IPCC 2006 GUIDELINES
VOL.2 ENERGY

ENERGY SECTOR EMISSIONS

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INTERGOVERNMENTAL PANEL ON climate change

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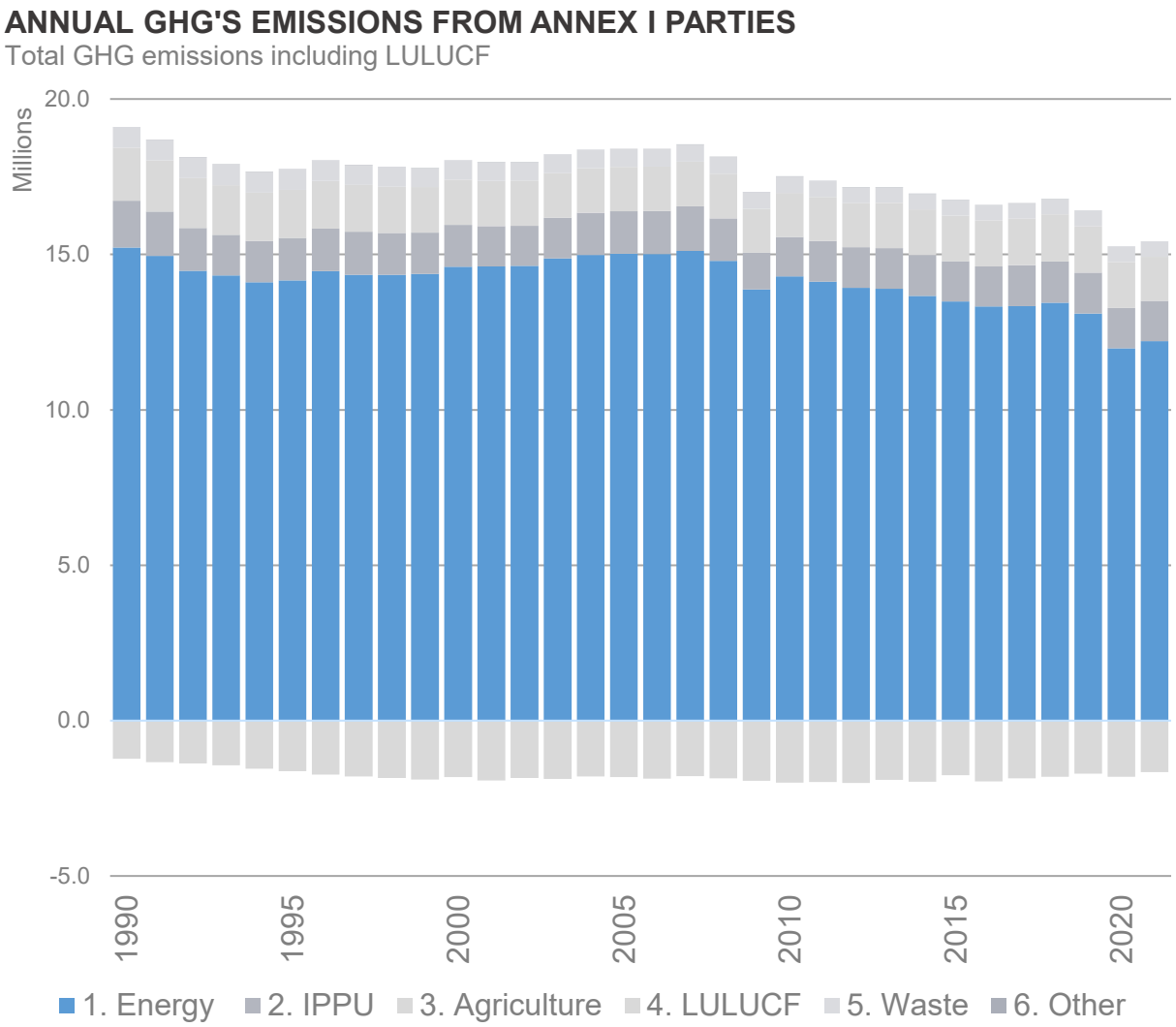
ENERGY

- **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**.

Importance of Energy Sector in Totals



The energy sector is usually the most important sector in greenhouse gas emission inventories, and typically contributes over 90 percent of the CO2 emissions and 75 percent of the total greenhouse gas emissions in developed countries.

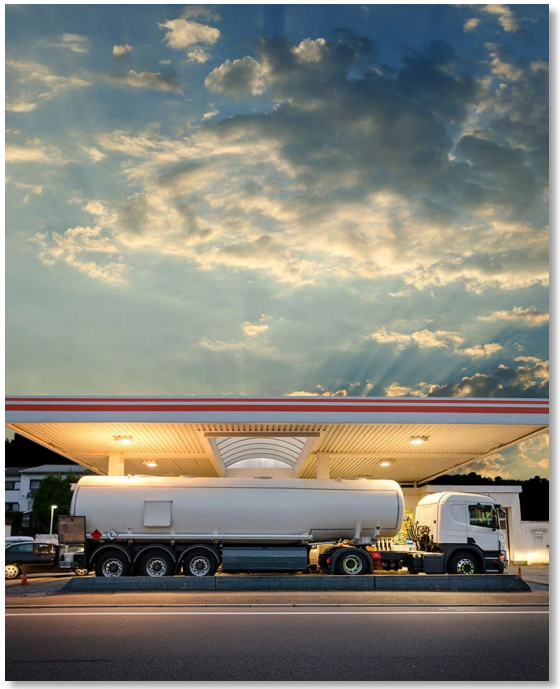
CO2 accounts typically for 95 percent of energy sector emissions with methane and nitrous oxide responsible for the balance.

