offshore areas (see Chapter 8 - section 8.2.1 in Vol. 1). These offshore areas may be an economic zone agreed upon with other countries.

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[1] Note that the combustion emissions due to transport of energy carriers by ship, rail and road are included in the mobile combustion processes.

Figure 1.1 shows the structure of activities and *source categories* within the energy sector. This structure is based on the coding and naming as defined in *the 1996 IPCC Guidelines and the Common Reporting Format (CRF)* used by the UNFCCC. The technical chapters of this Volume follow this source category structure.

# 1.3 METHODOLOGICAL APPROACHES

## 1.3.1 Emissions from fossil fuel combustion

There are three Tiers presented in the *2006 IPCC Guidelines* for estimating emissions from fossil fuel combustion. In addition a Reference Approach is presented. It can be used as an independent check of the sectoral approach and to produce a first-order estimate of national greenhouse gas emissions if only very limited resources and data structures are available to the inventory compiler.

The *2006 IPCC Guidelines* estimate carbon emissions in terms of the species which are emitted. During the combustion process, most carbon is immediately emitted as $CO_{2.}$ However, some carbon is released as carbon monoxide (CO), methane ($CH_4$) or non-methane volatile organic compounds (NMVOCs). Most of the carbon emitted as these non-$CO_2$ species eventually oxidises to $CO_2$ in the atmosphere. This amount can be estimated from the emissions estimates of the non-$CO_2$ gases (See Volume 1, Chapter 7).

In the case of fuel combustion, the emissions of these non-$CO_2$ gases contain very small amounts of carbon compared to the $CO_2$ estimate and, at Tier 1, it is more accurate to base the $CO_2$ estimate on the total carbon in the fuel. This is because the total carbon in the fuel depends on the fuel alone, while the emissions of the non-$CO_2$ gases depend on many factors such as technologies, maintenance etc which, in general, are not well known. At higher tiers, the amount of carbon in these non-$CO_2$ gases can be accounted for.

Since $CO_2$ emissions are independent of combustion technology whilst $CH_4$ and $N_2O$ emissions are strongly dependent on the technology, this chapter only provides default emission factors for $CO_2$ that are applicable to all combustion processes, both stationary and mobile. Default emission factors for the other gases are provided in subsequent chapters of this volume, since combustion technologies differ widely between source categories within the source sector “Combustion” and hence will vary between these subsectors.

### 1.3.1.1 TIERS

#### TIER 1

The Tier 1 method is fuel-based, since emissions from all sources of combustion can be estimated on the basis of the quantities of fuel combusted (usually from national energy statistics) and average emission factors. Tier 1 emission factors are available for all relevant direct greenhouse gases.

The quality of these emission factors differs between gases. For $CO_2$, emission factors mainly depend upon the carbon content of the fuel. Combustion conditions (combustion efficiency, carbon retained in slag and ashes etc.) are relatively unimportant. Therefore, $CO_2$ emissions can be estimated fairly accurately based on the total amount of fuels combusted and the averaged carbon content of the fuels.

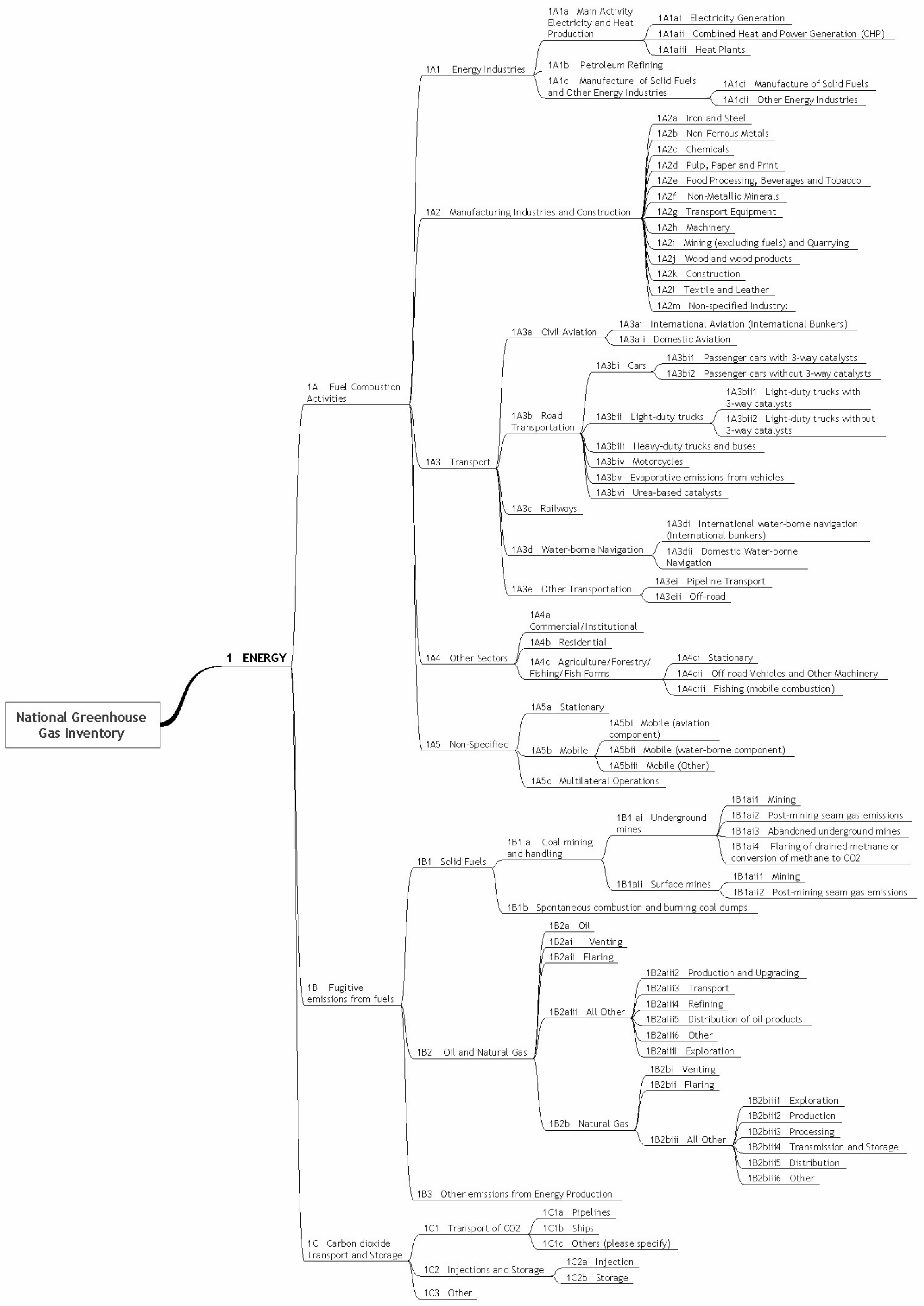
However, emission factors for methane and nitrous oxide depend on the combustion technology and operating conditions and vary significantly, both between individual combustion installations and over time. Due to this variability, use of averaged emission factors for these gases, that must account for a large variability in technological conditions, will introduce relatively large uncertainties.

#### TIER 2

In the Tier 2 method for energy, emissions from combustion are estimated from similar fuel statistics, as used in the Tier 1 method, but country-specific emission factors are used in place of the Tier 1 defaults. Since available country-specific emission factors might differ for different specific fuels, combustion technologies or even individual plants, activity data could be further disaggregated to properly reflect such disaggregated sources. If these country-specific emission factors indeed are derived from detailed data on carbon contents in different batches of fuels used or from more detailed information on the combustion technologies applied in the country, the uncertainties of the estimate should decrease, and the trends over time can be better estimated.

If an inventory compiler has well documented measurements of the amount of carbon emitted in non-$CO_2$ gases or otherwise not oxidised, it can be taken into account in this tier in the country-specific emission factors. It is *good practice* to document how this has been done.

**Figure 1.1 Activity and source structure in the Energy Sector**



### TIER 3

In the Tier 3 methods for energy, either detailed emission models or measurements and data at individual plant level are used where appropriate. Properly applied, these models and measurements should provide better estimates primarily for non-$CO_2$ greenhouse gases, though at the cost of more detailed information and effort.

Continuous emissions monitoring (CEM) of flue gases is generally not justified for accurate measurement of $CO_2$ emissions only (because of the comparatively high cost) but could be undertaken particularly when monitors are installed for measurement of other pollutants such as $SO_2$ or $NO_x$. Continuous emissions monitoring is particularly useful for combustion of solid fuels where it is more difficult to measure fuel flow rates, or when fuels are highly variable, or fuel analysis is otherwise expensive. Direct measurement of fuel flow, especially for gaseous or liquid fuels, using quality assured fuel flow meters may improve the accuracy of $CO_2$ emission calculations for sectors using these fuel flow meters. When considering using measurement data, it is *good practice* to assess the representativeness of the sample and suitability of measurement method. The best measurement methods are those that have been developed by official standards organisations and field-tested to determine their operational characteristics. For further information on the usage of measured data, check Chapter 2, Approaches to Data Collection in Volume 1.

It should be noted that additional types of uncertainties are introduced through the use of such models and measurements should therefore be well validated, including a comparison of calculated fuel consumption with energy statistics, thorough assessments of their uncertainties and systematic errors, as described in Volume 1, Chapter 6.

If an inventory compiler has well documented measurements of the amount of carbon emitted in non-$CO_2$ gases or otherwise not oxidised, it can be taken into account in this tier in the country-specific emission factors. It is *good practice* to document how this has been done. If emission estimates are based on measurements then they will already include the direct emissions of $CO_2$ only.

