2006 IPCC Guidelines: Key concepts for the Energy sector: Transparency Workshop, Pacific Region

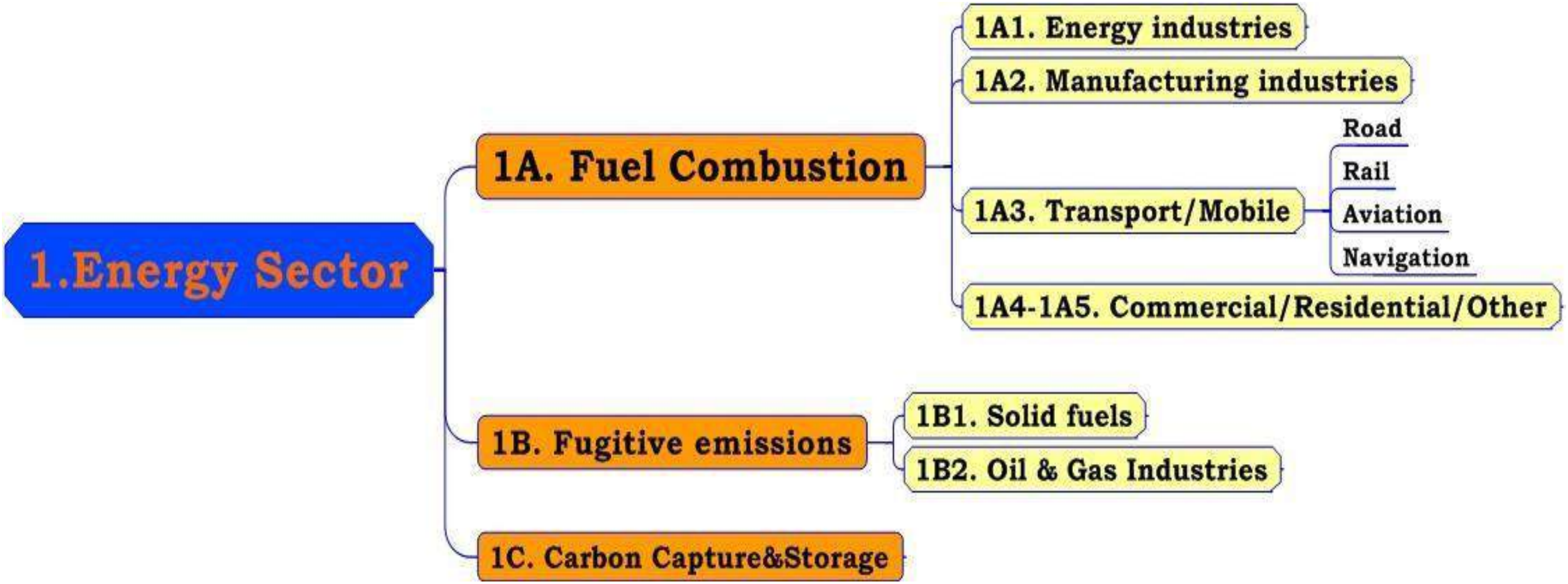
Venue: Crown Beach Resort & Spa, Rarotonga, Cook Islands
Date: 25-28 March 2025

