Training on preparation and reporting of results of national GHG inventories under the ETF of the Paris Agreement

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Tokyo, Japan 22-24 May 2024

Energy data and approaches: international bunker fuel emissions, reference approach, and feedstocks and non-energy use of fuels. Include examples and exercises

Jaypalsinh Chauhan
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Energy Sector

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Source categories and definitions

- 1.A Fuel combustion (stationary and mobile)
- 1.B Fugitive emissions
- 1.C Carbon Capture and Storage (CCS)

Methodological approaches

- Tier 1, Tier 2, Tier 3
- Activity data
- Emission factor
- Reference approach
- Energy Balance

Other

- Main activity electricity generation and autoproducers
- International bunker fuel emissions
- Feedstocks and non-energy use of fuels

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Energy Sector (1A)

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Activities in the energy sector

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

- 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.

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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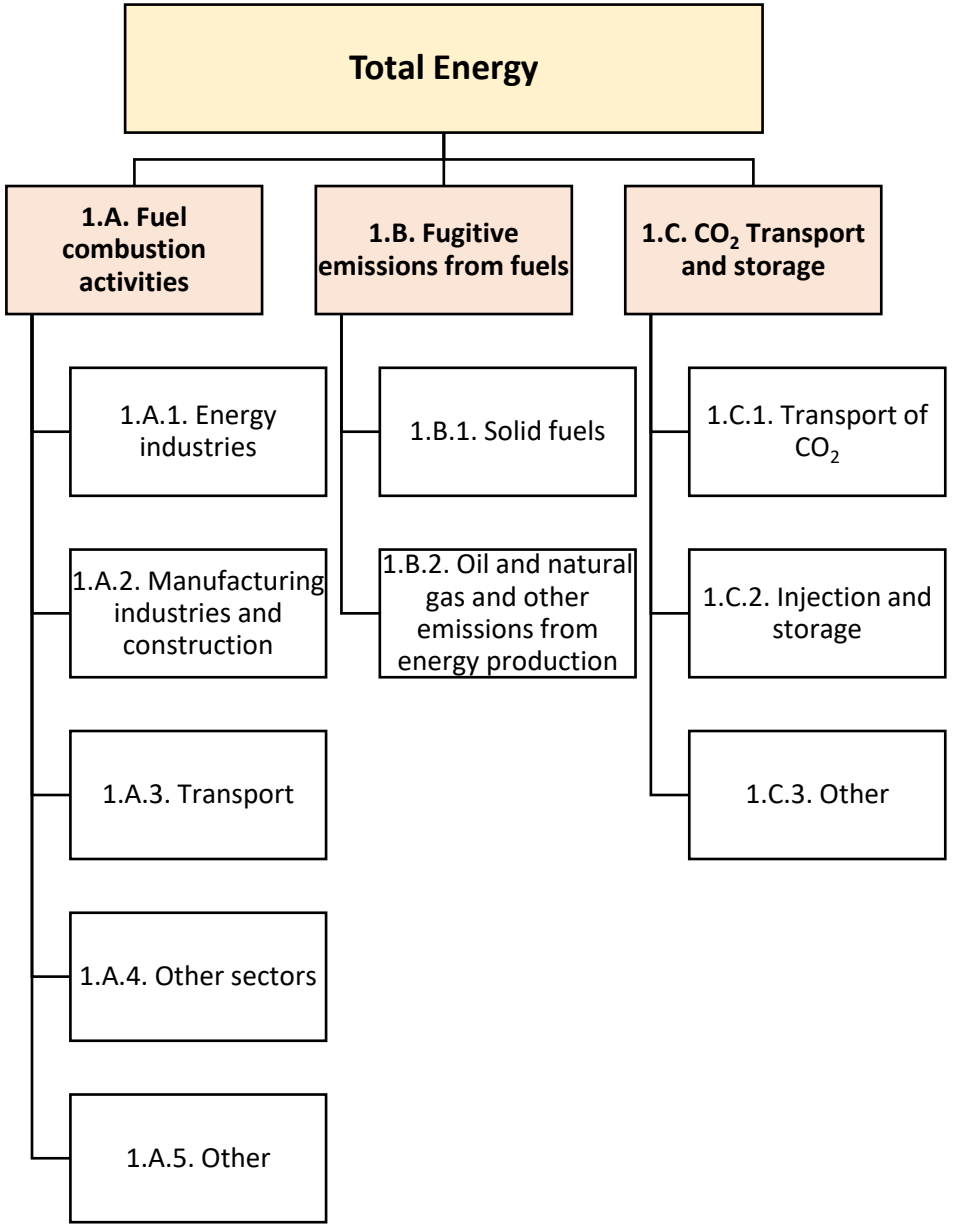
Energy sector: Scope and Coverage