Energy Sector: Source Categories

- Energy systems are for most economies largely driven by the combustion of fossil fuels

Exploration and exploitation of primary energy sources

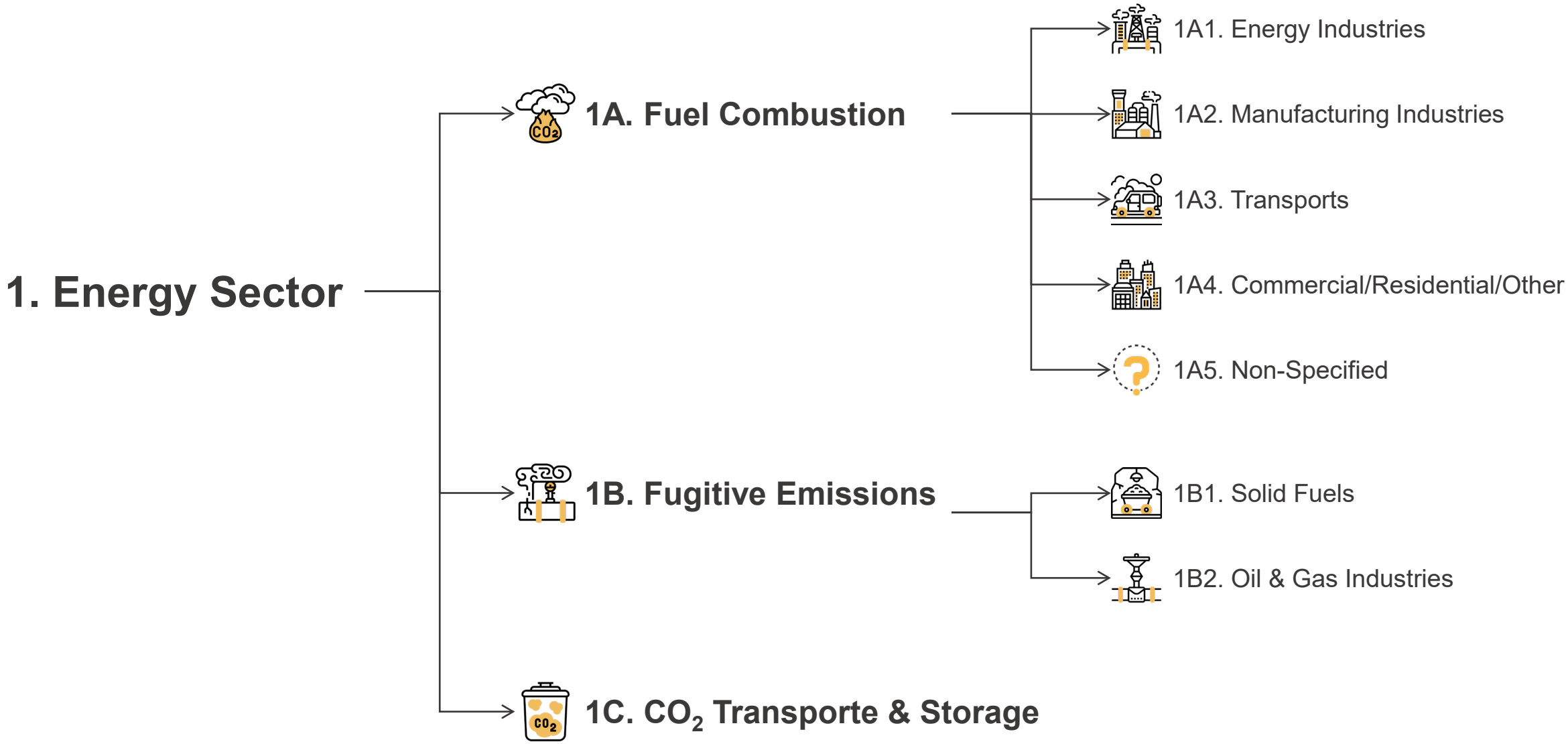
Conversion of primary energy sources into more useable energy forms in refineries and power plants



Transmission and distribution of fuels

Use of fuels in stationary and mobile applications

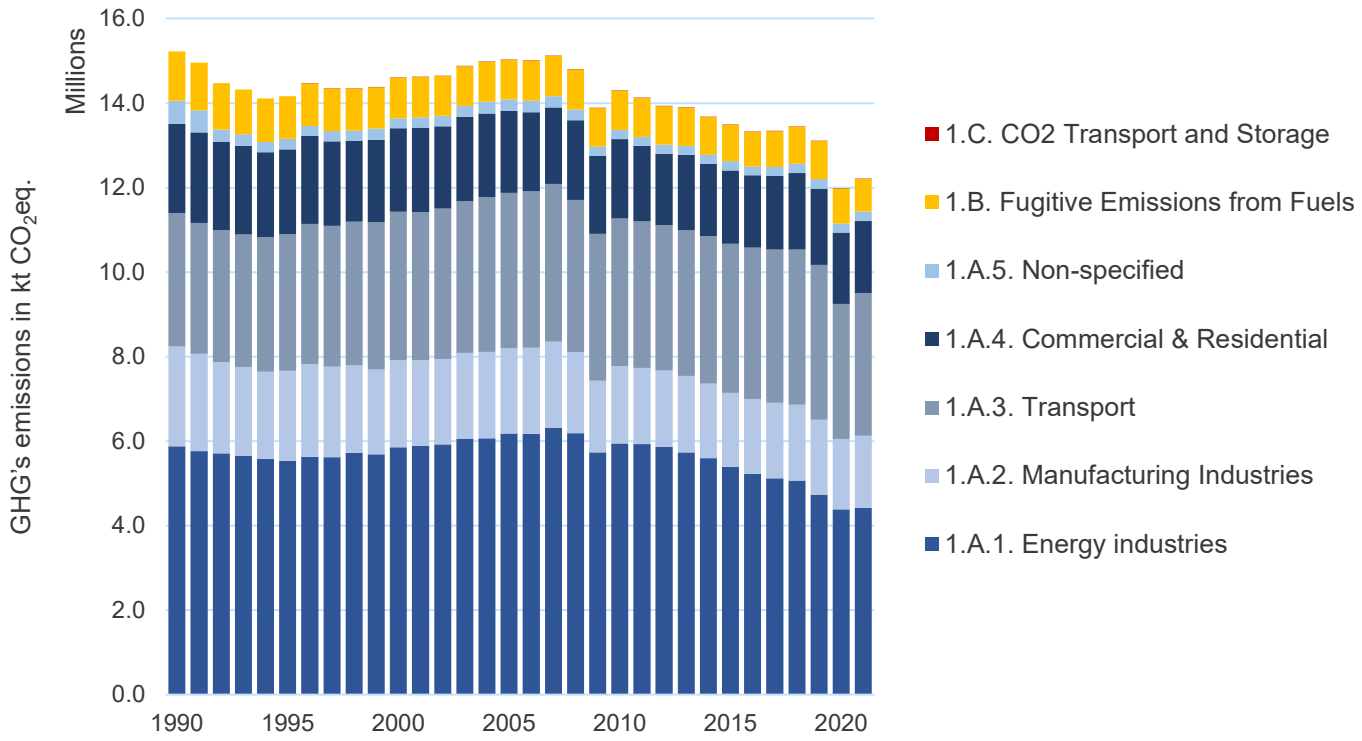
Introduce CRF1 structure



Importance of Energy Sector in Totals

1.ENERGY SECTOR

GHG's emissions by main categories - Annex I Parties *(2023 submission)*



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.