Sekai Ngarize
Climate Transparency Advisor : UNEP-CCC

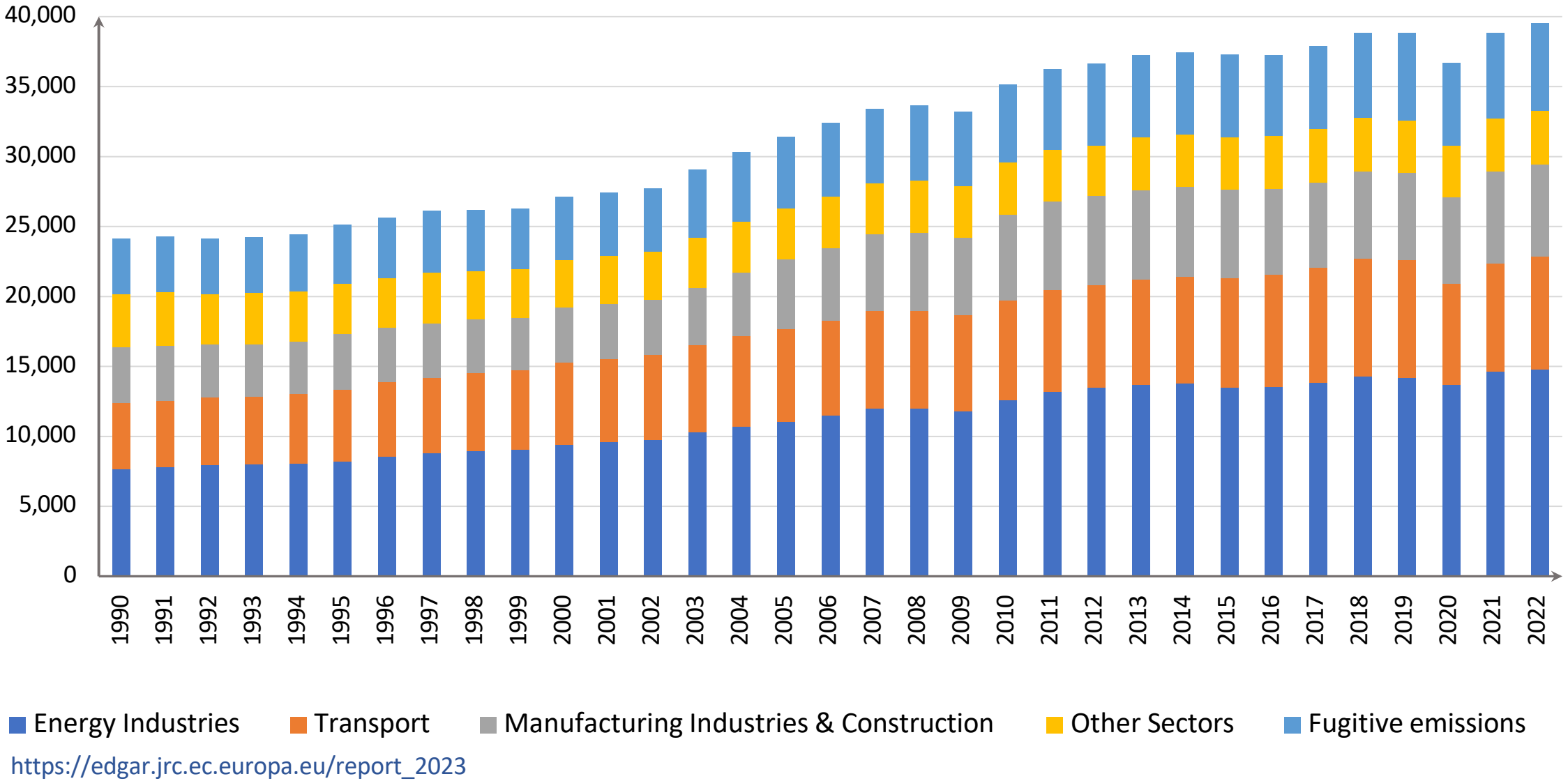
The Outline

- Define the key terms and concepts related to activities associated with the energy sector
- Identify the main sources and types of energy-related activities
- Identify the main categories and subcategories used by the IPCC Guidelines for the Energy sector
- Outline the common methods used to estimate emissions for energy-related activities
- Explain the Reference approach to energy emissions calculations

Energy sector: basic sectoral structure



Energy: Sector composition (Global energy emissions, Mt CO_2-e)



https://edgar.jrc.ec.europa.eu/report_2023

Energy overview

According to https://edgar.jrc.ec.europa.eu/report_2023) and EDGARv8.0 website (https://edgar.jrc.ec.europa.eu/dataset_ghg80, the total world emissions were **53.8** Gt CO_2-e in 2022; and Global total CO_2 emissions (excl. LULUCF) = **38.5 Gt**

IEA Facts

In 2022:

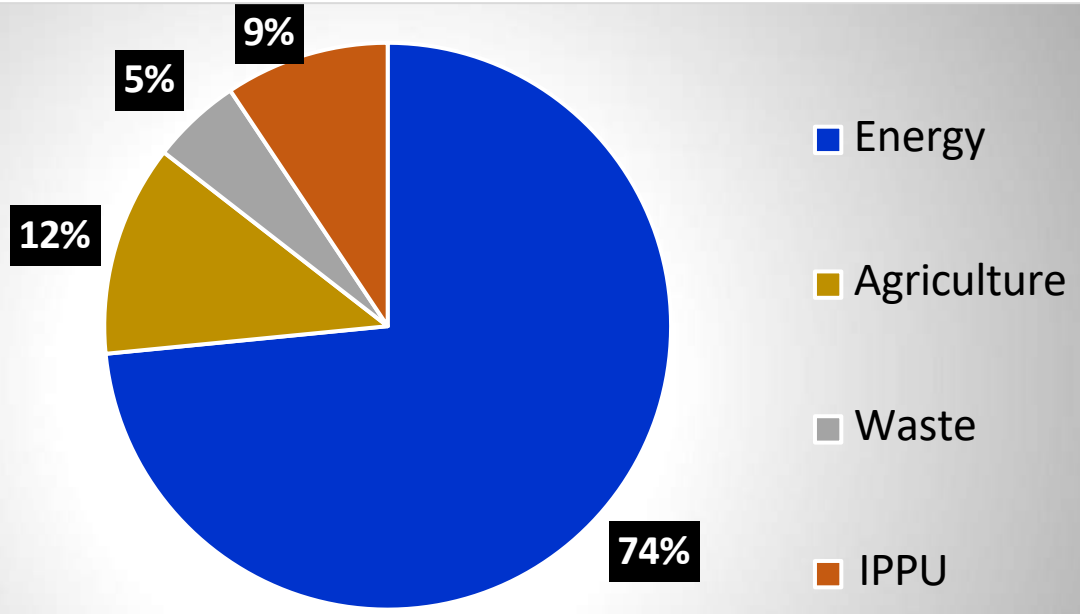
- Coal accounted for over **40% of the overall growth** in global CO_2 emissions in 2022.
- Coal emissions stand at **15.5 Gt CO_2** (**40%** of global CO_2 emissions; **29%** of all GHGs world total)
- Natural gas generated only 50% of emissions from coal – **7.4 Gt CO_2** (**19%** of world total CO_2)
- Oil generated **11.2 Gt CO_2** (**29%** of world total CO_2)

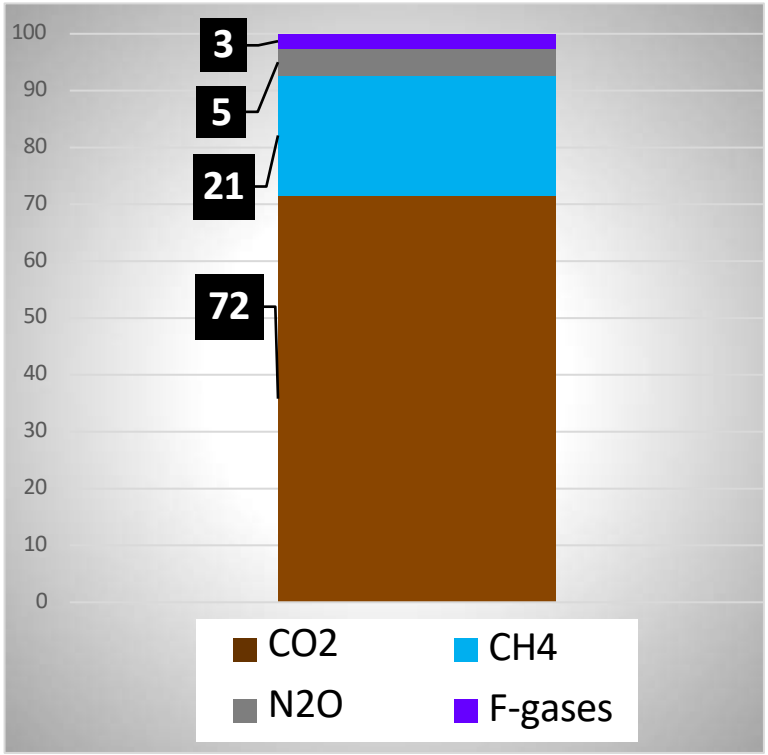
https://iea.blob.core.windows.net/assets/3c8fa115-35c4-4474-b237-1b00424c8844/CO2Emissionsin2022.pdf