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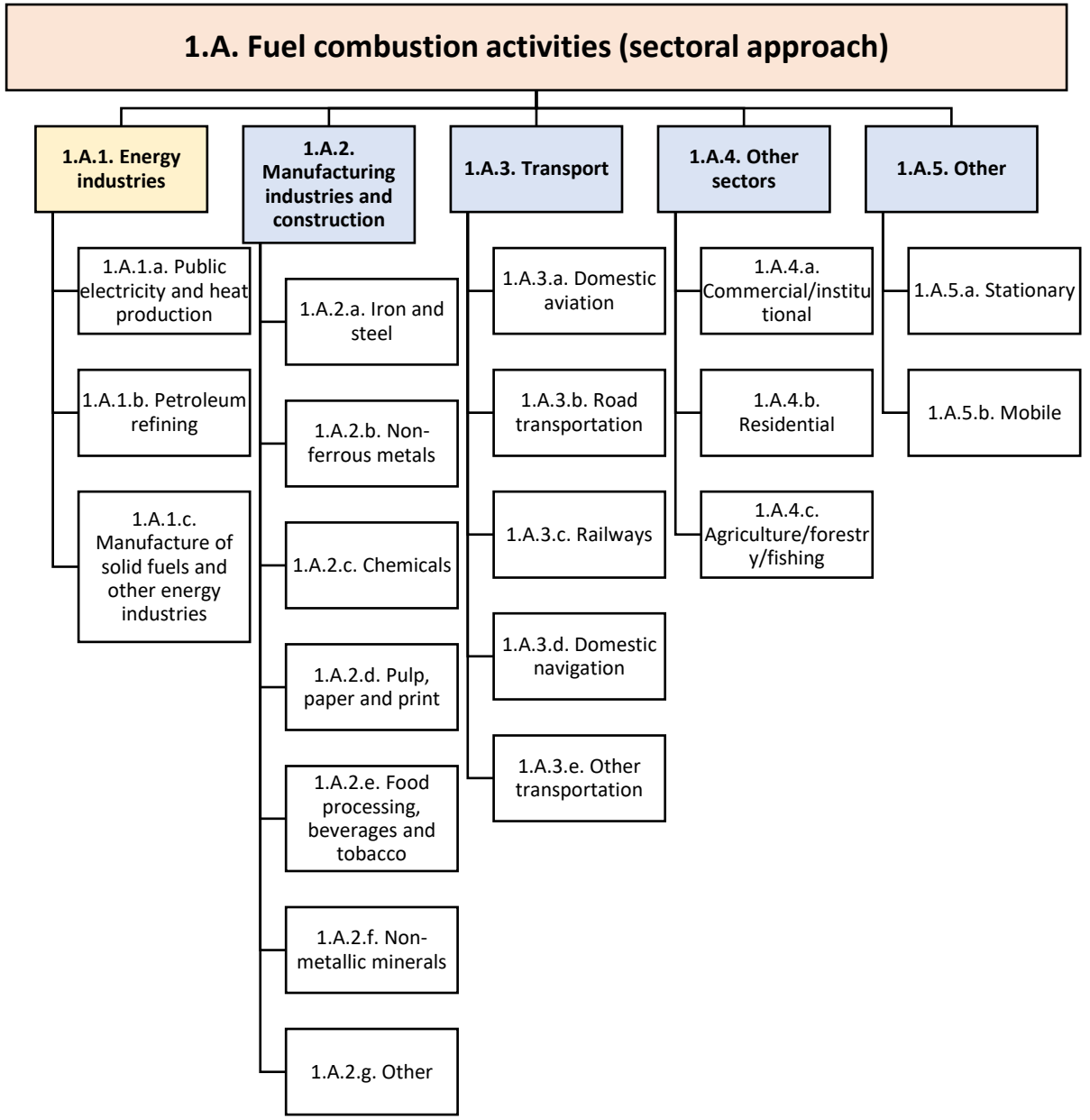
Energy sector: Scope and Coverage