## 1.3.1.2 SELECTING TIERS: A GENERAL DECISION TREE

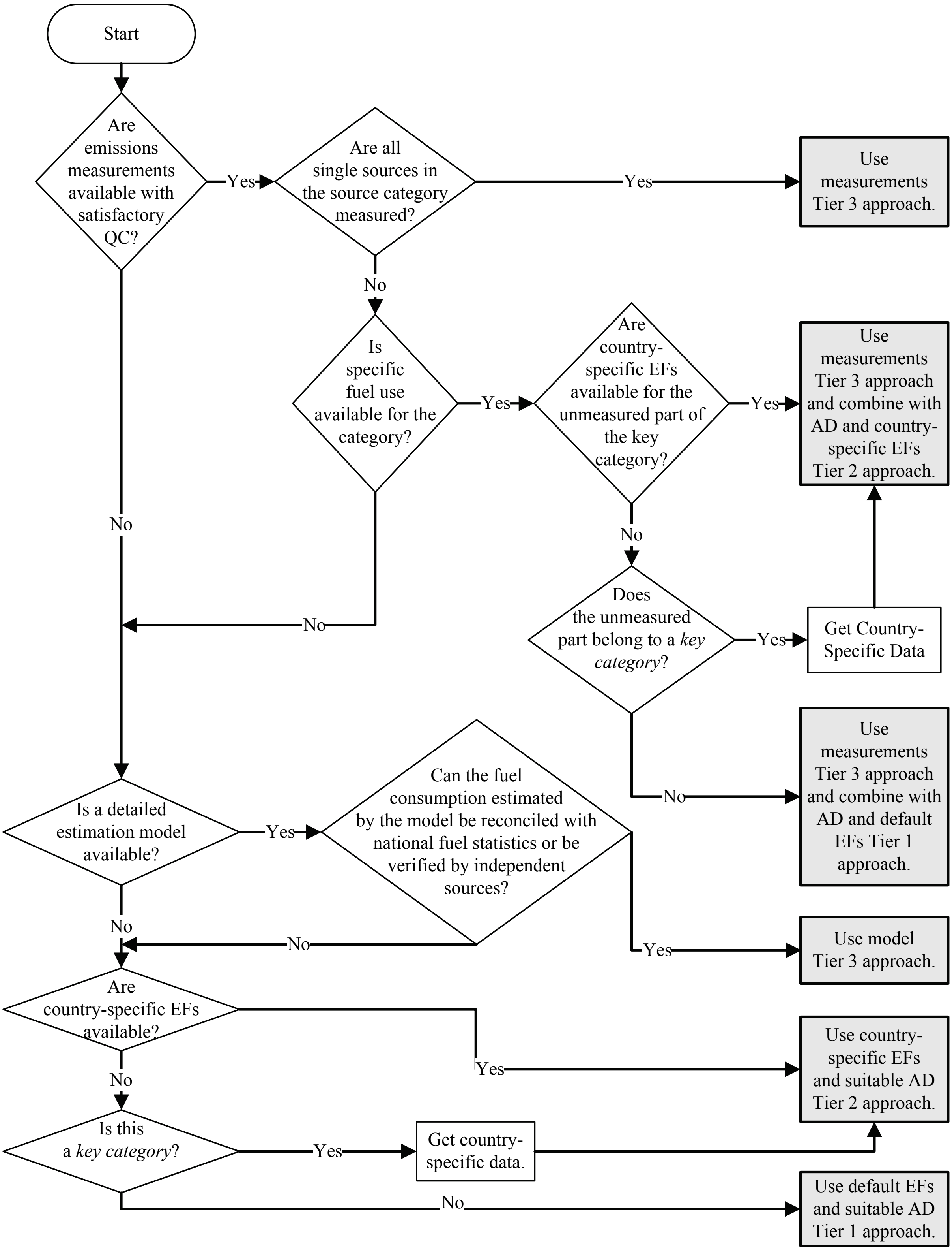
For each source category and greenhouse gas, the inventory compiler has a choice of applying different methods, as described in the Tiers for the source category and gas. The inventory compiler could use different tiers for different source categories, depending on the importance of the source category within the national total (cf. *key categories* Chapter 4 of Volume 1) and the availability of resources in terms of time, work force, sophisticated models, and budget. To perform a *key category* analysis, data on the relative importance of each source category already calculated is required. This knowledge could be derived from an earlier inventory, and updated if necessary.

Figure 1.2 presents a generalized decision tree for selecting Tiers for fuel combustion. This decision tree applies in general for each of the fuel combustion activities and for each of the gases.

The measurements referred to in this decision tree should be considered as continuous measurements. Continuous measurements are becoming more widely available and this increase in availability is in part driven by regulatory pressure and emissions trading. The decision tree allows available emission measurements to be used (Tier 3) in combination with a Tier 2 or Tier 1 estimate within the same activity. Measurements will typically be available only for larger industrial sources and hence only occur in stationary combustion. For $CO_2$, particularly for gaseous and liquid fuels, such measurements should in most cases preferably be used to determine the carbon content of the fuel before combustion, whereas for other gases stack measurements could be applied. For some inhomogeneous solid fuels, stack measurements might provide more precise emission data.

Particularly for road transport, using a Tier 2 or Tier 3 technology-specific method for estimating $N_2O$ and $CH_4$ emissions will usually bring large benefits. However, for $CO_2$ in general, a Tier 1 method based on fuel carbon and fuel amount used will often suffice. This means that the generalized decision tree might result in different approaches for different gases for the same source category. Since emission models and technology-specific methods for road transport might be based on vehicle kilometres travelled rather than on fuel used, it is *good practice* to show that the activity data applied in such models and higher tier methods are consistent with the fuel sales data. These fuel sales data are likely to be used to estimate $CO_2$ emissions from road transport. The decision tree allows the inventory compiler to use sophisticated models in combination with any other Tier methodology, including measurements, provided that the model is consistent with the fuel combustion statistics. In cases where a discrepancy between fuel sales and vehicle kilometres travelled is detected, the activity data, used in the technology-specific method should be adjusted to match fuel sales statistics, unless it can be shown that the fuel sales statistics are inaccurate.

**Figure 1.2 Generalised decision tree for estimating emissions from fuel combustion**



Note: See Volume 1 Chapter 4, "Methodological Choice and Key Categories" (noting section 4.1.2 on limited resources) for discussion of *key categories* and use of decision trees.

### 1.3.1.3 RELATION TO OTHER INVENTORY APPROACHES

The *IPCC Guidelines for National Greenhouse Gas Inventories* are specifically designed for countries to prepare and report inventories of greenhouse gases. Some countries may also be required to submit emission inventories of various gases from the Energy Sector to United Nations Economic Commission for Europe (UNECE) Long Range Transboundary Air Pollution (LRTAP) Convention[2]. The UNECE has adopted the joint European Monitoring Evaluation Programme (EMEP)/CORINAIR Emission Inventory Guidebook [3] for inventory reporting.

Countries which are Parties to different Conventions have to use the appropriate reporting procedures when reporting to a specific Convention. The IPCC approach meets UNFCCC 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.

Considerable progress has been made in the harmonisation of the IPCC and EMEP/CORINAIR approaches. UNECE LRTAP reporting now has accepted a source category split that is fully compatible with the UNFCCC split as defined in the Common Reporting Framework (CRF). Differences only occur in the level of aggregation for some specific sources. Such differences only occur in the energy sector in the transport source categories, where UNECE LRTAP requires further detail in the emissions from road transport.

The CORINAIR programme has developed its approach further to include additional sectors and sub-divisions so that a complete CORINAIR inventory, including emission estimates, can be used to produce reports in both the UNFCCC/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 significant difference between the approaches that remain is the spatial allocation of road transport emissions: while CORINAIR, with a view to the input requirements of atmospheric dispersion models, applies the principle of territoriality (emission allocation according to fuel consumption), the *2006 IPCC Guidelines* follow what is usually the most accurate data: fuel sales (usually fuel sales are more accurate than vehicle kilometres). In the context of these IPCC Guidelines, countries with a substantial disparity between emissions as calculated from fuel sales and from fuel consumption have the option of estimating true consumption and reporting the emissions from consumption and trade separately using appropriate higher tier methods. National totals must be consistent with fuel sales.

Since both approaches are now generally well harmonised, the *2006 IPCC Guidelines* will concentrate on emissions of direct greenhouse gases, $CO_2$, $CH_4$ and $N_2O$ with some advice on NMVOCs where these are closely linked to emissions of direct greenhouse gases (non-energy use of fuels, $CO_2$ inputs to the atmosphere from oxidation of NMVOCs). Users are referred to the EMEP/CORINAIR Emission Inventory Guidebook for emission estimation methods for indirect greenhouse gases and other air pollutants.

## 1.3.2 Fugitive emissions

This volume provides methodologies for the estimation of fugitive emissions of $CO_2$, $CH_4$ and $N_2O$. Methodologies for estimating fugitive emissions from the Energy Sector are very different from those used for fossil fuel combustion. Fugitive emissions tend to be diffuse and may be difficult to monitor directly. In addition, the methods are quite specific to the type of emission release. For example, methods for coal mining are linked

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[2] There are 49 parties to the UNECE Convention on Long-range Transboundary Air Pollution including USA, Canada, most of Europe including Russia, Armenia and Georgia and some central Asian countries such as Kazakhstan and Kyrgyzstan.

[3] See EEA 2005.

to the geological characteristics of the coal seams, whereas methods for fugitive leaks from oil and gas facilities are linked to common types of equipment.

There can be anthropogenic emissions associated with the use of geothermal power. At this stage no methodology to estimate these emissions is available. However if these emissions can be measured, they should be reported in source category 1.B.3 "Other emissions from energy production".

### 1.3.3 $CO_2$ capture and storage

According to the IPCC Third Assessment Report, over the 21st century substantial amounts of $CO_2$ emissions need to be avoided to achieve stabilization of atmospheric greenhouse gas concentrations. $CO_2$ capture and storage (CCS) will be one of the options in the portfolio of measures for stabilization of greenhouse gas concentrations while the use of fossil fuels continues. Chapter 5 of this volume presents an overview of the CCS system and provides emission estimation methods for $CO_2$ capture, $CO_2$ transport, $CO_2$ injection and underground $CO_2$ storage. It is *good practice* for inventory compilers to ensure that the CCS system is handled in a complete and consistent manner across the entire Energy Sector.

## 1.4 DATA COLLECTION ISSUES

### 1.4.1 Activity data

In the Energy sector, the activity data are typically the amounts of fuels combusted. Such data are sufficient to perform a Tier 1 analysis. In higher Tier approaches additional data are required on fuel characteristics and the combustion technologies applied.