How the Energy sector contributes to GHG Inventories

2022

Total:
53.8 Gt CO_2-e
(AR5)





LULUCF = -0.176 Gt (sink) → not included in the diagram

https://iea.blob.core.windows.net/assets/3c8fa115-35c4-4474-b237-1b00424c8844/CO2Emissionsin2022.pdf

CO_2 CH_4 N_2O HFCs PFCs SF_6 NF_3

Key terms and concepts - 1

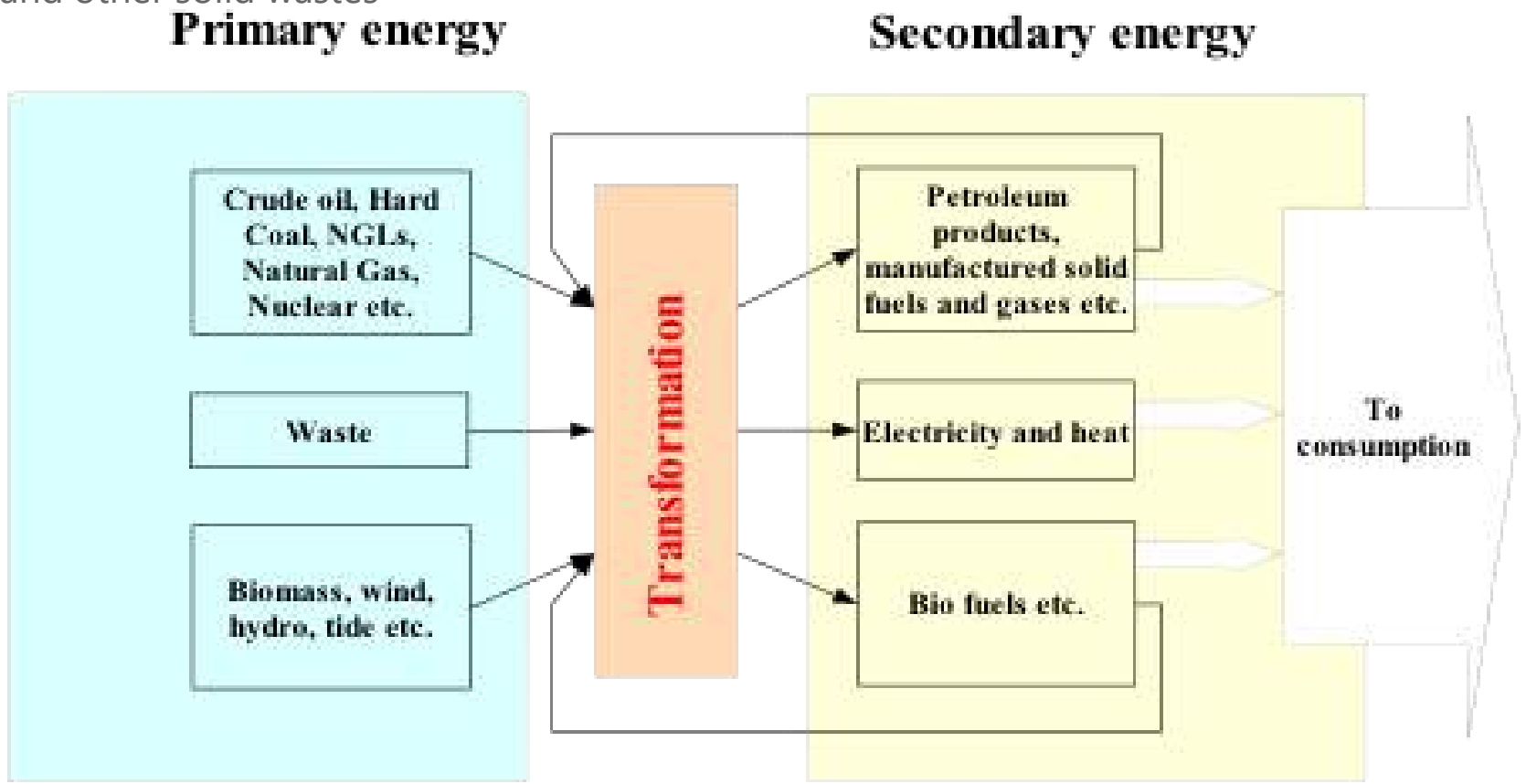
- Fuel:
  - Fuel is any substance burned as a source of energy (as heat or power) in either mechanical or electrical form. Most fuels are of a fossil origin, although biomass can also be used as a fuel source (e.g., wood or ethanol).
- Energy:
  - Generally, it is the capacity of doing work (as defined in physical sciences).
  - In terms of GHG inventory, the energy sector accounts for emissions produced as a result of energy release from fossil and biofuels as well as other sources such as geothermal, solar, and wind to enable various activities.
  - The sector also includes emissions from technologies and processes used for exploration, production, transformation, transportation, and storage of fuels. The transfer and consumption of secondary forms of energy—such as electricity, steam, and heat—are also reported in energy data.