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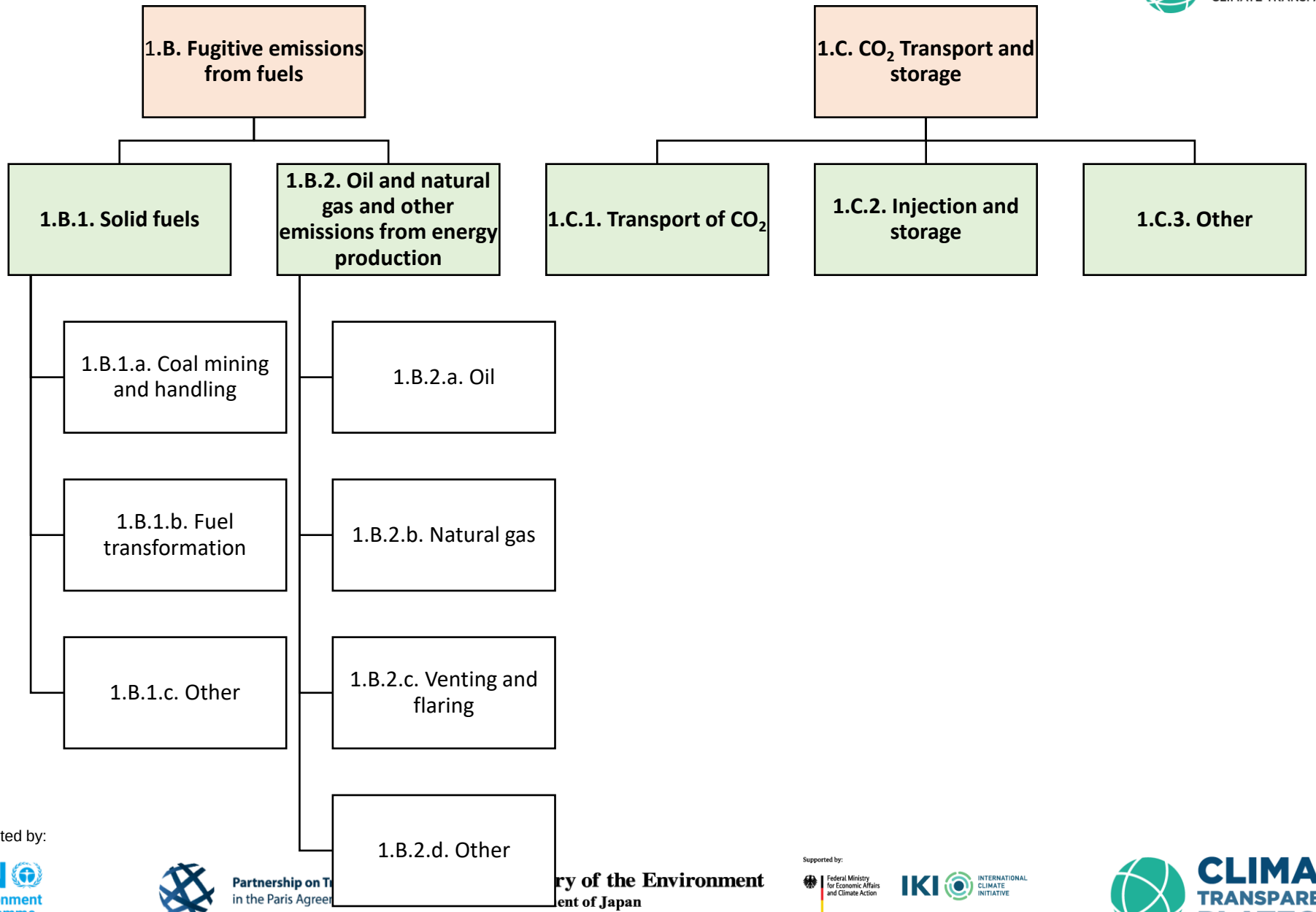
Energy sector: Scope and Coverage



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Distinction between fuel combustion and fugitive emissions

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Methodologies for estimating fugitive emissions from the Energy Sector are very different from those used for fossil fuel combustion.

Fuel combustion

- Definition: **intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process**

Fugitive emissions

- Fugitive emissions from extraction, transformation and transportation of primary energy carriers.
  - **Leakage of natural gas and the emissions of methane during coal mining and flaring during oil/gas extraction and refining**
  - Typically, only a few percent of the emissions in the energy sector arise as fugitive emissions
  - 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.