In order to ensure transparency and comparability, a consistent classification scheme for fuel types need to be used. This section provides:

1. definitions of the different fuels
2. the units in which to express the activity data
3. guidance on possible sources of activity data and
4. guidance on time series consistency

A clear explanation of energy statistics and energy balances is provided in the "Energy Statistics Manual" of the International Energy Agency (IEA)[4].

#### 1.4.1.1 FUEL DEFINITIONS

Common terms and definitions of fuels are necessary for countries to describe emissions from fuel combustion activities, consistently. A list of fuel types based primarily on the definitions of the International Energy Agency (IEA) is provided below. These definitions are used in the *2006 IPCC Guidelines.*

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[4] OECD/IEA Energy Statistics Manual (2004), OECD/IEA, Paris. This publication can be downloaded for free at www.iea.org .

**TABLE 1.1**
**DEFINITIONS OF FUEL TYPES USED IN THE *2006 IPCC GUIDELINES***

| **English Description** | | **Comments** |
|---|---|---|
| **LIQUID (Crude oil and petroleum products)** | | |
| Crude Oil | | Crude oil is a mineral oil consisting of a mixture of hydrocarbons of natural origin, being yellow to black in colour, of variable density and viscosity. It also includes lease condensate (separator liquids) which are recovered from gaseous hydrocarbons in lease separation facilities. |
| Orimulsion | | A tar-like substance that occurs naturally in Venezuela. It can be burned directly or refined into light petroleum products. |
| Natural Gas Liquids (NGLs) | | NGLs are the liquid or liquefied hydrocarbons produced in the manufacture, purification and stabilisation of natural gas. These are those portions of natural gas which are recovered as liquids in separators, field facilities, or gas processing plants. NGLs include but are not limited to ethane, propane, butane, pentane, natural gasoline and condensate. They may also include small quantities of non-hydrocarbons. |
| Gasoline | Motor Gasoline | This is light hydrocarbon oil for use in internal combustion engines such as motor vehicles, excluding aircraft. Motor gasoline is distilled between 35ºC and 215ºC and is used as a fuel for land based spark ignition engines. Motor gasoline may include additives, oxygenates and octane enhancers, including lead compounds such as TEL (Tetraethyl lead) and TML (Tetramethyl lead). |
| | Aviation Gasoline | Aviation gasoline is motor spirit prepared especially for aviation piston engines, with an octane number suited to the engine, a freezing point of -60ºC, and a distillation range usually within the limits of 30ºC and 180ºC. |
| | Jet Gasoline | This includes all light hydrocarbon oils for use in aviation turbine power units. They distil between 100ºC and 250ºC. It is obtained by blending kerosenes and gasoline or naphthas in such a way that the aromatic content does not exceed 25 percent in volume, and the vapour pressure is between 13.7 kPa and 20.6 kPa. Additives can be included to improve fuel stability and combustibility. |
| Jet Kerosene | | This is medium distillate used for aviation turbine power units. It has the same distillation characteristics and flash point as kerosene (between 150ºC and 300ºC but not generally above 250ºC). In addition, it has particular specifications (such as freezing point) which are established by the International Air Transport Association (IATA). |
| Other Kerosene | | Kerosene comprises refined petroleum distillate intermediate in volatility between gasoline and gas/diesel oil. It is a medium oil distilling between 150ºC and 300ºC. |
| Shale Oil | | A mineral oil extracted from oil shale. |
| Gas/Diesel Oil | | Gas/diesel oil includes heavy gas oils. Gas oils are obtained from the lowest fraction from atmospheric distillation of crude oil, while heavy gas oils are obtained by vacuum redistillation of the residual from atmospheric distillation. Gas/diesel oil distils between 180ºC and 380ºC. Several grades are available depending on uses: diesel oil for diesel compression ignition (cars, trucks, marine, etc.), light heating oil for industrial and commercial uses, and other gas oil including heavy gas oils which distil between 380ºC and 540ºC and are used as petrochemical feedstocks. |
| Residual Fuel Oil | | This heading defines oils that make up the distillation residue. It comprises all residual fuel oils, including those obtained by blending. Its kinematic viscosity is above 0.1cm$^2$ (10 cSt) at 80ºC. The flash point is always above 50ºC and the density is always more than 0.90 kg/l. |
| Liquefied Petroleum Gases | | These are the light hydrocarbons fraction of the paraffin series, derived from refinery processes, crude oil stabilisation plants and natural gas processing plants comprising propane (C3H8) and butane (C4H10) or a combination of the two. They are normally liquefied under pressure for transportation and storage. |

### TABLE 1.1 (CONTINUED)
### DEFINITIONS OF FUEL TYPES USED IN THE *2006 IPCC GUIDELINES*

| **English Description** | | **Comments** |
|---|---|---|
| **LIQUID (Crude oil and petroleum products)** | | |
| Ethane | | Ethane is a naturally gaseous straight-chain hydrocarbon (C2H6). It is a colourless paraffinic gas which is extracted from natural gas and refinery gas streams. |
| Naphtha | | Naphtha is a feedstock destined either for the petrochemical industry (e.g. ethylene manufacture or aromatics production) or for gasoline production by reforming or isomerisation within the refinery. Naphtha comprises material in the 30ºC and 210ºC distillation range or part of this range. |
| Bitumen | | Solid, semi-solid or viscous hydrocarbon with a colloidal structure, being brown to black in colour, obtained as a residue in the distillation of crude oil, vacuum distillation of oil residues from atmospheric distillation. Bitumen is often referred to as asphalt and is primarily used for surfacing of roads and for roofing material. This category includes fluidised and cut back bitumen. |
| Lubricants | | Lubricants are hydrocarbons produced from distillate or residue; they are mainly used to reduce friction between bearing surfaces. This category includes all finished grades of lubricating oil, from spindle oil to cylinder oil, and those used in greases, including motor oils and all grades of lubricating oil base stocks. |
| Petroleum Coke | | Petroleum coke is defined as a black solid residue, obtained mainly by cracking and carbonising of petroleum derived feedstocks, vacuum bottoms, tar and pitches in processes such as delayed coking or fluid coking. It consists mainly of carbon (90 to 95 percent) and has a low ash content. It is used as a feedstock in coke ovens for the steel industry, for heating purposes, for electrode manufacture and for production of chemicals. The two most important qualities are "green coke" and "calcinated coke". This category also includes "catalyst coke" deposited on the catalyst during refining processes: this coke is not recoverable and is usually burned as refinery fuel. |
| Refinery Feedstocks | | A refinery feedstock is a product or a combination of products derived from crude oil and destined for further processing other than blending in the refining industry. It is transformed into one or more components and/or finished products. This definition covers those finished products imported for refinery intake and those returned from the petrochemical industry to the refining industry. |
| Other Oil | Refinery Gas | Refinery gas is defined as non-condensable gas obtained during distillation of crude oil or treatment of oil products (e.g. cracking) in refineries. It consists mainly of hydrogen, methane, ethane and olefins. It also includes gases which are returned from the petrochemical industry. |
| | Waxes | Saturated aliphatic hydrocarbons (with the general formula $C_nH_{2n+2}$). These waxes are residues extracted when dewaxing lubricant oils, and they have a crystalline structure with carbon number greater than 12. Their main characteristics are that they are colourless, odourless and translucent, with a melting point above 45ºC. |
| | White Spirit & SBP | White spirit and SBP are refined distillate intermediates with a distillation in the naphtha/kerosene range. They are sub-divided as: i) Industrial Spirit (SBP): Light oils distilling between 30ºC and 200ºC, with a temperature difference between 5 percent volume and 90 percent volume distillation points, including losses, of not more than 60ºC. In other words, SBP is a light oil of narrower cut than motor spirit. There are 7 or 8 grades of industrial spirit, depending on the position of the cut in the distillation range defined above. ii) White Spirit: Industrial spirit with a flash point above 30ºC. The distillation range of white spirit is 135ºC to 200ºC. |
| | Other Petroleum Products | Includes the petroleum products not classified above, for example: tar, sulphur, and grease. This category also includes aromatics (e.g. BTX or benzene, toluene and xylene) and olefins (e.g. propylene) produced within refineries. |