Key terms and concepts

- **Primary energy sources** refer to all fossil fuels in the form that they are when they are extracted from the ground as well as waste and renewable energy sources.
  - crude oil,
  - all types of coal (i.e., anthracite, lignite/brown coal, coking coal),
  - natural gas.
  - Solid biomass
  - Municipal wastes, industrial wastes, and other solid wastes
  - Peat.

typical fuel flows



Carbon content of fuels

Natural gas

- Depends on composition (methane, ethane, propane, butane and heavier hydrocarbons)
- Natural gas flared at the production site will usually be “wet’’ – its carbon content factor will be different
- Typical: 15 to 17 tonnes C/TJ.

Oil

- Lower carbon content for light refined petroleum products such as gasoline
- Higher for heavier products such as residual fuel oil
- Typical for crude oil: 20 tonnes C/TJ.

Coal

- Depend on coal's rank and composition of hydrogen, sulphur, ash, oxygen and nitrogen
- Typical ranges: from 25 to 28 tonnes C/TJ.

Energy value of fuels: NCV and GCV

- **NCV** = **Net** Calorific Value
- **GCV** = **Gross** Calorific Value
- **The difference between NCV and GCV** is the latent heat of vaporization of the water produced during the combustion of the fuel:
  - for coal and oil, the NCV is about 5 % less than the GCV
  - for most natural and manufactured gas, the NCV is about 10 % less
- **Where fuel characteristics (**moisture, hydrogen, and oxygen contents**)** are known, the 2006 IPCC Guidelines give a more precise method to convert GCV to NCV data:

$$NCV = GCV - 0.212\,H - 0.0245M - 0.008Y$$

M – Moisture, H – Hydrogen, Y – Oxygen, %

- Emission factors for CO_2 are in units of kg CO_2/TJ on an **NCV** basis and reflect the carbon content of the fuel and the assumption that the carbon **oxidation factor is 1**
- **IPCC default NCV values** can be found here: tbl. 1.2,

https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

Quiz

Q1

The IPCC default NCVs for oil, natural gas, and anthracite are 42.3 TJ/Gg, 48 TJ/Gg, and 26.7 TJ/Gg respectively.