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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1.A Fuel Combustion

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Not included in Energy Sector

- waste incineration *without* energy recovery; → Included in Waste
- use of fossil fuels as a feedstock in industry (e.g. coke in *Iron & Steel*); → Included in IPPU
- biomass fires / open burning. → Included in AFOLU

Not included in 1.A Fuel combustion

- Coal mines fires, gas flaring → Included in fugitive emissions

Source: 2006 IPCC Guidelines, Volume 2: Energy, Chapter 1 Introduction - 1.3.2 Fugitive emissions & Chapter 2 Stationary Combustion

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1.B Fugitive emissions

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Includes all intentional and unintentional emissions from the extraction, processing, storage and transport of fuel to the point of final use.

are emissions of gases or vapour from equipment due to leaks and other unintended or irregular releases of gases, mostly from activities associated with the production and distribution of fossil fuels.

- It includes leaks from pressurised equipment, evaporation and displacement of vapour and accidental releases.

Significant CH4 emissions from:

- Coal mines,
- Refinery leaks,
- Gas distribution pipelines.

Source: 2006 IPCC Guidelines, Volume 2: Energy, Chapter 1 Introduction - 1.3.2 Fugitive emissions & Chapter 3 Fugitive emissions

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1.C Carbon Capture and Storage (CCS)

Carbon dioxide (CO_2) capture and storage (CCS) is an option in the portfolio of actions that could be used to reduce greenhouse gas emissions from the continued use of fossil fuels.

At its simplest, the CCS process is a chain consisting of three major steps:

- capture and compression of CO2 (usually at a large industrial installation),
- transport of CO2 to a storage location, and
- long-term isolation of CO2 from the atmosphere.

Geological storage can take place in natural underground reservoirs such as oil and gas fields, coal seams and saline water-bearing formations utilizing natural geological barriers to isolate the CO2 from the atmosphere.

The emissions of CO2 can happen during this process. The Guidelines provide emission estimation guidance for carbon dioxide transport, injection and geological storage.

Source: 2006 IPCC Guidelines, Volume 2: Energy, Chapter 1 Introduction - 1.3.3 CO2 capture and storage & Chapter 4 CO2 transport, injection and geological storage

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CRT Tables for the Energy sector

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Table 1 Sectoral report for energy

Table 1. A Fuel combustion

- Table1.A(a)s1 Energy - Fuel Combustion (sectoral approach)
- Table1.A(a)s2 Energy - Fuel Combustion (sectoral approach)
- Table1.A(a)s3 Energy - Fuel Combustion (sectoral approach)
- Table1.A(a)s4 Energy - Fuel Combustion (sectoral approach)
- Table1.A(b) Energy - Fuel Combustion (reference approach)
- Table1.A(c) Energy - Fuel Combustion (comparison of sectoral and reference approaches)
- Table1.A(d) Energy - Feedstocks, reductants and other non-energy use of fuels

Table 1. B Fugitive emissions

- Table1.B.1 Energy - Fugitive emissions from solid fuels
- Table1.B.2 Energy - Fugitive emissions from oil and natural gas

Table1.C Energy - CO2 Transport and storage

Table1.D International aviation and international navigation (international bunkers) and multilateral operations

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Methodological approaches

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Three tiers for stationary combustion (sectoral approach)

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Tier 1

Fuel combustion from national energy statistics and **default emission factors**;

Tier 2

Fuel combustion from national energy statistics, together with **country-specific emission factors**, where possible, derived from national fuel characteristics;

Tier 3

Fuel statistics and data on combustion technologies applied together with **technology-specific emission factors**; this includes the use of models and facility level emission data where available.

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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Tier 1

$$Emissions_{GHG,fuel} = Fuel\ consumption_{fuel} \times Emission\ factor_{GHG,fuel}$$

For each source category and fuel:

- Data on the amount of fuel combusted in the source category
- **A default emission factor**

Total emissions by gas from the source category:

- $Emissions_{GHG} = \sum_{fuels} Emissions_{GHG,fuel}$

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Tier 1 method for estimating CO_2 emissions

CO_2 Emissions = Fuel Consumption x CO_2 emission factor (EF CO_2)

CO_2 emission factor (EF CO_2) = Carbon content × Oxidation fraction × 44/12

OXIDATION FRACTION

- measure the percentage of carbon that is actually oxidized when combustion occurs.
- Default CO2 emission factors: the fraction of carbon oxidised is assumed to be 1
- is used to calculate the amount of the fuel that is contributing to GHG emissions.
- Efficient fuel combustion ensures oxidation of the maximum amount of carbon available the fuel.

Source: 2006 IPCC Guidelines, Volume 2: Energy, Chapter 1 Introduction - 1.4.2.1 CO2 Emission factors

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Tier 2

$$Emissions_{GHG,fuel} = Fuel\ consumption_{fuel} \times Emission\ factor_{GHG,fuel}$$

For each source category and fuel:

- Data on the amount of fuel combusted in the source category
- **A country-specific emission factor** for the source category and fuel for each gas.