**TABLE 1.1 (CONTINUED)**
**DEFINITIONS OF FUEL TYPES USED IN THE *2006 IPCC GUIDELINES***

| English Description | | Comments |
|---|---|---|
| **SOLID (Coal and coal products)** | | |
| Anthracite | | Anthracite is a high rank coal used for industrial and residential applications. It has generally less than 10 percent volatile matter and a high carbon content (about 90 percent fixed carbon). Its gross calorific value is greater than 23 865 kJ/kg (5 700 kcal/kg) on an ash-free but moist basis. |
| Coking Coal | | Coking coal refers to bituminous coal with a quality that allows the production of a coke suitable to support a blast furnace charge. Its gross calorific value is greater than 23 865 kJ/kg (5 700 kcal/kg) on an ash-free but moist basis. |
| Other Bituminous Coal | | Other bituminous coal is used for steam raising purposes and includes all bituminous coal that is not included under coking coal. It is characterized by higher volatile matter than anthracite (more than 10 percent) and lower carbon content (less than 90 percent fixed carbon). Its gross calorific value is greater than 23 865 kJ/kg (5 700 kcal/kg) on an ash-free but moist basis. |
| Sub-Bituminous Coal | | Non-agglomerating coals with a gross calorific value between 17 435 kJ/kg (4 165 kcal/kg) and 23 865 kJ/kg (5 700 kcal/kg) containing more than 31 percent volatile matter on a dry mineral matter free basis. |
| Lignite | | Lignite/brown coal is a non-agglomerating coal with a gross calorific value of less than 17 435 kJ/kg (4 165 kcal/kg), and greater than 31 percent volatile matter on a dry mineral matter free basis. |
| Oil Shale and Tar Sands | | Oil shale is an inorganic, non-porous rock containing various amounts of solid organic material that yields hydrocarbons, along with a variety of solid products, when subjected to pyrolysis (a treatment that consists of heating the rock at high temperature). Tar sands refers to sand (or porous carbonate rocks) that are naturally mixed with a viscous form of heavy crude oil sometimes referred to as bitumen. Due to its high viscosity this oil cannot be recovered through conventional recovery methods. |
| Brown Coal Briquettes | | Brown coal briquettes (BKB) are composition fuels manufactured from lignite/brown coal, produced by briquetting under high pressure. These figures include dried lignite fines and dust. |
| Patent Fuel | | Patent fuel is a composition fuel manufactured from hard coal fines with the addition of a binding agent. The amount of patent fuel produced may, therefore, be slightly higher than the actual amount of coal consumed in the transformation process. |
| Coke | Coke Oven Coke and Lignite Coke | Coke oven coke is the solid product obtained from the carbonisation of coal, principally coking coal, at high temperature. It is low in moisture content and volatile matter. Also included are semi-coke, a solid product obtained from the carbonisation of coal at a low temperature, lignite coke, semi-coke made from lignite/brown coal, coke breeze and foundry coke. Coke oven coke is also known as metallurgical coke. |
| | Gas Coke | Gas coke is a by-product of hard coal used for the production of town gas in gas works. Gas coke is used for heating purposes. |
| Coal Tar | | The result of the destructive distillation of bituminous coal. Coal tar is the liquid by-product of the distillation of coal to make coke in the coke oven process. Coal tar can be further distilled into different organic products (e.g. benzene, toluene, naphthalene) which normally would be reported as a feedstock to the petrochemical industry. |
| Derived Gases | Gas Works Gas | Gas works gas covers all types of gases produced in public utility or private plants, whose main purpose is manufacture, transport and distribution of gas. It includes gas produced by carbonization (including gas produced by coke ovens and transferred to gas works gas), by total gasification with or without enrichment with oil products (LPG, residual fuel oil, etc.), and by reforming and simple mixing of gases and/or air. It excludes blended natural gas, which is usually distributed through the natural gas grid. |
| | Coke Oven Gas | Coke oven gas is obtained as a by-product of the manufacture of coke oven coke for the production of iron and steel. |
| | Blast Furnace Gas | Blast furnace gas is produced during the combustion of coke in blast furnaces in the iron and steel industry. It is recovered and used as a fuel partly within the plant and partly in other steel industry processes or in power stations equipped to burn it. |
| | Oxygen Steel Furnace Gas | Oxygen steel furnace gas is obtained as a by-product of the production of steel in an oxygen furnace and is recovered on leaving the furnace. The gas is also known as converter gas, LD gas or BOS gas. |

**TABLE 1.1 (CONTINUED)**
**DEFINITIONS OF FUEL TYPES USED IN THE *2006 IPCC GUIDELINES***

| English Description | | Comments |
|---|---|---|
| **GAS (Natural Gas)** | | |
| Natural Gas | | Natural gas should include blended natural gas (sometimes also referred to as Town Gas or City Gas), a high calorific value gas obtained as a blend of natural gas with other gases derived from other primary products, and usually distributed through the natural gas grid (eg coal seam methane). Blended natural gas should include substitute natural gas, a high calorific value gas, manufactured by chemical conversion of a hydrocarbon fossil fuel, where the main raw materials are: natural gas, coal, oil and oil shale. |
| **OTHER FOSSIL FUELS** | | |
| Municipal Wastes (non-biomass fraction) | | Non-biomass fraction of municipal waste includes waste produced by households, industry, hospitals and the tertiary sector which are incinerated at specific installations and used for energy purposes. Only the fraction of the fuel that is non-biodegradable should be included here. |
| Industrial Wastes | | Industrial waste consists of solid and liquid products (e.g. tyres) combusted directly, usually in specialised plants, to produce heat and/or power and that are not reported as biomass. |
| Waste Oils | | Waste oils are used oils (e.g. waste lubricants) that are combusted for heat production. |
| **PEAT** | | |
| Peat [5] | | Combustible soft, porous or compressed, sedimentary deposit of plant origin including woody material with high water content (up to 90 percent in the raw state), easily cut, can contain harder pieces of light to dark brown colour. Peat used for non-energy purposes is not included. |
| **BIOMASS** | | |
| Solid Biofuels | Wood/Wood Waste | Wood and wood waste combusted directly for energy. This category also includes wood for charcoal production but not the actual production of charcoal (this would be double counting since charcoal is a secondary product). |
| | Sulphite Lyes (Black Liquor) | Sulphite lyes is an alkaline spent liquor from the digesters in the production of sulphate or soda pulp during the manufacture of paper where the energy content derives from the lignin removed from the wood pulp. This fuel in its concentrated form is usually 65-70 percent solid. |
| | Other Primary Solid Biomass | Other primary solid biomass includes plant matter used directly as fuel that is not already included in wood/wood waste or in sulphite lyes. Included are vegetal waste, animal materials/wastes and other solid biomass. This category includes non-wood inputs to charcoal production (e.g. coconut shells) but all other feedstocks for production of biofuels should be excluded. |
| | Charcoal | Charcoal combusted as energy covers the solid residue of the destructive distillation and pyrolysis of wood and other vegetal material. |

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[5] Although peat is not strictly speaking a fossil fuel, its greenhouse gas emission characteristics have been shown in life cycle studies to be comparable to that of fossil fuels (Nilsson and Nilsson, 2004; Uppenberg *et al*., 2001; Savolainen *et al*., 1994). Therefore, the $CO_2$ emissions from combustion of peat are included in the national emissions as for fossil fuels.

**TABLE 1.1 (CONTINUED)**
**DEFINITIONS OF FUEL TYPES USED IN THE *2006 IPCC GUIDELINES***

| English Description | | Comments |
|---|---|---|
| Liquid Biofuels | Biogasoline | Biogasoline should only contain that part of the fuel that relates to the quantities of biofuel and not to the total volume of liquids into which the biofuels are blended. This category includes bioethanol (ethanol produced from biomass and/or the biodegradable fraction of waste), biomethanol (methanol produced from biomass and/or the biodegradable fraction of waste), bioETBE (ethyl-tertio-butyl-ether produced on the basis of bioethanol: the percentage by volume of bioETBE that is calculated as biofuel is 47 percent) and bioMTBE (methyl-tertio-butyl-ether produced on the basis of biomethanol: the percentage by volume of bioMTBE that is calculated as biofuel is 36 percent). |
| | Biodiesels | Biodiesels should only contain that part of the fuel that relates to the quantities of biofuel and not to the total volume of liquids into which the biofuels are blended. This category includes biodiesel (a methyl-ester produced from vegetable or animal oil, of diesel quality), biodimethylether (dimethylether produced from biomass), fischer tropsh (fischer tropsh produced from biomass), cold pressed bio oil (oil produced from oil seed through mechanical processing only) and all other liquid biofuels which are added to, blended with or used straight as transport diesel. |
| | Other Liquid Biofuels | Other liquid biofuels not included in biogasoline or biodiesels. |
| Gas Biomass | Landfill Gas | Landfill gas is derived from the anaerobic fermentation of biomass and solid wastes in landfills and combusted to produce heat and/or power. |
| | Sludge Gas | Sludge gas is derived from the anaerobic fermentation of biomass and solid wastes from sewage and animal slurries and combusted to produce heat and/or power. |
| | Other Biogas | Other biogas not included in landfill gas or sludge gas. |
| Other non-fossil fuels | Municipal Wastes (biomass fraction) | Biomass fraction of municipal waste includes waste produced by households, industry, hospitals and the tertiary sector which are incinerated at specific installations and used for energy purposes. Only the fraction of the fuel that is biodegradable should be included here. |

## 1.4.1.2 CONVERSION OF ENERGY UNITS

In energy statistics and other energy data compilations, production and consumption of solid, liquid and gaseous fuels are specified in physical units, e.g. in tonnes or cubic metres. To convert these data to common energy units, eg joules, requires calorific values. To convert tonnes to energy units, in this case terajoules, requires calorific values. These Guidelines use net calorific values (NCVs), expressed in SI units or multiples of SI units (for example TJ/Mg). Some statistical offices use gross calorific values (GCV). The difference between NCV and GCV is the latent heat of vaporisation of the water produced during combustion of the fuel. As a consequence for coal and oil, the NCV is about 5 percent less than the GCV For most forms of natural and manufactured gas, the NCV is about 10 percent less. The Box 1.1 below provides an algorithm for the conversion if fuel characteristics (moisture, hydrogen and oxygen contents) are known. For common biomass fuels default conversion from NCV to GCV especially bark, wood and wood waste are derived in the Pulp and Paper Greenhouse Gas Calculation Tools available via the WRI/WBCSD Greenhouse Gas Protocol web site[6].

If countries use GCV, they should identify them as such. For further explanations of this issue and how to convert from the one into the other, please consult the IEA's Energy Statistics Manual (OECD/IEA, 2004).

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[6] See page 9 of "Calculation Tools for Estimating Greenhouse Gas Emissions from Pulp and Paper Mills, Version 1.1, July 8, 2005" page 9 available at http://www.ghgprotocol.org/includes/getTarget.asp?type=d&id=MTYwNjQ

**BOX 1.1**
**CONVERSION BETWEEN GROSS AND NET CALORIFIC VALUES**

Units: MJ/kg - Megajoules per kilogram; 1 MJ/kg = 1 Gigajoule/tonne (GJ/tonne)

Gross CV (GCV) or ‘higher heating value’ (HHV) is the calorific value under laboratory conditions.

Net CV (NCV) or 'lower heating value' (LHV) is the useful calorific value in boiler plant. The difference is essentially the latent heat of the water vapour produced.

Conversions - Gross/Net (per ISO, for As Received* figures) in MJ/kg:

$$Net\,CV = Gross\,CV - 0.212H - 0.0245M - 0.008Y$$

where M is percent Moisture, H is percent Hydrogen, Y is percent Oxygen (from ultimate analysis which determines the amount of carbon, hydrogen, oxygen, nitrogen and sulphur) As Received (i.e. includes Total Moisture (TM)).

Source: World Coal Institute (http://www.worldcoal.org/pages/content/index.asp?PageID=190), which provides more details.