a) *Which fuel type is most efficient in terms of energy?* **Natural gas**

a) *What produces more energy:*

a) *150 kt of anthracite* **4,005 TJ**

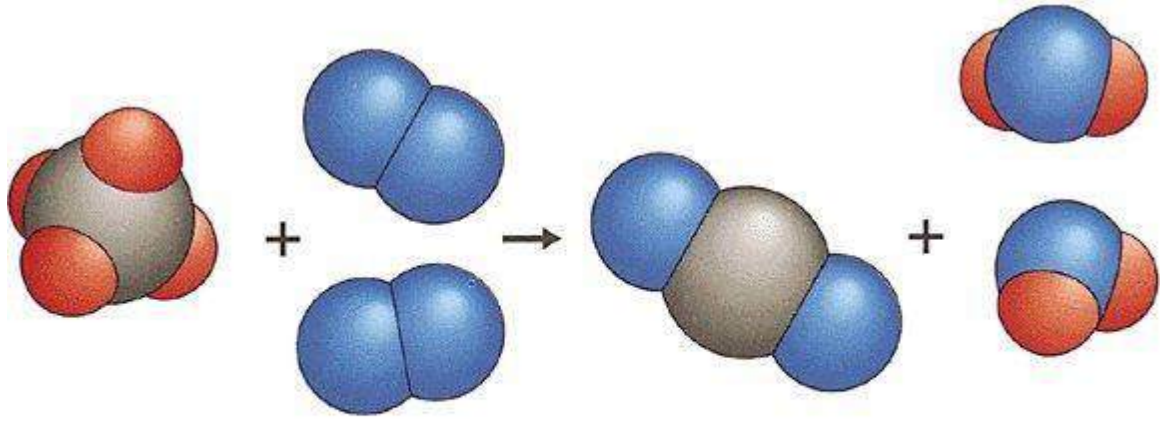
√ b) *90 kt of natural gas* **4,320 TJ**

c) *100 kt of oil?* **4,230 TJ**

GHG emissions from the energy sector

- Fossil fuels are primarily made up of hydrocarbon molecules that (as their name suggests) are composed of hydrogen and carbon atoms.
- In addition to hydrogen and carbon, fossil fuels contain sulfur, nitrogen, and heavy metals.
- When fossil fuels are combusted, these atoms combine with oxygen from the air to form relevant oxides: largely CO_2 and water (H_2O). Other products include oxides of other elements (e.g., SO_2, N_2O, etc.)
- Incomplete combustion could also lead to the formation of CH_4, CO, non-methane volatile organic compounds (NMVOCs), etc.
- The energy sector reports the following direct GHGs:
  - **CO_2**
  - **CH_4**
  - **N_2O**

- CO_2 formed from biofuels is reported as a memo item and does not count to the national totals



$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Energy-related activities and major sources of emissions

Mobile combustion means the burning of fuel in a mobile device, like an engine or a generator. Mobile combustion is associated with transport activity, i.e., road, off-road, air, railways, and water-borne navigation.
Mobile sources produce direct greenhouse gas emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from the combustion of various fuel types, as well as several other pollutants such as carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs), sulfur dioxide (SO_2), particulate matter (PM) and different nitrogen oxides (NO_x), which cause or contribute to local or regional air pollution.

During different stages of CO_2 capture and storage (CCS) amounts of CO_2 could be released in the atmosphere either as result of leaks or intentionally as part of equipment maintenance.

Stationary fuel combustion sources are devices that combust solid, liquid, or gaseou fuel, generally for the purposes of producing electricity, generating steam, or providi useful heat or energy for industrial, commercial, or institutional use, or reducing the volume of waste by removing combustible matter. Stationary fuel combustion sourc could include boilers, simple and combined-cycle combustion turbines, engines, incinerators, and process heaters.

During the extraction, transportation and storage of fossil fuels, amounts of CH_4 and N_2O are released into the atmosphere:

- CH_4 is released accidentally (e.g., leaks) or intentionally (e.g., releasing pipeline pressure).
- N_2O emissions from coal mining and oil and gas systems arise from flaring of gases.

These emissions are usually referred to as fugitive emissions.

Quiz

Q1

The energy sector accounts for the majority of GHG emissions for most countries –

True *or* ***False****?* **TRUE**

Q2

Which GHG dominates emissions from the energy sector?

- **N_2O (Nitrous oxide)**
- **CO (Carbon monoxide)**
- √ **CO_2 (Carbon dioxide)**
- **CH_4 (methane)**

Q3

Which source is not covered under the energy sector?