Country-specific emission factors can be developed by taking into account country-specific data:

- Carbon contents of the fuels
- Carbon oxidation factors
- Fuel quality
- The state of technological development (for non-CO2 gases in particular)

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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Tier 3

$$Emissions_{GHG,fuel,technology} = Fuel\ consumption_{fuel,technology} \times Emission\ factor_{GHG,fuel.technology}$$

Data requirements

- Data on the amount of fuel combusted in the source category for each relevant technology (**fuel type used, combustion technology, operating conditions, control technology, and maintenance and age of the equipment**).
- **A specific emission factor for each technology** (fuel type used, combustion technology, operating conditions, control technology, oxidation factor, and maintenance and age of the equipment).
- Facility level measurements can also be used when available

When the amount of fuel combusted for a certain technology is not directly known, it can be estimated by means of models.

- For example, a simple model for this is based on the penetration of the technology into the source category:
- $Fuel\ consumption_{fuel,technology} = Fuel\ consumption_{fuel} \times Penetration_{technology}$

To calculate the emissions of a gas for a source category, emissions per technology must be summed over all technologies applied in the source category.

- $Fuel\ consumption_{fuel,technology} = \sum_{technologies} Fuel\ consumption_{fuel,technology} \times Emission\ Factor_{GHG,fuel,technology}$

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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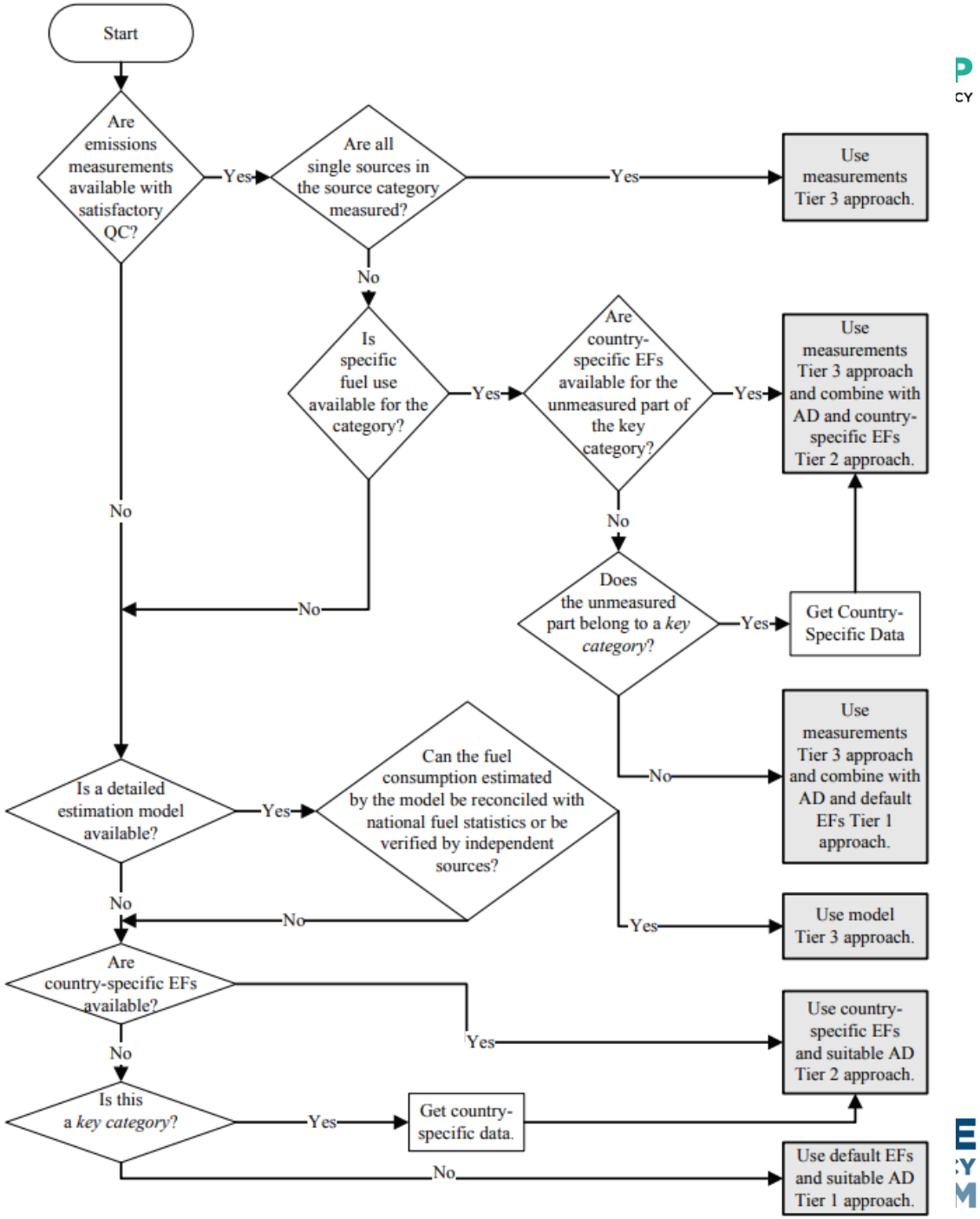
Decision tree to select Tier Approach