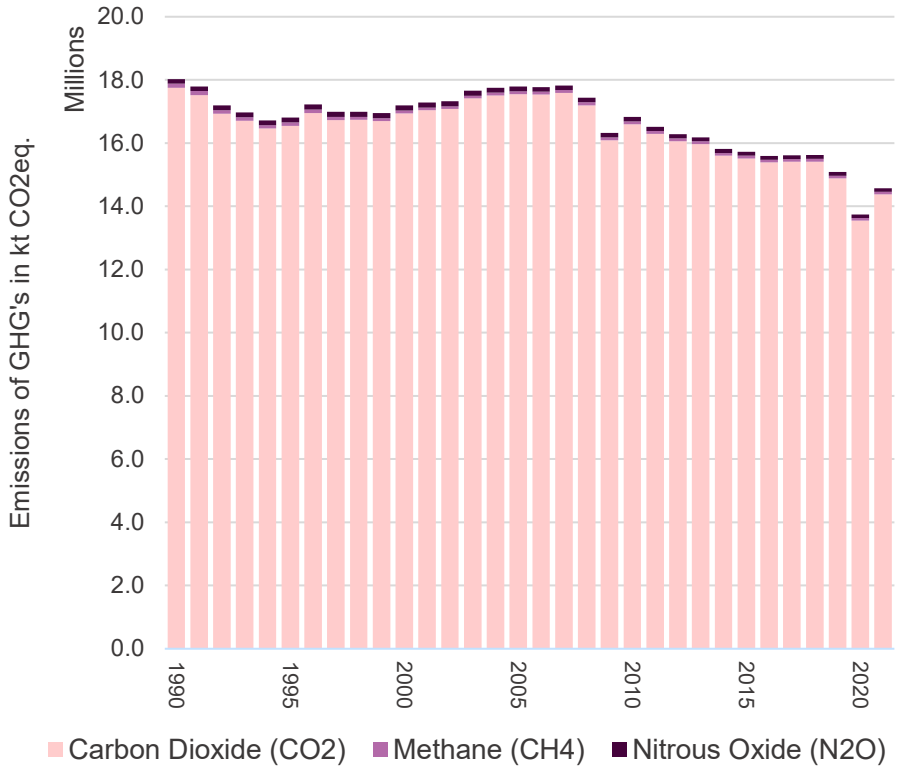
Fugitive emissions represent around 7%

Of these emissions, 93% originated from the combustion of fuels, while the remaining 7% arose from fugitive emissions in fuel industries. The emissions from CO2 transport and storage, as reported by Annex I Parties, did not have a significant impact on national totals.

GHG emissions by gas

1A. ENERGY - FUEL COMBUSTION

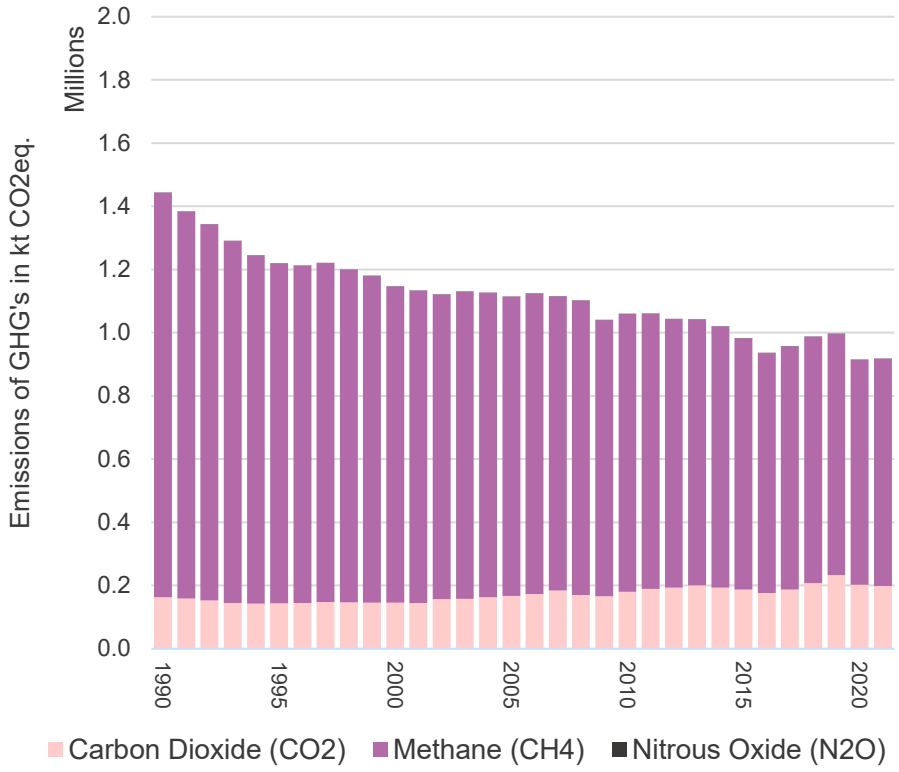
GHG's emissions by gas - Annex I Parties *(2023 submission)*



Around 99% do the emissions from category 1A come from Carbon Dioxide

1B. ENERGY - FUGITIVE EMISSIONS

GHG's emissions by gas - Annex I Parties *(2023 submission)*



Around 80% to 85% do the emissions from category 1B come from Methane

1.A Fuel combustion

1.A Fuel combustion

- **Fuel combustion** involves the **intentional** **burning** of materials within an apparatus to **produce heat or mechanical energy**.

- This process is typically employed in various sectors such as **power generation**, **transportation**, and **industrial production** to generate electricity, propel vehicles, or provide heat for manufacturing processes.