- Exploration of oil and gas
- √ Use of fossil fuels in chemical reactions in industrial processes
- Use of fuels in transport
- Fuel transformation from primary to secondary fuels
- Distribution of liquid fuels

Special cases – reported, but not counted towards total emissions

Biomass

- CO_2 emissions from biomass combustion are not included in the national total. They are reported separately (*information or memo item*)
- Non-CO_2 emissions (CH_4, N_2O) are reported in the national total
- Net carbon emissions are accounted for in the LULUCF/AFOLU sector
- Peat is treated as a fossil fuel

International bunkers

Aviation and Shipping (water-borne navigation):

- Domestic emissions included in National Total
- International emissions reported separately as ***"Bunker Fuels"***

- Domestic trips are journeys between points in one country
- International trips - between countries

How to recognize international bunkers?

Criteria for defining international or domestic aviation

applies to individual legs of journeys with more than one take-off and landing

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

Quiz

A flight from Wellington (New Zealand) to Seoul (South Korea) has two connection stops - one in Auckland (New Zealand) and one in Hong Kong (China).

Emissions for which legs of the flight should be counted towards the national emissions and which should be reported as an information (memo) item only:

Flight leg	Is this leg Domestic (D) or International (I)?	Counted to the national total emissions? (Yes/No)	Reported as a memo item only? (Yes/No)
Wellington - Auckland	**D**	**Yes**	**No**
Auckland – Hong Kong	**I**	**No**	**Yes**
Hong Kong- Seoul	**I**	**No**	**Yes**

Energy Sector: Scope

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

Carbon capture and storage

Waste as a Fuel

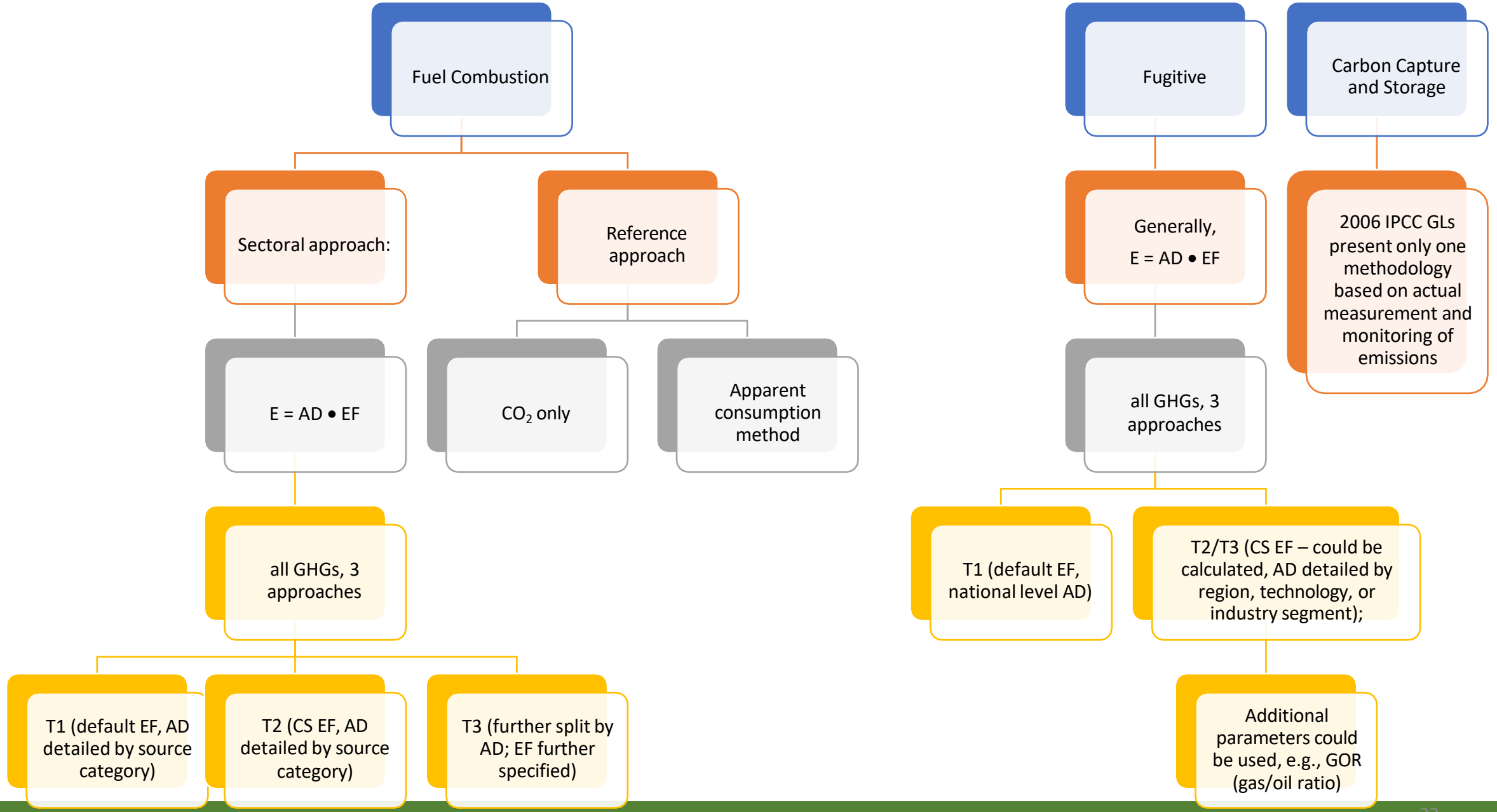
- Some waste incinerators also produce heat or power
- In such cases the waste stream will show up in national energy statistics and it is good practice to report these emissions under the energy sector
- This could lead to double counting when in the waste sector the total volume of waste is used to estimate emissions
- Only the fossil fuel derived fraction of CO_2 from waste is included in national total emissions