If a category is key, it is good practice to estimate emissions using a Tier 2 or Tier 3 approach.

The decision tree will help in selecting which tier should be used to estimate emissions from sources of stationary combustion.

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories



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Methodological approaches

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The amount and types of fuel combusted can be obtained from the following sources

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National energy statistics agencies	• National energy statistics agencies may collect data on the amount and types of fuel combusted from individual enterprises that consume fuels)
Reports provided by enterprises to national energy statistics agencies	• These reports are most likely to be produced by the operators or owners of large combustion plants
Reports provided by enterprises to regulatory agencies	• For example, reports produced to demonstrate how enterprises are complying with emission control regulations
Individuals within the enterprise responsible for the combustion equipment	• Periodic surveys, by statistical agencies, of the types and quantities of fuels consumed by a sample of enterprises
Suppliers of fuels	• Who may record the quantities of fuels delivered to their customers, and may also record the identity of their customers usually as an economic activity code)

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Activity data

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For Stationary Combustion, the activity data for all tiers are the amounts and types of fuel combusted.

Most fuels consumers (enterprises, small commercial consumers, or households) normally pay for the solid, liquid and gaseous fuels they consume.

Therefore, the masses or volumes of fuels they consume are measured or metered.

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Data collection - Activity data sources

National Agencies

- National Statistical Offices (NSO)
- Ministry of Energy
- other Ministries (Oil, Transport, Forest, etc.)

International Agencies

- United Nations Statistics Division (UN Stat) https://unstats.un.org/home/
- International Energy Agency (IEA) https://www.iea.org/

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Emission factors

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CO2 emissions

- Depend almost entirely on the **carbon content of the fuel**, though a small amount of carbon is un-oxidized (less than 1%).
- During the combustion process, most carbon is immediately emitted as CO2 **regardless combustion technology**.
- By default the 2006 IPCC Guidelines assume a **complete combustion process** (100% carbon conversion or oxidation fraction is 1).

Non-CO2 gases

- From fuel combustion are dependent on fuel and technology used **operating conditions, control technology, and maintenance and age of the equipment**.
- 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.

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Default emission factors for stationary combustion in the energy industries

Fuel		CO_2			CH_4			N_2O		
		Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper	Default Emission Factor	Lower	Upper
Crude Oil		73 300	71 100	75 500	r 3	1	10	0.6	0.2	2
Orimulsion		r 77 000	69 300	85 400	r 3	1	10	0.6	0.2	2
Natural Gas Liquids		r 64 200	58 300	70 400	r 3	1	10	0.6	0.2	2
Gasoline	Motor Gasoline	r 69 300	67 500	73 000	r 3	1	10	0.6	0.2	2
	Aviation Gasoline	r 70 000	67 500	73 000	r 3	1	10	0.6	0.2	2
	Jet Gasoline	r 70 000	67 500	73 000	r 3	1	10	0.6	0.2	2
Jet Kerosene		r 71 500	69 700	74 400	r 3	1	10	0.6	0.2	2
Other Kerosene		71 900	70 800	73 700	r 3	1	10	0.6	0.2	2
Shale Oil		73 300	67 800	79 200	r 3	1	10	0.6	0.2	2
Gas/Diesel Oil		74 100	72 600	74 800	r 3	1	10	0.6	0.2	2
Residual Fuel Oil		77 400	75 500	78 800	r 3	1	10	0.6	0.2	2
Liquefied Petroleum Gases		63 100	61 600	65 600	r 1	0.3	3	0.1	0.03	0.3

Source: 2006 IPCC Guidelines, Volume 2: Energy, Chapter 2 Stationary Combustion, 2.3.2 Choice of emission factors, TABLE 2.2 Default emission factors for stationary combustion in the energy industries, page -2.16-2.17.