What sources are NOT INCLUDED in 1.A Fuel combustion

- Waste incineration without energy recovery *(Waste)*
- Use of fossil fuels as feedstock in the Industrial sector *(IPPU)*
- Biomass fires/open burning *(AFOLU)*
- Coal mine fires and gas flaring *(Fugitive Emissions)*

Emissions Estimates – Key concepts

The primary factor in estimating emissions from fuel combustion is the **amounts of fuel consumed.**

- Emission factor in most cases will be related to the **fuel combusted** and **combustion conditions**

CO_2 EMISSIONS

- **CO_2 emissions depend almost entirely on the carbon content of the fuel**, though a small amount of carbon is un-oxidized (less than 1%).
- By default, *the 2006 IPCC Guidelines* assume a complete combustion process (oxidation fraction is 1)

Non-CO_2 EMISSIONS

- **Emission factors for CH_4 and N_2O** from fuel combustion are **dependent on fuel and technology** used .
- Operating conditions, control technologies, quality of maintenance, age of equipment will influence non-CO2 emissions

Emissions Estimates – Key Equations

GREENHOUSE GAS EMISSIONS BY FUEL TYPE

$$\text{Emission}_{GHG,fuel} = \text{Fuel Consumption}_{fuel} \bullet \text{Emission Factor}_{GHG,fuel}$$

Where:

$\text{Emission}_{GHG,fuel}$	= emissions of a given GHG by type of fuel
$\text{Fuel Consumption}_{fuel}$	= amount of fuel combusted
$\text{Emission Factor}_{GHG,fuel}$	= emission factor of a given GHG by type of fuel

GREENHOUSE GAS EMISSIONS BY FUEL AND TECHNOLOGY TYPE

$$\text{Emission}_{GHG,fuel,technology} = \text{Fuel Consumption}_{fuel,\ technology} \bullet \text{Emission Factor}_{GHG,fuel,technology}$$

Where:

$\text{Emission}_{GHG,fuel,technology}$	= emissions of a given GHG by type of fuel and technology
$\text{Fuel Consumption}_{fuel,technology}$	= amount of fuel combusted per type of technology
$\text{Emission Factor}_{GHG,fuel,technology}$	= emission factor of a given GHG by type of fuel and technology

Fuels – Definitions and Type of Fuels

- The **carbon content varies among fossil fuels**, leading to unique Emission Factors for each fuel.
- Accurate identification and differentiation of the various fuels consumed within a country are essential for the precise application of these emission factors. *(see Table 1.1 of Volume 2 of the 2006 IPCC Guidelines)*

LIQUID FUELS

Crude and Petroleum Product

- Fuel oil
- Gasoline & Gas/Diesel Oil
- Petroleum Coke
- Refinery gas
- others

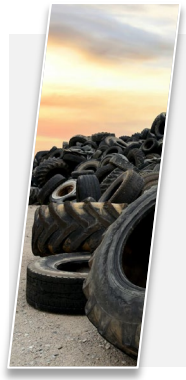
SOLID FUELS

Coal and Coal Products

- Coal
- Coking Coal
- Coke Oven Gas
- others

GASEOUS FUELS

- Natural Gas



OTHER FOSSIL FUELS

- Fossil Fraction of Waste
- Used Tires

BIOMASS *

- Wood and Wood Waste
- Biofuels
- Non-Fossil Fraction of Waste

** CO_2 emissiosn not included in Energy sector totals*

PEAT *

** Peat is not technically a fossil fuel, but GHG's emissions are comparable to those of fossil fuels.*

Data Sources: Fuel Consumption

- the **amount and types of fuel combusted** could be obtained from one, or a combination, of the sources:


National energy statistics agencies


Reports provided by enterprises to regulatory agencies


Individuals within the enterprise responsible for the combustion equipment


Periodic surveys of the types and quantities of fuels consumed by a sample of enterprises


Suppliers of fuels

- **Fuel statistics** collected by an **officially recognised national body** are usually the **most appropriate and accessible activity data**.
- Some countries may lack comprehensive national data accessibility, leading inventory compilers to rely on country-data from **international organizations**. - *International Energy Agency (IEA), and the United Nations (UN).*

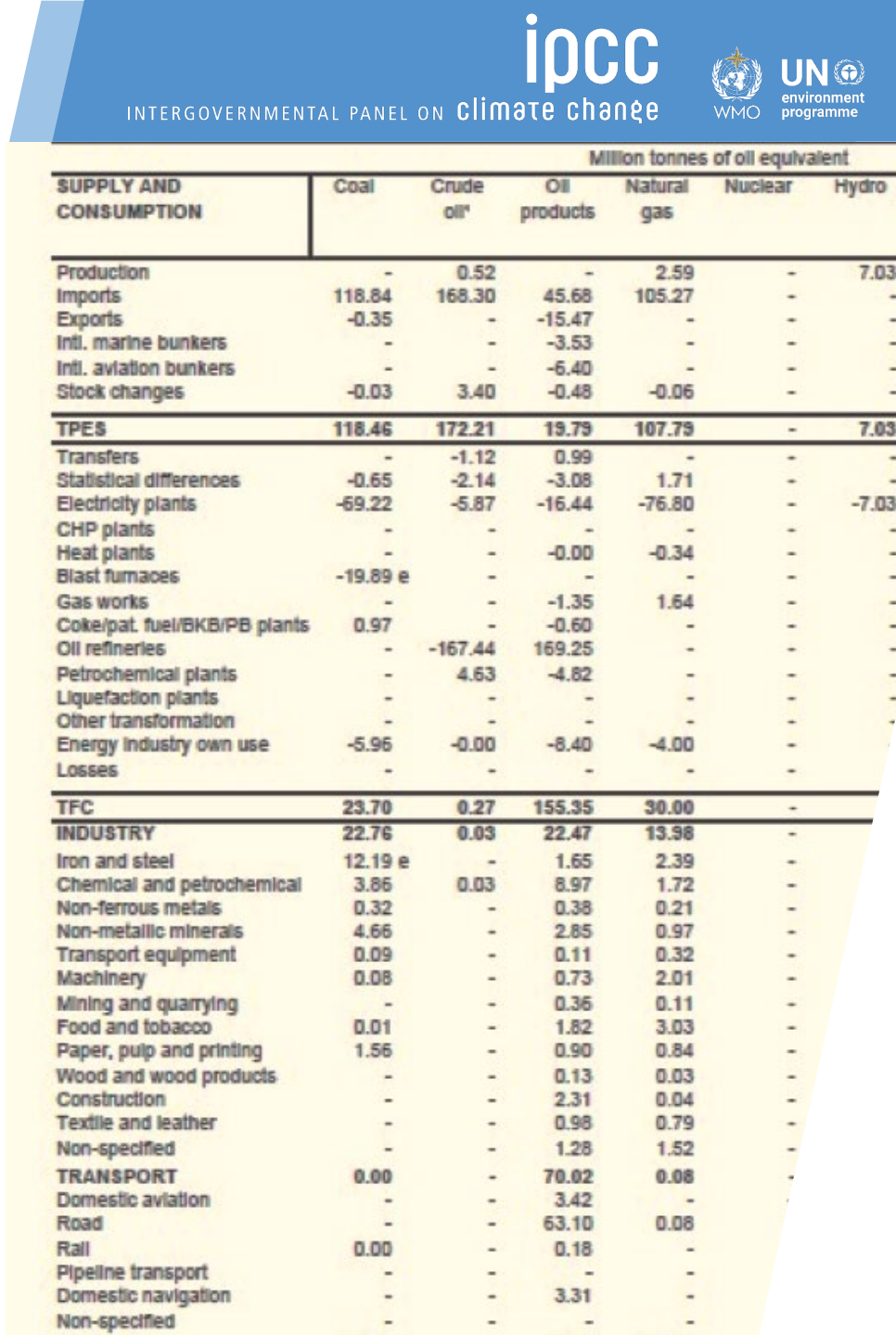
Data Sources - Energy Balance

Energy balances are structured frameworks that analyze the **flow of energy within an economy**,

They integrate data from various energy **sources and sectors** to quantify energy production, transformation, and consumption in a standardized format.