Default NCV values to convert from units of $10^3$ tonnes to units of terajoules are in Table 1.2. These values are based on a statistical analysis of three data sources:

1. **Annual greenhouse gas inventory submissions of Annex I Parties**: UNFCCC Annex-1 countries’ national submissions in 2004 on 2002 emissions (Table-1A(b) of the CRF). This dataset contains Net Calorific Values (NCVs), Carbon Emission Factor (CEF) and Carbon Oxidation Factor (COF) for individual fuels for more than 33 Annex 1 countries.
2. **Emission Factor Database**: The IPCC Emission Factor Database (EFDB), version-1, as of December 2003 contains all default values included in the *1996 IPCC Guidelines* and additional data accepted by the EFDB editorial board. The EFDB contains country-specific data for NCV and CEF including developing countries.
3. **IEA Database**: International Energy Agency NCV database for all fuels, as of November 2004. The IEA database contains country-specific NCV data for many countries, including developing countries.

The statistical analysis performed on these datasets has been described in detail in a separate document (Kainou, 2005). The same data set was used to compile a table of default values and uncertainty ranges.

### 1.4.1.3 ACTIVITY DATA SOURCES

Fuel statistics collected by an officially recognised national body are 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.

There are currently two main sources of international energy statistics: the International Energy Agency (IEA), and the United Nations (UN). 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. [7]

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[7] Approximately 130 countries (of about 170 UN Member countries) are included in the IEA data, and represent about 98 per cent of worldwide energy consumption and nearly all energy production.

### TABLE 1.2
### DEFAULT NET CALORIFIC VALUES (NCVS) AND LOWER AND UPPER LIMITS OF THE 95% CONFIDENCE INTERVALS [1]

| Fuel type English description | | Net calorific value (TJ/Gg) | Lower | Upper |
|---|---|---|---|---|
| Crude Oil | | 42.3 | 40.1 | 44.8 |
| Orimulsion | | 27.5 | 27.5 | 28.3 |
| Natural Gas Liquids | | 44.2 | 40.9 | 46.9 |
| Gasoline | Motor Gasoline | 44.3 | 42.5 | 44.8 |
| | Aviation Gasoline | 44.3 | 42.5 | 44.8 |
| | Jet Gasoline | 44.3 | 42.5 | 44.8 |
| Jet Kerosene | | 44.1 | 42.0 | 45.0 |
| Other Kerosene | | 43.8 | 42.4 | 45.2 |
| Shale Oil | | 38.1 | 32.1 | 45.2 |
| Gas/Diesel Oil | | 43.0 | 41.4 | 43.3 |
| Residual Fuel Oil | | 40.4 | 39.8 | 41.7 |
| Liquefied Petroleum Gases | | 47.3 | 44.8 | 52.2 |
| Ethane | | 46.4 | 44.9 | 48.8 |
| Naphtha | | 44.5 | 41.8 | 46.5 |
| Bitumen | | 40.2 | 33.5 | 41.2 |
| Lubricants | | 40.2 | 33.5 | 42.3 |
| Petroleum Coke | | 32.5 | 29.7 | 41.9 |
| Refinery Feedstocks | | 43.0 | 36.3 | 46.4 |
| Other Oil | Refinery Gas [2] | 49.5 | 47.5 | 50.6 |
| | Paraffin Waxes | 40.2 | 33.7 | 48.2 |
| | White Spirit and SBP | 40.2 | 33.7 | 48.2 |
| | Other Petroleum Products | 40.2 | 33.7 | 48.2 |
| Anthracite | | 26.7 | 21.6 | 32.2 |
| Coking Coal | | 28.2 | 24.0 | 31.0 |
| Other Bituminous Coal | | 25.8 | 19.9 | 30.5 |
| Sub-Bituminous Coal | | 18.9 | 11.5 | 26.0 |
| Lignite | | 11.9 | 5.50 | 21.6 |
| Oil Shale and Tar Sands | | 8.9 | 7.1 | 11.1 |
| Brown Coal Briquettes | | 20.7 | 15.1 | 32.0 |
| Patent Fuel | | 20.7 | 15.1 | 32.0 |
| Coke | Coke Oven Coke and Lignite Coke | 28.2 | 25.1 | 30.2 |
| | Gas Coke | 28.2 | 25.1 | 30.2 |
| Coal Tar [3] | | 28.0 | 14.1 | 55.0 |
| Derived Gases | Gas Works Gas [4] | 38.7 | 19.6 | 77.0 |
| | Coke Oven Gas [5] | 38.7 | 19.6 | 77.0 |
| | Blast Furnace Gas [6] | 2.47 | 1.20 | 5.00 |
| | Oxygen Steel Furnace Gas [7] | 7.06 | 3.80 | 15.0 |
| Natural Gas | | 48.0 | 46.5 | 50.4 |
| Municipal Wastes (non-biomass fraction) | | 10 | 7 | 18 |
| Industrial Wastes | | NA | NA | NA |
| Waste Oil [8] | | 40.2 | 20.3 | 80.0 |
| Peat | | 9.76 | 7.80 | 12.5 |

**TABLE 1.2 (CONTINUED)**
**DEFAULT NET CALORIFIC VALUES (NCVS) AND LOWER AND UPPER LIMITS OF THE 95% CONFIDENCE INTERVALS [1]**

| Fuel type English description | | Net calorific value (TJ/Gg) | Lower | Upper |
|---|---|---|---|---|
| Solid Biofuels | Wood/Wood Waste [9] | 15.6 | 7.90 | 31.0 |
| | Sulphite lyes (black liquor) [10] | 11.8 | 5.90 | 23.0 |
| | Other Primary Solid Biomass [11] | 11.6 | 5.90 | 23.0 |
| | Charcoal [12] | 29.5 | 14.9 | 58.0 |
| Liquid Biofuels | Biogasoline [13] | 27.0 | 13.6 | 54.0 |
| | Biodiesels [14] | 27.0 | 13.6 | 54.0 |
| | Other Liquid Biofuels [15] | 27.4 | 13.8 | 54.0 |
| Gas Biomass | Landfill Gas [16] | 50.4 | 25.4 | 100 |
| | Sludge Gas [17] | 50.4 | 25.4 | 100 |
| | Other Biogas [18] | 50.4 | 25.4 | 100 |
| Other non-fossil fuels | Municipal Wastes (biomass fraction) | 11.6 | 6.80 | 18.0 |

Notes:

[1] The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5.

[2] Japanese data; uncertainty range: expert judgement

[3] EFDB; uncertainty range: expert judgement

[4] Coke Oven Gas; uncertainty range: expert judgement

[5-7] Japan and UK small number data; uncertainty range: expert judgement

[8] For waste oils the values of "Lubricants" are taken

[9] EFDB; uncertainty range: expert judgement

[10] Japanese data ; uncertainty range: expert judgement

[11] Solid Biomass; uncertainty range: expert judgement

[12] EFDB; uncertainty range: expert judgement

[13-14] Ethanol theoretical number; uncertainty range: expert judgement;

[15] Liquid Biomass; uncertainty range: expert judgement

[16 -18] Methane theoretical number uncertainty range: expert judgement;

In general, the IEA and UN data for a country can be obtained free of charge by that country's national inventory agencies by contacting stats@iea.org or energy_stat@un.org.

Two types of fuels deserve special attention:

**Biomass:**

Biomass data are generally more uncertain than other data in national energy statistics. A large fraction of the biomass, used for energy, may be part of the informal economy, and the trade in these type of fuels (fuel wood, agricultural residues, dung cakes, etc.) is frequently not registered in the national energy statistics and balances.

The AFOLU Volume 4 Chapter 4 (Forest Land) provides an alternative method to estimate activity data for fuel wood use.

Where data from energy statistics and AFOLU statistics are both available, the inventory compiler should take care to avoid any double counting, and should indicate how data from both sources have been integrated to obtain the best possible estimate of fuel wood use in the country. $CO_2$ emissions from biomass combustion are not included in national totals, but are recorded as an information item for cross-checking purposes as well as avoiding double counting. Note that peat is not treated as biomass in these guidelines, therefore $CO_2$ emissions from peat are estimated.

**Waste:**

Waste incineration may occur in installations where the combustion heat is used as energy in other processes. In such cases, this waste must be treated as a fuel and the emissions should be reported in the energy sector. When waste is incinerated without using the combustion heat as energy, emissions should be reported under waste incineration. Methodologies in both cases are provided in Volume 5 Chapter 5. $CO_2$ emissions from combustion of biomass in waste used for energy are not included in national totals, but are recorded as an information item for cross-checking purposes.

### 1.4.1.4 TIME SERIES CONSISTENCY

Many countries have long time series of energy statistics that can be used to derive time series of energy sector greenhouse gas emissions. However, in many cases statistical practices (including definitions of fuels, of fuel use by sectors) will have changed over time and recalculations of the energy data in the latest set of definitions is not always feasible. In compiling time series of emissions from fuel combustion, these changes might give rise to time series inconsistencies, which should be dealt with using the methods provided in Time Series Consistency Chapter 5 of Volume 1 of the *2006 IPCC Guidelines*.

## 1.4.2 Emission factors

### 1.4.2.1 $CO_2$ EMISSION FACTORS

Combustion processes are optimized to derive the maximum amount of energy per unit of fuel consumed, hence delivering the maximum amount of $CO_2$. Efficient fuel combustion ensures oxidation of the maximum amount of carbon available in the fuel. $CO_2$ emission factors for fuel combustion are therefore relatively insensitive to the combustion process itself and hence are primarily dependent only on the carbon content of the fuel.

The carbon content may vary considerably both among and within primary fuel types on a per mass or per volume basis:

- For natural gas, the carbon content depends on the composition of the gas which, in its delivered state, is primarily methane, but can include small quantities of ethane, propane, butane, and heavier hydrocarbons. Natural gas flared at the production site will usually contain far larger amounts of non-methane hydrocarbons. The carbon content will be correspondingly different.
- Carbon content per unit of energy is usually less for light refined products such as gasoline than for heavier products such as residual fuel oil.
- For coal, carbon emissions per tonne vary considerably depending on the coal's composition of carbon, hydrogen, sulphur, ash, oxygen, and nitrogen.

By converting to energy units this variability is reduced.