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Emission factors

Tier 2: Country-specific EF

- *Good practice* is to use the most disaggregated, technology-specific and country-specific emission factors available, particularly those derived from direct measurements at the different stationary combustion sources.

Tier 3: Technology-specific EF

- Due to the nature of the emissions of non-CO2 greenhouse gases, technology-specific emission factors are needed for Tier 3.

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Reference approach

Part of QA/QC activities and provides information regarding completeness of CO2 emission from sector 1.A. Fuel combustion;

Can be seen as a verification cross-check.

A top-down approach, using a country's energy supply data to calculate the emissions of CO2 from combustion of mainly fossil fuels.

A straightforward method that can be applied on the basis of relatively easily available energy supply statistics (Energy balance).

- 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.

Source: 2006 IPCC Guidelines, Volume 2: Energy, Chapter 1 Introduction - 1.6.1 Reference Approach & Chapter 6: Reference Approach, 6.1 OVERVIEW

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Reference approach

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 un-utilised 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.

Source: 2006 IPCC Guidelines, Volume 2: Energy, Chapter 1 Introduction - 1.6.1 Reference Approach & Chapter 6: Reference Approach, 6.1 OVERVIEW

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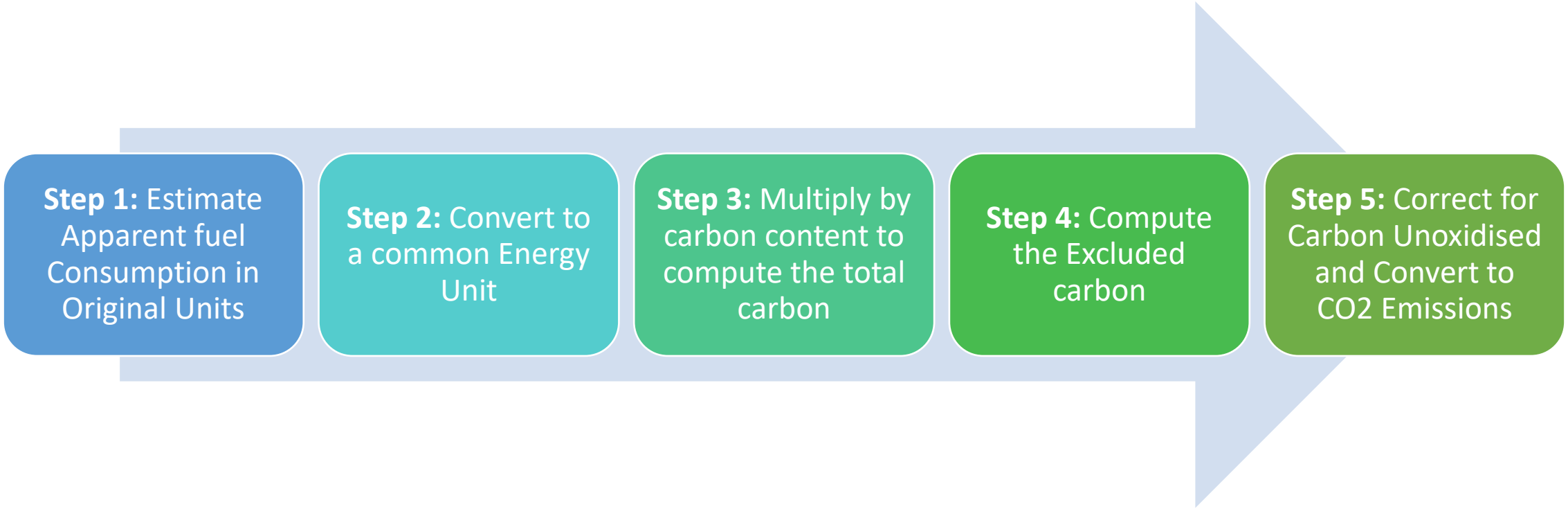
Reference approach methodology

The Reference Approach methodology breaks the calculation of carbon dioxide emissions from fuel combustion into 5 steps:



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Reference approach

$$CO2\ emissions = \sum_{all\ fuels} ((Apparent\ consumption_{fuel} \times ConvFactor_{fuel} \times CC_{fuel}) \times 10^{-3}) - Excluded\ Carbon_{fuel}) \times COF_{fuel} \times 44/12$$

Apparent Consumption = production + imports – exports – international bunkers - stock change

Where:

CO2 Emissions = CO2 emissions (Gg CO2)

Conv Factor (conversion factor) = conversion factor for the fuel to energy units (TJ) on a net calorific value basis

CC = carbon content (tonne C/TJ)

Excluded Carbon =carbon in feedstocks and non-energy use excluded from fuel combustion emissions (Gg C)

COF (carbon oxidation factor) = fraction of carbon oxidised. Usually the value is 1, reflecting complete oxidation.