Energy balances serve as robust activity data sources for calculating GHG emissions from fuel combustion:

- **Comprehensive coverage** of energy production, transformation, and consumption.
- **Standardized data presentation**, ensuring accuracy and comparability.
- **Detailed granularity**, enabling precise estimation of fuel consumption and emissions.
- **Transparent methodologies**, enhancing data reliability.
- **Verification and quality assurance processes**, bolstering credibility.



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Million tonnes of oil equivalent

SUPPLY AND CONSUMPTION	Coal	Crude oil*	Oil products	Natural gas	Nuclear	Hydro
Production	-	0.52	-	2.59	-	7.03
Imports	118.84	168.30	45.68	105.27	-	-
Exports	-0.35	-	-15.47	-	-	-
Intl. marine bunkers	-	-	-3.53	-	-	-
Intl. aviation bunkers	-	-	-6.40	-	-	-
Stock changes	-0.03	3.40	-0.48	-0.06	-	-
TPES	**118.46**	**172.21**	**19.79**	**107.79**	**-**	**7.03**
Transfers	-	-1.12	0.99	-	-	-
Statistical differences	-0.65	-2.14	-3.08	1.71	-	-
Electricity plants	-69.22	-5.87	-16.44	-76.80	-	-7.03
CHP plants	-	-	-	-	-	-
Heat plants	-	-	-0.00	-0.34	-	-
Blast furnaces	-19.89 e	-	-	-	-	-
Gas works	-	-	-1.35	1.64	-	-
Coke/pat. fuel/BKB/PB plants	0.97	-	-0.60	-	-	-
Oil refineries	-	-167.44	169.25	-	-	-
Petrochemical plants	-	4.63	-4.82	-	-	-
Liquefaction plants	-	-	-	-	-	-
Other transformation	-	-	-	-	-	-
Energy industry own use	-5.96	-0.00	-8.40	-4.00	-	
Losses	-	-	-	-	-	
TFC	**23.70**	**0.27**	**155.35**	**30.00**	**-**	
INDUSTRY	**22.76**	**0.03**	**22.47**	**13.98**	**-**	
Iron and steel	12.19 e	-	1.65	2.39	-	
Chemical and petrochemical	3.86	0.03	8.97	1.72	-	
Non-ferrous metals	0.32	-	0.38	0.21	-	
Non-metallic minerals	4.66	-	2.85	0.97	-	
Transport equipment	0.09	-	0.11	0.32	-	
Machinery	0.08	-	0.73	2.01	-	
Mining and quarrying	-	-	0.36	0.11	-	
Food and tobacco	0.01	-	1.82	3.03	-	
Paper, pulp and printing	1.56	-	0.90	0.84	-	
Wood and wood products	-	-	0.13	0.03	-	
Construction	-	-	2.31	0.04	-	
Textile and leather	-	-	0.98	0.79	-	
Non-specified	-	-	1.28	1.52	-	
TRANSPORT	**0.00**	**-**	**70.02**	**0.08**	**-**	
Domestic aviation	-	-	3.42	-		
Road	-	-	63.10	0.08		
Rail	0.00	-	0.18	-		
Pipeline transport	-	-	-	-		
Domestic navigation	-	-	3.31	-		
Non-specified	-	-	-	-		

Fuels – Double Counting

In the context of GHGs emissions estimates, **double counting** refers to the **inadvertent counting of the same emissions or reductions more than once**. Double counting can **undermine the accuracy and integrity** of emissions estimates.

NON-ENERGY USE OF FUELS

- For a number of industrial applications fossil hydrocarbons are not only used as energy sources, but also have other uses e.g. **feedstocks, lubricants, solvents**, etc.
- Hence, the use of **fuel combustion statistics** rather than **fuel delivery statistics** is key to avoid double counting in emission estimates.

WASTE AS FUEL

- Some waste incinerators also produce heat or power
- In such cases it is good practice to report these emissions under the energy sector
- To avoid double counting, subtract the amount of waste considered as fuel in the energy sector from the total amounts of waste used in the waste sector estimate.

Fuels – Double Counting

BIOMASS IS A SPECIAL CASE:

- **Biomass CO_2 emissions**, including from combustion, **are accounted for in the AFOLU sector** to avoid double counting. This method captures emissions through estimated changes in carbon stocks from biomass harvest.
- In the **Energy sector**, CO_2 emissions from biomass combustion are **recorded as information items**, not included in sectoral total emissions since they're accounted for in AFOLU.
- However, **CH_4 and N_2O emissions from biomass combustion** are included in **sectoral total** emissions as they can't be estimated using AFOLU methodologies.

BIO-FRACTION OF WASTE AND BIOFUELS

- For waste incinerated for energy, record **CO_2 emissions from the biogenic part** as **information items** in the Energy sector, similar to biomass combustion emissions.
- When **biofuels** are combusted with fossil fuels, determine the split between fossil and non-fossil fractions and apply emission factors to each fraction appropriately.

National Boundaries – International Bunkers

All emissions from fuels used for **international aviation** and **international waterborne navigation** (International Bunkers) are to be **excluded from national totals** and **reported separately as memo items.**

Criteria:

- **Domestic:** Journeys where the start and end points are within the **same country.**

- **International:** Journeys where the start and end points are in **different countries.**

Independence from carrier's nationality or flag

FISHING VESSELS

- **All fuel supplied to commercial fishing** activities within the reporting country is considered **domestic.**
- This classification applies regardless of where the fishing activity occurs (e.g., in domestic or international waters).