A small part of the fuel carbon entering the combustion process escapes oxidation. This fraction is usually small (99 to 100 percent of the carbon is oxidized) and so the default emission factors in Table 1.4 are derived on the assumption of 100 percent oxidation. For some fuels, this fraction may in practice not be negligible and where representative country-specific values, based on measurements are available, they should be used. In other words: the fraction of carbon oxidised is assumed to be 1 in deriving default $CO_2$ emission factors.

Table 1.3 gives carbon contents of fuels from which emission factors on a full molecular weight basis can be calculated (Table 1.4). These emission factors are default values that are suggested only if country-specific factors are not available. More detailed and up-to-date emission factors may be available at the IPCC EFDB.

Note that $CO_2$ emissions from biomass fuels are not included in the national total but are reported as an information item. Net emissions or removals of $CO_2$ are estimated in the AFOLU sector and take account of these emissions. Note that peat is treated as a fossil fuel and not a biofuel and emissions from its combustion are therefore included in the national total.

The data presented in Table 1.3 is used to calculate default emission factors for each fuel on a per energy basis. If activity data are available on a per mass basis, a similar approach can be applied to these activity data directly. Obviously the carbon content then should be known on a per mass basis.

### TABLE 1.3
### DEFAULT VALUES OF CARBON CONTENT

| Fuel type English description | Default carbon content [1] (kg/GJ) | Lower | Upper |
|---|---|---|---|
| Crude Oil | 20.0 | 19.4 | 20.6 |
| Orimulsion | 21.0 | 18.9 | 23.3 |
| Natural Gas Liquids | 17.5 | 15.9 | 19.2 |
| Motor Gasoline | 18.9 | 18.4 | 19.9 |
| Aviation Gasoline | 19.1 | 18.4 | 19.9 |
| Jet Gasoline | 19.1 | 18.4 | 19.9 |
| Jet Kerosene | 19.5 | 19 | 20.3 |
| Other Kerosene | 19.6 | 19.3 | 20.1 |
| Shale Oil | 20.0 | 18.5 | 21.6 |
| Gas/Diesel Oil | 20.2 | 19.8 | 20.4 |
| Residual Fuel Oil | 21.1 | 20.6 | 21.5 |
| Liquefied Petroleum Gases | 17.2 | 16.8 | 17.9 |
| Ethane | 16.8 | 15.4 | 18.7 |
| Naphtha | 20.0 | 18.9 | 20.8 |
| Bitumen | 22.0 | 19.9 | 24.5 |
| Lubricants | 20.0 | 19.6 | 20.5 |
| Petroleum Coke | 26.6 | 22.6 | 31.3 |
| Refinery Feedstocks | 20.0 | 18.8 | 20.9 |
| Refinery Gas [2] | 15.7 | 13.3 | 19.0 |
| Paraffin Waxes | 20.0 | 19.7 | 20.3 |
| White Spirit & SBP | 20.0 | 19.7 | 20.3 |
| Other Petroleum Products | 20.0 | 19.7 | 20.3 |
| Anthracite | 26.8 | 25.8 | 27.5 |
| Coking Coal | 25.8 | 23.8 | 27.6 |
| Other Bituminous Coal | 25.8 | 24.4 | 27.2 |
| Sub-Bituminous Coal | 26.2 | 25.3 | 27.3 |
| Lignite | 27.6 | 24.8 | 31.3 |
| Oil Shale and Tar Sands | 29.1 | 24.6 | 34 |
| Brown Coal Briquettes | 26.6 | 23.8 | 29.6 |
| Patent Fuel | 26.6 | 23.8 | 29.6 |
| Coke Oven Coke and Lignite Coke | 29.2 | 26.1 | 32.4 |
| Gas Coke | 29.2 | 26.1 | 32.4 |
| Coal Tar [3] | 22.0 | 18.6 | 26.0 |
| Gas Works Gas [4] | 12.1 | 10.3 | 15.0 |
| Coke Oven Gas [5] | 12.1 | 10.3 | 15.0 |
| Blast Furnace Gas [6] | 70.8 | 59.7 | 84.0 |
| Oxygen Steel Furnace Gas [7] | 49.6 | 39.5 | 55.0 |
| Natural Gas | 15.3 | 14.8 | 15.9 |

**TABLE 1.3 (CONTINUED)**
**DEFAULT VALUES OF CARBON CONTENT**

| Fuel type English description | Default carbon content [1] (kg/GJ) | Lower | Upper |
|---|---|---|---|
| Municipal Wastes (non-biomass fraction)[8] | 25.0 | 20.0 | 33.0 |
| Industrial Wastes | 39.0 | 30.0 | 50.0 |
| Waste Oils [9] | 20.0 | 19.7 | 20.3 |
| Peat | 28.9 | 28.4 | 29.5 |
| Wood/Wood Waste [10] | 30.5 | 25.9 | 36.0 |
| Sulphite lyes (black liquor) [11] | 26.0 | 22.0 | 30.0 |
| Other Primary Solid Biomass [12] | 27.3 | 23.1 | 32.0 |
| Charcoal [13] | 30.5 | 25.9 | 36.0 |
| Biogasoline [14] | 19.3 | 16.3 | 23.0 |
| Biodiesels [15] | 19.3 | 16.3 | 23.0 |
| Other Liquid Biofuels [16] | 21.7 | 18.3 | 26.0 |
| Landfill Gas [17] | 14.9 | 12.6 | 18.0 |
| Sludge Gas [18] | 14.9 | 12.6 | 18.0 |
| Other Biogas [19] | 14.9 | 12.6 | 18.0 |
| Municipal Wastes (biomass fraction) [20] | 27.3 | 23.1 | 32.0 |

Notes:

[1] The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5

[2] Japanese data; uncertainty range: expert judgement;

[3] EFDB; uncertainty range: expert judgement

[4] Coke Oven Gas; uncertainty range: expert judgement

[5] Japan & UK small number data; uncertainty range: expert judgement

[6] 7. Japan & UK small number data; uncertainty range: expert judgement

[8] Solid Biomass; uncertainty range: expert judgement

[9] Lubricants ; uncertainty range: expert judgement

[10] EFDB; uncertainty range: expert judgement

[11] Japanese data; uncertainty range: expert judgement

[12] Solid Biomass; uncertainty range: expert judgement

[13] EFDB; uncertainty range: expert judgement

[14] Ethanol theoretical number; uncertainty range: expert judgement

[15] Ethanol theoretical number; uncertainty range: expert judgement

[16] Liquid Biomass; uncertainty range: expert judgement

[17-19] Methane theoretical number; uncertainty range: expert judgement

[20] Solid Biomass; uncertainty range: expert judgement

### TABLE 1.4
### DEFAULT $CO_2$ EMISSION FACTORS FOR COMBUSTION [1]

| Fuel type English description | | Default carbon content (kg/GJ) | Default carbon oxidation factor | Effective $CO_2$ emission factor (kg/TJ) [2] | | |
|---|---|---|---|---|---|---|
| | | | | Default value [3] | 95% confidence interval | |
| | | A | B | C=A*B*44/12*1000 | Lower | Upper |
| Crude Oil | | 20.0 | 1 | 73 300 | 71 100 | 75 500 |
| Orimulsion | | 21.0 | 1 | 77 000 | 69 300 | 85 400 |
| Natural Gas Liquids | | 17.5 | 1 | 64 200 | 58 300 | 70 400 |
| Gasoline | Motor Gasoline | 18.9 | 1 | 69 300 | 67 500 | 73 000 |
| | Aviation Gasoline | 19.1 | 1 | 70 000 | 67 500 | 73 000 |
| | Jet Gasoline | 19.1 | 1 | 70 000 | 67 500 | 73 000 |
| Jet Kerosene | | 19.5 | 1 | 71 500 | 69 700 | 74 400 |
| Other Kerosene | | 19.6 | 1 | 71 900 | 70 800 | 73 700 |
| Shale Oil | | 20.0 | 1 | 73 300 | 67 800 | 79 200 |
| Gas/Diesel Oil | | 20.2 | 1 | 74 100 | 72 600 | 74 800 |
| Residual Fuel Oil | | 21.1 | 1 | 77 400 | 75 500 | 78 800 |
| Liquefied Petroleum Gases | | 17.2 | 1 | 63 100 | 61 600 | 65 600 |
| Ethane | | 16.8 | 1 | 61 600 | 56 500 | 68 600 |
| Naphtha | | 20.0 | 1 | 73 300 | 69 300 | 76 300 |
| Bitumen | | 22.0 | 1 | 80 700 | 73 000 | 89 900 |
| Lubricants | | 20.0 | 1 | 73 300 | 71 900 | 75 200 |
| Petroleum Coke | | 26.6 | 1 | 97 500 | 82 900 | 115 000 |
| Refinery Feedstocks | | 20.0 | 1 | 73 300 | 68 900 | 76 600 |
| Other Oil | Refinery Gas | 15.7 | 1 | 57 600 | 48 200 | 69 000 |
| | Paraffin Waxes | 20.0 | 1 | 73 300 | 72 200 | 74 400 |
| | White Spirit & SBP | 20.0 | 1 | 73 300 | 72 200 | 74 400 |
| Other Petroleum Products | | 20.0 | 1 | 73 300 | 72 200 | 74 400 |
| Anthracite | | 26.8 | 1 | 98 300 | 94 600 | 101 000 |
| Coking Coal | | 25.8 | 1 | 94 600 | 87 300 | 101 000 |
| Other Bituminous Coal | | 25.8 | 1 | 94 600 | 89 500 | 99 700 |
| Sub-Bituminous Coal | | 26.2 | 1 | 96 100 | 92 800 | 100 000 |
| Lignite | | 27.6 | 1 | 101 000 | 90 900 | 115 000 |
| Oil Shale and Tar Sands | | 29.1 | 1 | 107 000 | 90 200 | 125 000 |
| Brown Coal Briquettes | | 26.6 | 1 | 97 500 | 87 300 | 109 000 |
| Patent Fuel | | 26.6 | 1 | 97 500 | 87 300 | 109 000 |
| Coke | Coke oven coke and lignite Coke | 29.2 | 1 | 107 000 | 95 700 | 119 000 |
| | Gas Coke | 29.2 | 1 | 107 000 | 95 700 | 119 000 |
| Coal Tar | | 22.0 | 1 | 80 700 | 68 200 | 95 300 |
| Derived Gases | Gas Works Gas | 12.1 | 1 | 44 400 | 37 300 | 54 100 |
| | Coke Oven Gas | 12.1 | 1 | 44 400 | 37 300 | 54 100 |
| | Blast Furnace Gas [4] | 70.8 | 1 | 260 000 | 219 000 | 308 000 |
| | Oxygen Steel Furnace Gas [5] | 49.6 | 1 | 182 000 | 145 000 | 202 000 |