44/12= molecular weight ratio of CO2 to C

Source: 2006 IPCC Guidelines, Volume 2: Energy, Chapter 6: Reference Approach, 6.3 Algorithm

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What is an Energy Balance?

The energy balance is a table matrix represented by rows and columns.

The concept of "energy balance" is an **accounting framework** for the compilation and understanding of data on all energy products entering, exiting and being used in a country.

The energy balance is the most complete statistical accounting of energy products and their flow in the economy.

- Columns of the energy balance represent energy products (fuels).
- Rows represent energy flows.

The balance shows the relationships between supply, inputs to the energy transformation processes and their outputs as well as the actual energy consumption by different sectors of end-use.

Source: http://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_balance

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Other

- Main activity electricity generation and autoproducers
- International bunker fuel emissions
- Feedstocks and non-energy use of fuels

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Main activity producers and autoproducers

Main activity producers

- Main activity producers are defined as those undertakings whose primary activity is to supply the public.
- They may be in public or private ownership.
- Emissions from own on-site use of fuel should be included.

1 A 1 a. Main Activity Electricity and Heat Production

Auto producers

- An autoproducer of electricity and/or heat is an enterprise that, in support of its primary activity, generates electricity and/or heat for its own use or for sale, but not as its main business

Emissions from autoproducers should be assigned to the sector where they were generated and **not under 1 A 1 a.**

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Other

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International aviation and international navigation (international bunkers) and multilateral operations

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1.D.1.a. International aviation (aviation bunkers)

- Emissions from flights that depart **in one country and arrive in a different country.**
- Include take-offs and landings for these flight stages.

1.D.1.b. International navigation (marine bunkers)

- The international navigation may take place at sea, on inland lakes and waterways and in coastal waters.
- Includes emissions from journeys **that depart in one country and arrive in a different country**

Emissions from fuel sold **to any air or marine vessel** engaged in international transport (1 A 3 a i and 1 A 3 d i) should as far as possible **be excluded from the totals and subtotals in this category and should be reported separately.**

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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International aviation and international navigation (international bunkers) and multilateral operations

Since emissions from domestic aviation are reported separately from international aviation, it is necessary to disaggregate activity data between domestic and international components.

Journey type between two airports	Domestic	International
Departs and arrives in same country	Yes	No
Departs from one country and arrives in another	No	Yes

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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Approaches to split between domestic and international fuel consumption

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Top-down data

- Can be obtained from taxation authorities in cases where fuel sold for domestic use is subject to taxation, but that for international use is not taxed.
- Airports or fuel suppliers may have data on delivery of aviation kerosene and aviation gasoline to domestic and to international flights.
- In most countries tax and custom dues are levied on fuels for domestic consumption, and fuels for international consumption (bunkers) are free of such dues.
- In the absence of more direct sources of data, information about domestic taxes may be used to distinguish between domestic and international fuel consumption.

Bottom-up data

- Can be obtained from surveys of airline companies for fuel used on domestic and international flights, or estimates from aircraft movement data and standard tables of fuel consumed or both.
- Fuel consumption factors for aircraft (fuel used per LTO and per nautical mile cruised) can be used for estimates and may be obtained from the airline companies.

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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Other

- Main activity electricity generation and autoproducers
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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.

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories

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Allocation of CO_2 emissions to fuel combustion or industrial process emissions

Fuel combustion is 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.

The aim of this definition is to **separate the combustion of fuels for distinct and productive energy use from the heat released from the use of hydrocarbons in chemical reactions** defining an industrial process.

Process fuels may be obtained directly from the feedstock as in the case of ammonia manufacture where natural gas provides both feedstock and fuel.

- Alternatively, process fuels may be obtained indirectly through the use of by-products of feedstock processing or reductant use.
- Examples are the off gases obtained from the steam cracking of naphtha feedstock for ethylene manufacture and blast furnace gas from blast furnaces.

During these activities emissions may occur **from both the fuel combustion and industrial process stages.**

- However, it is often impractical or impossible to report separately the two types of emissions.

Accordingly the following rule has been formulated to simplify reporting:

- 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).

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Thank you for your attention!

For more information:
https://climate-transparency-platform.org

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