1.AB Reference Approach

Reference Approach - Overview

- The Reference Approach is a **top-down method** that uses a country's energy supply data to calculate CO_2 emissions from combustion, primarily of fossil fuels.
- It's a **straightforward** method based on easily accessible energy supply statistics.
- It's recommended to use both the **sectoral approach** and the **reference approach** to estimate CO2 emissions and compare the results for **validation**.

Carbon Conservation

- The Reference Approach assumes that the **carbon content of a primary fuel** remains **unchanged** as it is processed into **derived products** (secondary fuels).
- This means that the total amount of carbon present in the primary fuel is distributed among the various products obtained from it, whether through refining, processing, or other means.

Reference Approach – The Algorithm

THE ALGORITHM

1: Estimate Apparent Fuel Consumption in Original Units

2: Convert to a Common Energy Unit

3: Multiply by Carbon Content to Compute the Total Carbon

4: Compute the Excluded Carbon

5: Correct for Carbon Unoxidised and Convert to CO2 Emissions

THE EQUATION

EQUATION 6.1
CO_2 EMISSIONS FROM FUEL COMBUSTION USING THE REFERENCE APPROACH

$$CO_2\ Emissions = \sum_{all\ fuels}\left[\begin{array}{l}((Apparent\ Consumption_{fuel} \bullet Conv\ Factor_{fuel} \bullet CC_{fuel}) \bullet 10^{-3} \\ -Excluded\ Carbon_{fuel}) \bullet COF_{fuel} \bullet 44/12\end{array}\right]$$

For a single fuel

CO_2 EMISSIONS$_{fuel}$ = (Apparent Consumption$_{fuel}$ ● Carbon Content$_{fuel}$) – Exclude Carbon$_{fuel}$ ● *1* ● *44/12*

Represents the **total estimated consumption of a fuel**, considering factors like **production**, **imports**, **exports**, and **changes in stocks**.

Represents carbon emissions that are **not directly** attributed to the act of **burning fuel for energy purposes**.

Apparent consumption

- **Apparent consumption** represents the total amount of fuel consumed within a country, including both primary and secondary fuels.

  - **Primary Fuel** *(raw energy sources extracted directly from nature, like crude oil or coal)*

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

  - **Secondary Fuel** *(processed or refined forms of primary fuels, such as gasoline or coke oven gas)*

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

** Data on production, imports, exports, international bunkers, and stock changes are compiled into **Energy Balances** by national or international statistical agencies.*

Excluded Carbon

Excluded carbon refers to carbon emissions that **do not result from fuel combustion**. This includes carbon emitted in **other sectors** or **stored in products manufactured from the fuel**.

$$\textbf{Excluded Carbon} = \text{Carbon}_{Feedstocks} + \text{Carbon}_{NEU} + \text{Carbon}_{Reductant}$$

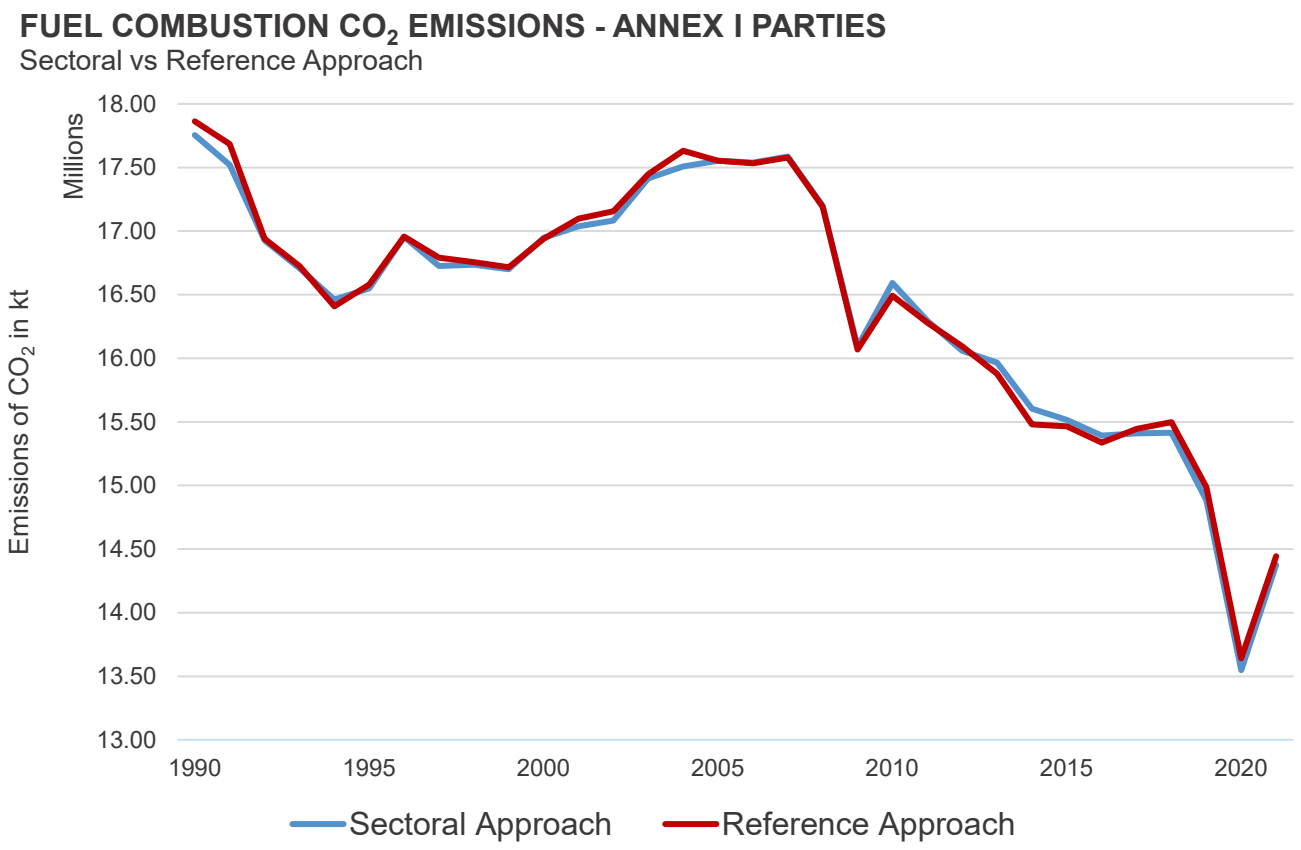
Feedstocks: Exclude carbon used in feedstocks for industrial processes or non-energy products.