**TABLE 1.4 (CONTINUED)**
**DEFAULT $CO_2$ EMISSION FACTORS FOR COMBUSTION [1]**

| Fuel type English description | | Default carbon content (kg/GJ) | Default carbon oxidation Factor | Effective $CO_2$ emission factor (kg/TJ) [2] | | |
|---|---|---|---|---|---|---|
| | | | | Default value | 95% confidence interval | |
| | | | | | Lower | Upper |
| | | A | B | C=A*B*44/ 12*1000 | | |
| Natural Gas | | 15.3 | 1 | 56 100 | 54 300 | 58 300 |
| Municipal Wastes (non-biomass fraction) | | 25.0 | 1 | 91 700 | 73 300 | 121 000 |
| Industrial Wastes | | 39.0 | 1 | 143 000 | 110 000 | 183 000 |
| Waste Oil | | 20.0 | 1 | 73 300 | 72 200 | 74 400 |
| Peat | | 28.9 | 1 | 106 000 | 100 000 | 108 000 |
| Solid Biofuels | Wood/Wood Waste | 30.5 | 1 | 112 000 | 95 000 | 132 000 |
| | Sulphite lyes (black liquor)[5] | 26.0 | 1 | 95 300 | 80 700 | 110 000 |
| | Other Primary Solid Biomass | 27.3 | 1 | 100 000 | 84 700 | 117 000 |
| | Charcoal | 30.5 | 1 | 112 000 | 95 000 | 132 000 |
| Liquid Biofuels | Biogasoline | 19.3 | 1 | 70 800 | 59 800 | 84 300 |
| | Biodiesels | 19.3 | 1 | 70 800 | 59 800 | 84 300 |
| | Other Liquid Biofuels | 21.7 | 1 | 79 600 | 67 100 | 95 300 |
| Gas biomass | Landfill Gas | 14.9 | 1 | 54 600 | 46 200 | 66 000 |
| | Sludge Gas | 14.9 | 1 | 54 600 | 46 200 | 66 000 |
| | Other Biogas | 14.9 | 1 | 54 600 | 46 200 | 66 000 |
| Other non-fossil fuels | Municipal Wastes (biomass fraction) | 27.3 | 1 | 100 000 | 84 700 | 117 000 |

Notes:

[1] The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5

[2] TJ = 1000GJ

[3] The emission factor values for BFG includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas.

[4] The emission factor values for OSF includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas

[5] Includes the biomass-derived $CO_2$ emitted from the black liquor combustion unit and the biomass-derived $CO_2$ emitted from the kraft mill lime kiln.

### 1.4.2.2 OTHER GREENHOUSE GASES

Emission factors for non-$CO_2$ gases from fuel combustion are strongly dependent on the technology used. Since the set of technologies, applied in each sector varies considerably, so do the emission factors. Therefore it is not useful to provide default emission factors for these gases on the basis of fuels only. Tier 1 default emission factors are therefore provided in the subsequent chapters for each subsector separately.

### 1.4.2.3 INDIRECT GREENHOUSE GASES

This volume will not present guidance on the estimation of emissions of indirect greenhouse gases. For information on these gases, the user is referred to guidance provided under other conventions (see also section 1.3.1.3 Relation to other inventory approaches). Default methods for estimating these emissions are provided in the EMEP/CORINAIR Guidebook. Chapter 7 of Volume 1 provides full details on how to link to this information.

# 1.5 UNCERTAINTY IN INVENTORY ESTIMATES

## 1.5.1 General

A general treatment of uncertainties in emission inventories is provided in Chapter 3 of Volume 1 of the *2006 IPCC Guidelines*. A quantitative analysis of the uncertainties in the inventory need quantitative input values for both activity data and emission factors. This chapter will provide recommended default uncertainty ranges (95 percent confidence interval limits) to be used if further information is not available. The lower limit (marked as “lower” in the tables) is set at the 2.5 percent percentile of the probability distribution function and the upper limit (marked “upper” in the tables) at the 97.5 percentile.

All default values in this chapter are rounded to three significant digits, both for the default emission factor itself and for the lower and upper limits of the 95 percent confidence intervals. Although applying exact arithmetic could provide more digits, these are not considered as significant.

## 1.5.2 Activity data uncertainties

Activity data needed for emission estimates in the Energy Sector are largely derived from national and international energy balances and energy statistics. Such data are generally seen as quite accurate. Uncertainty information on the fuel combustion statistics or the energy balances could be obtained from the national or international institutions responsible.

If no further data are available, the recommended default uncertainty range for fossil fuel combustion data should be assumed to be plus or minus 5 percent. In other words:

- The value in the energy statistics or energy balance is interpreted as the point estimate for the activity data
- The lower limit value of the 95 percent confidence interval is 0.95 times the point estimate;
- The upper limit value of the 95 percent confidence interval is 1.05 times this value.

The "statistical difference", frequently given in energy balances, could also be used to obtain a feeling for the uncertainty in the data. The “statistical difference” is calculated from the difference between data derived from the supply of fuels and data derived from the demand of fuels. The year-to-year variation in its value reflects the aggregated uncertainty in all underlying fuel data including their inter relationships. Hence, the variation of the “statistical difference” will be an indication of the combined uncertainty of all supply and demand data for a specific fuel. Recalling that the uncertainties are expressed in percentage terms, the uncertainties in the fuel combustion data for specific sectors or applications will usually be higher than the uncertainty suggested by the “statistical difference”. The recommended default uncertainty range is based on this line of thought. However, if a “statistical difference” is zero, the balance is immediately suspect and should be treated as though a “statistical difference” had not been given. In these instances, the data quality should be examined for QA/QC purposes and subsequent improvements made if appropriate.

Since data on biomass as fuel are not as well developed as for fossil fuels, the uncertainty range for biomass fuels will be significantly higher. A value of plus or minus 50 percent is recommended.

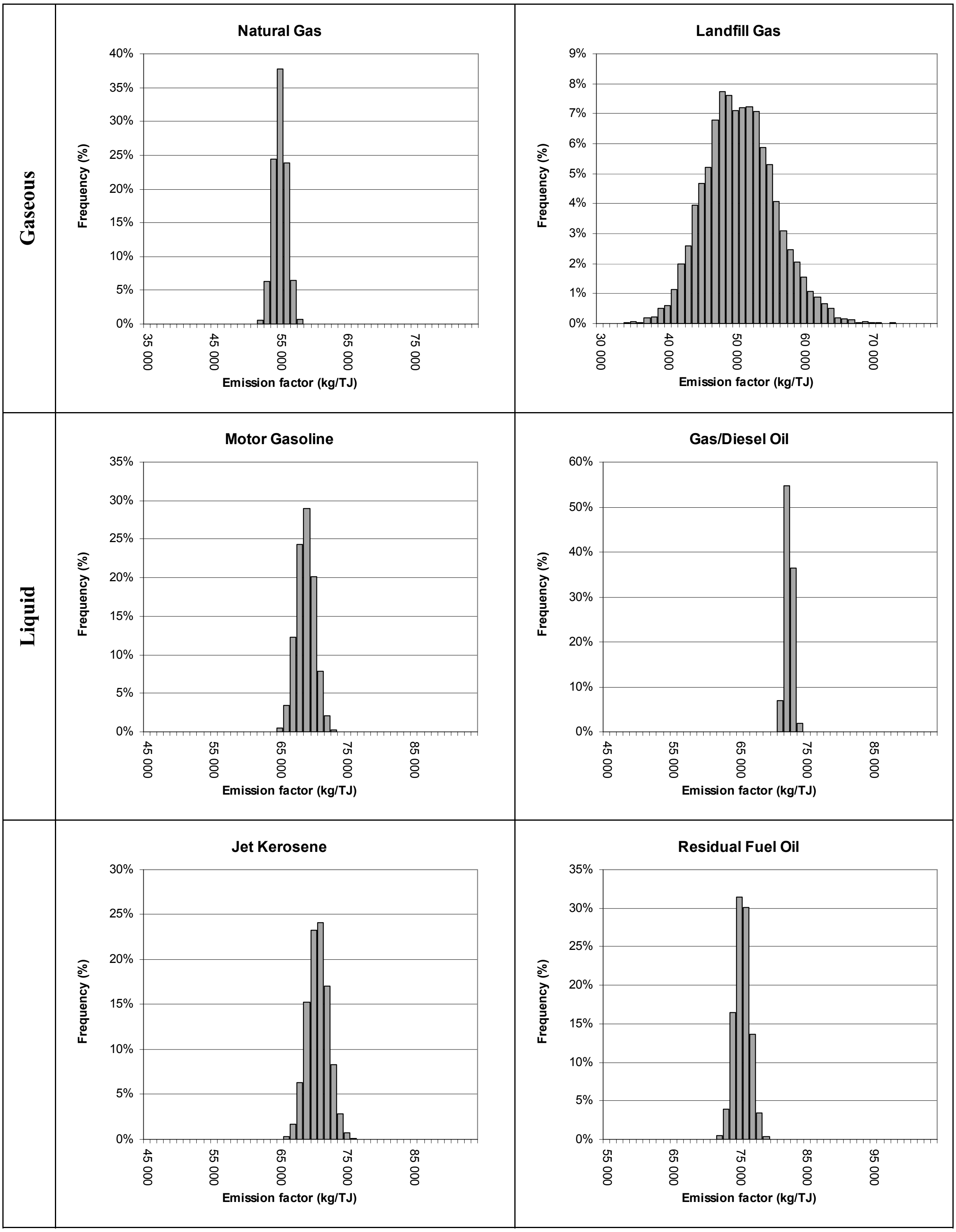
## 1.5.3 Emission factor uncertainties

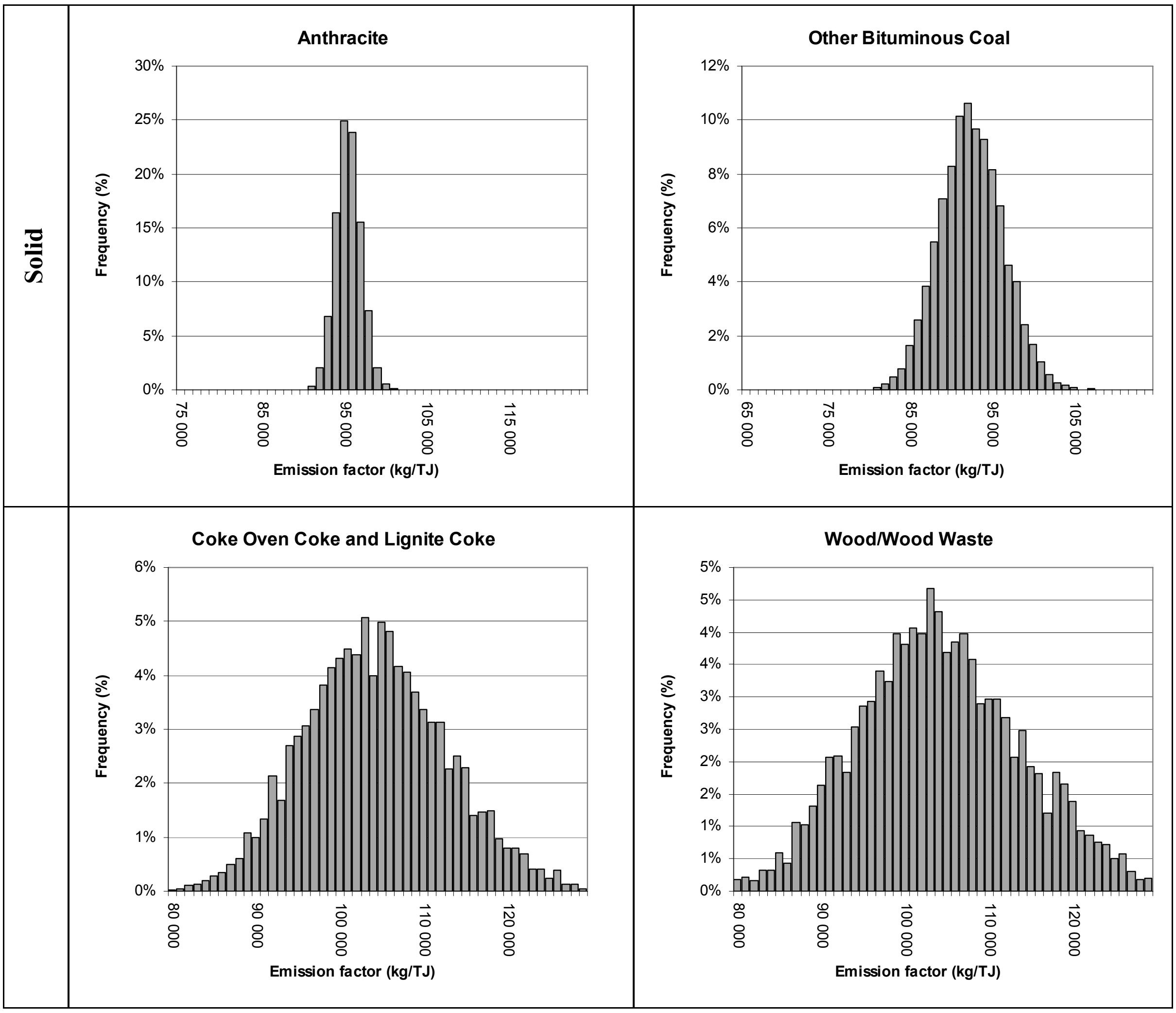
The default emission factors, derived in this chapter are based on a statistical analysis of available data on fuel characteristics. The analysis provides lower and upper limits of the 95 percent confidence intervals as provided in Table 1.2 for net calorific values and Table 1.3 for carbon contents of fuels.

The uncertainty ranges, provided in Table 1.4 are calculated from this information, using a Monte Carlo analysis (5 000 iterations). In this analysis, lognormal distributions, fitted to the provided lower and upper limits of the 95 percent confidence intervals were applied for the probability distribution functions.

For a few typical examples, the resulting probability distribution functions for the default final effective $CO_2$ emission factors are given below in Figure 1.3.

**Figure 1.3** **Some typical examples of probability distribution functions (PDFs) for the effective $CO_2$ emission factors for the combustion of fuels.**





The uncertainty information as presented in Table 1.4 can also be used when comparing country-specific emission factors with the default ones. Whenever a national specific emission factor falls within the 95 percent confidence interval, it could be regarded as consistent with the default value. In addition, one would expect the uncertainty range of country-specific values for application in that country to be smaller than the range provided in Figure 1.3. Uncertainties in emission factors for non-$CO_2$ emission factors are treated in the subsequent chapters for the different source categories separately.

# 1.6 QA/QC AND COMPLETENESS

## 1.6.1 Reference Approach

As carbon dioxide emissions from fuel combustion dominate greenhouse gas emissions in many countries, it is worthwhile to use an independent check providing a quick and easy alternative estimate of these emissions. The Reference Approach provides a methodology for producing a first-order estimate of national greenhouse gas emissions based on the energy supplied to a country, even if only very limited resources and data structures are available to the inventory compiler. Since the Reference Approach is a top-down approach and in that respect is relatively independent of the bottom-up approach as described in the Tier 1, 2 and 3 methods of this chapter, the Reference Approach can be seen as a verification cross-check. As such it is part of the required QA/QC for the energy sector. The Reference Approach is described in full detail in Chapter 6 of this Volume.

The Reference Approach requires statistics on the production of fuels, on their external trade, as well as on changes in their stocks. It also requires a limited amount of data on the consumption of fuels used for non-energy purposes where carbon may need to be excluded.

The Reference Approach is based on the assumption that, once carbon is brought into a national economy in the form of a fuel, it is either released into the atmosphere in the form of a greenhouse gas, or it is diverted (e.g., in increases of fuel stocks, stored in products, left unutilised in ash) and does not enter the atmosphere as a greenhouse gas. In order to calculate the amount of carbon released into the atmosphere, it is not necessary to know exactly how the fuel was used or what intermediate transformations it underwent. In view of this, the methodology may be described as *top-down* in contrast to the *bottom-up* methodologies applied in a sectoral approach.

## 1.6.2 Potential double counting between sectors

### 1.6.2.1 NON-ENERGY USE OF FUELS

For a number of applications, mainly in larger industrial processes, fossil hydrocarbons are not only used as energy sources, but also have other uses e.g. feedstocks, lubricants, solvents, etc. The sectoral approaches (Tier 1, 2 and 3) are therefore based on fuel combustion statistics.

Hence, the use of fuel combustion statistics rather than fuel delivery statistics is key to avoid double counting in emission estimates. When activity data are not quantities of fuel combusted but are instead deliveries to enterprises or main subcategories, there is a risk of double counting emissions from the IPPU (Chapter 5) or Waste Sectors.

In some types of non-energy use of fossil hydrocarbons, emissions of fossil carbon containing substances might occur. Such emissions should be reported under the IPPU sector where they occur. Methods to estimate these emissions are provided in Volume 3, Industrial Processes and Product Use.

### 1.6.2.2 WASTE AS A FUEL

Some waste incinerators also produce heat or power. In such cases the waste stream will show up in national energy statistics and it is *good practice* to report these emissions under the energy sector. This could lead to double counting when in the waste sector the total volume of waste is used to estimate emissions. Only the fossil fuel derived fraction of $CO_2$ from waste is included in national total emissions. For details please see Volume 5 (Waste)-Chapter 5 (Incineration and Open Burning of Waste) where methodological issues to estimate emissions are discussed.

## 1.6.3 Mobile versus stationary combustion

For most sources the distinction between mobile and stationary combustion is quite clear. In energy statistics, this however is not always the case. In some industries it might occur that fuels are in part used for stationary equipment and in part for mobile equipment. This could for example occur in agriculture, forestry, construction industry etc. When this occurs and a split between mobile and stationary is not feasible, the emissions could be reported in the source category that is expected to have the largest part of the emissions. In such cases, care must be taken to properly document the method and choices.

## 1.6.4 National boundaries

Mobile sources, while moving across national borders, might carry part of the fuel sold in one country for use in a second country. To estimate these emissions, however, the principle of using fuel sold to estimate the emissions should prevail over a strict application of the national territory for several reasons:

- data on fuels moving across borders in vehicle fuel tanks is unlikely to be available at all, and if it were it is likely to be much less accurate than national fuel sales data
- it is important that emissions from fuel sold appear in only one county's inventory. It would be nearly impossible to ensure consistency between neighbouring countries
- in most cases the net effect of trans-boundary traffic will be small since most vehicles will in the end return to their own country with fuel in their tanks. Only in cases of "fuel tourism[8]" this might not be the case.

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[8] People living near national borders might have an incentive to buy gasoline in one country for use in the other country if gasoline prices differ between these countries. In some regions this effect is substantial. See: Fuel tourism in border regions, Silvia Banfi, Massimo Filippini, Lester C. Hunt, CEPE, Centre for Energy Policy and Economics, Swiss Federal Institutes of Technology, 2003, http://e-collection.ethbib.ethz.ch/show?type=incoll&nr=888

Other advice on boundary issues associated with bunker fuels and carbon capture and storage is provided in subsequent chapters, consistent with the principles set out in Volume 1, Chapter 8.

## 1.6.5 New sources

The *2006 IPCC Guidelines* include, for the first time, methods for estimating emissions from carbon dioxide capture and storage (Chapter 5) so that the effect of these technologies on reducing emissions overall can be properly reflected in national inventories. The Guidelines also include new methods for estimation emissions from abandoned coal mines (Section 4.1), to complement the methods for working mines which were already included in the *1996 IPCC Guidelines and GPG2000.*

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