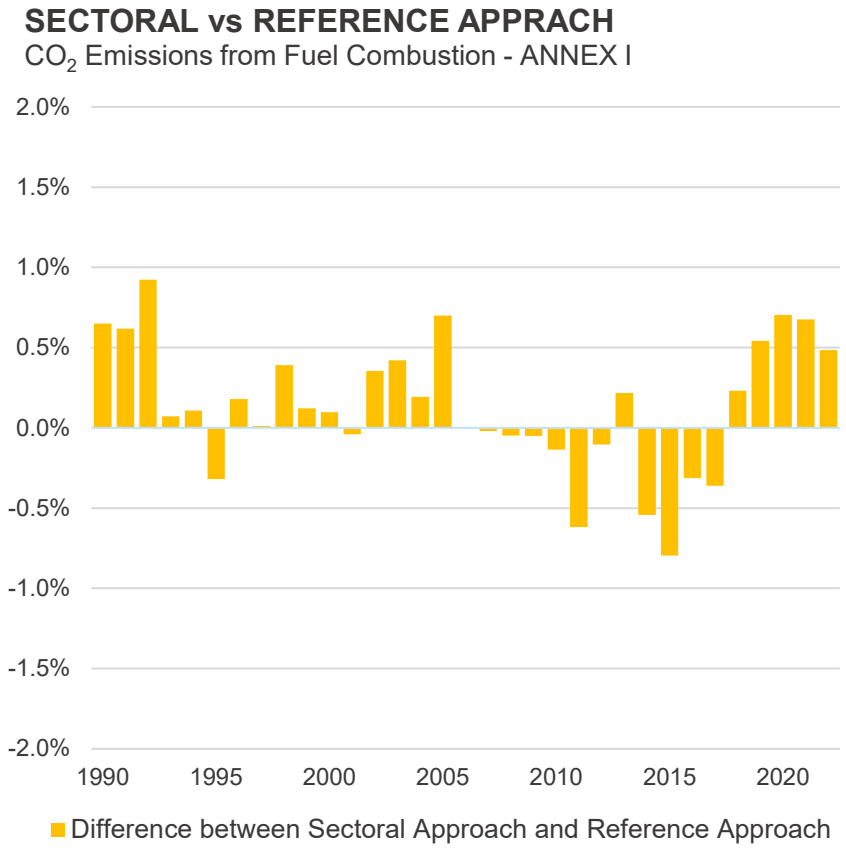
Non-Energy Use: Exclude carbon stored in products like bitumen, lubricants, and paraffin waxes.

Reductant: Exclude carbon used in reductants for industrial processes

** Refer to Tables 6.1 and 6.2 of Volume 1 of the IPCC 2006 Guidelines for detailed information on the carbon flows to consider when estimating Excluded Carbon.*

Comparison between the Reference Approach and Sectoral Approach





Reference Approach - Pratical Tips

Data Collection:

- Gather comprehensive data on fuel production, imports, exports, and stock changes.
- Ensure accuracy in distinguishing between primary and secondary fuels.

Calculations:

- Consistently use calorific values (net or gross) based on detailed national calculations.
- Apply weighted averages for carbon content to reflect fuel type variations.

Verification:

- Cross-check results with the sectoral approach to identify and explain discrepancies.
- Document all sources of data and any assumptions made during calculations.

1.B Fugitive Emissions

1.B Fugitive Emissions

- Fugitive emissions refer to the **unintentional release of gases or vapors** during the extraction, processing, storage, and transportation of primary energy sources such as **oil, natural gas, and coal**.
- These emissions are often diffuse and challenging to monitor directly, arising from **mining**, **leaks in equipment**, **pipelines**, or **storage facilities** associated with energy production and distribution.
- However, some sources in 1.B Fugitive Emissions sector are ***engineered or intentional*** (e.g., **tank**, **seal and process vents** and **flare systems**), and therefore relatively well characterized.

What sources are NOT INCLUDED in 1.B Fugitive Emissions

- Fugitive emissions from CCS Projects and CO2 Sequestration *(CO_2 Capture and Storage)*
- Fugitive emissions at non-Oil and non-Gas Industrial Facilities *(IPPU)*
- End-use of oil and gas at non-Oil and non-Gas Industrial Facilities *(IPPU)*
- Fugitive emissions from waste disposal outside the oil and gas Industry *(Waste)*

Coal Mines – Active Mines

Active mines source activities:

- Mining emissions – CH_4 emissions from the release of gas during the breakage of coal and surrounding rock in mining.
- Post-mining emissions – CH_4 emissions from gas released during the handling, processing, and transport of coal.
- Low-temperature oxidation - CO_2 emissions from the slow oxidation of coal when exposed to air.
- Uncontrolled combustion - CO_2 emissions from coal fires caused by trapped heat

When applying Tier 1

The activity data in estimating emissions from active mines is the **amounts of coal produced.**

- CH_4 Emissions = Coal production * EF_{CH_4}

To apply Tier 2 you will need basin-specific or mine-specific data and emission factors

Coal Mines – Abandoned Mines

Even after mining activities cease, **abandoned coal mines** may still emit CH_4 due to ongoing processes within the mine shafts and seams.

- A "**gassy coal mine**" contains significant amounts of CH_4 gas within its coal seams. *Abandoned mines deemed non-gassy during operation are presumed to have negligible emissions.*
- Coal mines that were significant CH_4 emitters during operation continue to emit methane **unless flooding cuts off the emissions**. *Emissions from completely flooded abandoned mines can be treated as negligible.*

Tier 1

$$CH_4 \text{ Emissions} = \underbrace{n^o \text{ Abandoned Mines not fully flooded} \bullet \% \text{ Gassy mines}}_{\text{all gassy mines remaining unflooded}} \bullet EF_{CH_4}$$

EF consider the **time elapsed** since the mine was abandoned and the **mine gassiness**

Tier 2 approach for developing an abandoned mine methane emission inventory follows a similar approach to Tier 1, but it incorporates **country- or basin-specific data.**

Oil and Gas Systems – Key concepts

- Oil & Gas fugitive emissions include **all emissions from oil and gas systems** *except those for the use of oil and gas for energy purpose or as a feedstock*

- It covers everything **from an oil well to a consumer**:

  - Exploration and Production
  - Processing and Refining
  - Distribution and Delivery

- Includes equipment leaks, evaporation losses, venting, flaring and accidental releases

Oil and Gas System – Key Methods

- It is good practice to **disaggregate the activities** into major categories and subcategories in the Oil and Gas Industry and then evaluate the emissions separately for each of these.

  - Well Drilling
  - Well Testing
  - Well Servicing
  - Gas Production
  - Gas Processing
  - Gas Distribution
  - Gas Transport
  - Oil Production
  - Oil Upgrading
  - Oil Transport
  - Oil Refining
  - Waste Oil Reclaiming
  - Oil Products Distribution

- Not all segments will necessarily apply to all countries. *For example, a country that only imports natural gas and does not produce any will probably only have gas transmission and distribution emissions.*

- Apply methodological tiers based on **emission levels** and **available resources**.

- **Use different tiers** for various categories and subcategories, including actual measurements for larger sources (if available)

- The overall approach, over time, should be **one of progressive refinement** to address the areas of greatest uncertainty and consequence, and to capture the impact of control measures.

Oil and Gas System – Key Methods

- Tier 1 comprises the application of appropriate default emission factors to a representative **activity parameter (usually throughput)** for each applicable segment or subcategory of a country's oil and natural gas industry

- Tier 1 should only be used for non-key sources. Besides having a high degree of uncertainty, the **Tier 1 does not allow countries to show any real changes in emission over time.**
- Tier 2 consists of using Tier 1 equations with country-specific emission factors.
- Tier 3 comprises the application of a rigorous bottom-up assessment by primary type of source.

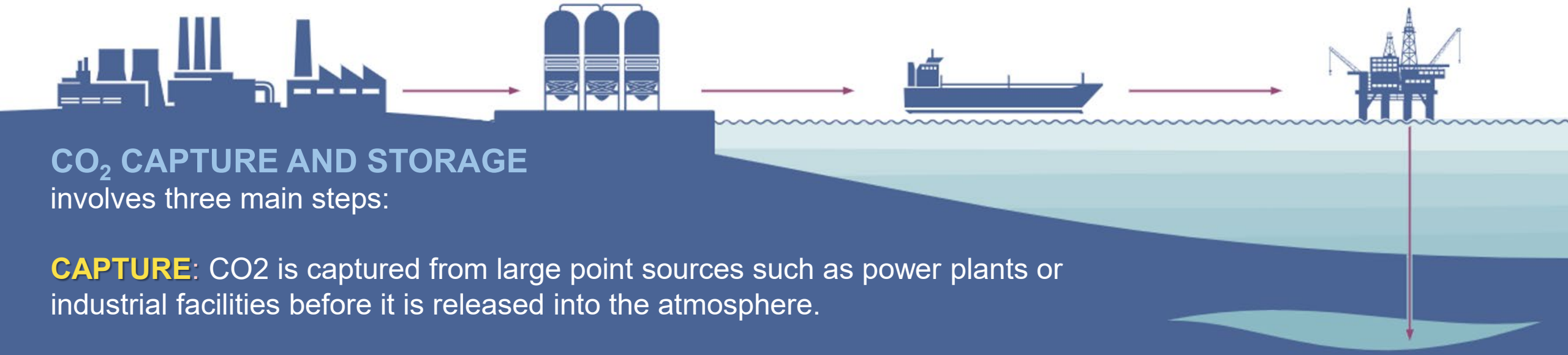
1.C CO2 Capture and Storage

CO_2 Capture and Storage

- CO_2 capture and storage (CCS) is a set of technologies aimed at **capturing CO_2 emissions** from industrial processes and power plants **before they are released** into the atmosphere.
- Once captured, the CO_2 is transported to a suitable storage site, typically deep underground, where it is **securely stored to prevent its release into the atmosphere.**
- Emissions may arise from both **intentional** and **unintentional** sources within the CCS system.

What sources are NOT INCLUDED in 1.C CO2 Capture and Storage

- Energy Use for CO2 Capture and Compression *(Fuel Combustion)*
- Energy Use for Pipeline and Injection Well Operations *(Fuel Combustion)*
- Emissions from Ships Transporting CO2 in International Waters *(International Bunkers)*
- Enhanced Recovery Techniques *(Fugitive Emissions)*



CO_2 CAPTURE AND STORAGE

involves three main steps:

CAPTURE: CO2 is captured from large point sources such as power plants or industrial facilities before it is released into the atmosphere.

TRANSPORT: Captured CO2 is transported via pipelines, ships, trucks, or rail to suitable storage sites. Pipelines are the most common means of bulk transport, followed by ships.

INJECTION AND STORAGE: The captured CO2 is then injected deep underground into geological formations such as saline formations, depleted oil or gas fields, or coal seams for long-term storage. Once injected, the CO2 is trapped in these formations, reducing its release into the atmosphere.

CCS – Emissions Estimates Guidance

Sources of Emissions

- Pipeline Leakages
- Compressor Stations
- Loading/off-Loading

ESTIMATING EMISSIONS

T1 Approach - Use default emission factors from natural gas transmission for estimate leakages from pipeline transport

T3 Approach – Meter emissions during the loading and offloading of ships/trucks

Sources of Emissions

- Compression of gas

ESTIMATING EMISSIONS

T1 Approach – No method suggested

T3 Approach – Direct measurements of injected CO2 using equipment at the wellhead are recommended

Sources of Emissions

- Reservoir Leakage

ESTIMATING EMISSIONS

T1 Approach – No method suggested

T3 Approach – Monitoring technologies and models are recommended for site characterization, risk assessment. Use monitoring data to validate and update models of the storage system.

Summary

Summary (1/2)

Energy Sector Components:

- **Fuel Combustion**: Includes both mobile (e.g., transportation) and stationary (e.g., power plants, industrial facilities) sources.
- **Fugitive Emissions**: Emissions from the unintentional release of gases during extraction, processing, and distribution of fuels.
- **Carbon Capture and Storage (CCS)**: Technologies to capture, transport, and store CO2 emissions from large point sources.

Significance of Energy Emissions:

- The energy sector holds the highest significance in overall emissions accounting, particularly in developed countries.

Major Sources of Emissions:

- CO_2 Emissions: Primarily from fuel combustion.
- CH_4 Emissions: Mainly from fugitive emissions.

Summary (2/2)

Factors Influencing emission factors:

- CO_2 Emissions: Influenced by the **carbon content** of the fuel.
- Non-CO_2 Emissions: Dependent on the **technology** and **conditions employed during combustion**.

Methodological Challenges:

- Proper accounting of biomass emissions to avoid double counting.
- Separate reporting for emissions from international aviation and marine transportation.
- Ensuring accurate sectoral allocation to avoid overlap.

Reference Approach for Verification:

A reference approach is used to verify CO2 emissions, ensuring the robustness and accuracy of emission estimates.

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