Approach to estimating emissions

- ✓ Collect activity data (AD) and metadata
- ✓ Preliminary data processing
- ✓ Select emission factors (EFs) and parameters
- ✓ Document assumptions
- ✓ Use IPCC equations or country-specific models to estimate emissions

Reference approach	Sectoral approach	Tier 2 or 3
• Estimate apparent consumption of fuels within the country.	• Collect actual consumption statistics by fuel type and economic sector	• Collect actual fuel consumption statistics by fuel type, economic sector and combustion technology type.

Common methods to calculate emissions from the energy sector



Reference approach

Reference Approach is a top-down approach, using national fuel supply data to calculate the emissions of CO_2 from fuel combustion:

- *CO_2 only*
- *Uses Apparent Consumption*
- *Applies "excluded carbon"*
- *Used as a check for Sectoral Approach (an example of Verification)*

Apparent consumption = Production + Import - Export - International bunker - Stock change

CO_2 emissions = (Apparent Consumption - Excluded Carbon) * EF

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

Basic steps for estimating CO_2

1. Collect fuel consumption data.
2. Convert fuel data to a common energy unit.
3. Calculate the Apparent consumption
4. Select carbon content factors for each fossil fuel/product type and estimate the total carbon content of fuels consumed.
5. Subtract the amount of carbon stored in products for long periods of time.
6. Multiply by an oxidation factor.
7. Convert carbon to full molecular weight of CO_2 and sum across all fuels.

Excluded Carbon/Non-Energy Use of Fuels

TABLE 1.2
TYPES OF USE AND EXAMPLES OF FUELS USED FOR NON-ENERGY APPLICATIONS

Type of use	Example of fuel types	Product/process	Chapter
Feedstock	natural gas, oils, coal	ammonia	3.2
	naphtha, natural gas, ethane, propane, butane, gas oil, fuel oils	methanol, olefins (ethylene, propylene), carbon black	3.9
Reductant	petroleum coke	carbides	3.6
	coal, petroleum coke	titanium dioxide	3.7
	metallurgical cokes, pulverised coal, natural gas	iron and steel (primary)	4.2
	metallurgical cokes	ferroalloys	4.3
	petroleum coke, pitch (anodes)	aluminium [1]	4.4
	metallurgical coke, coal	lead	4.6
	metallurgical coke, coal	zinc	4.7
Non-energy product	lubricants	lubricating properties	5.2
	paraffin waxes	misc. (e.g., candles, coating)	5.3
	bitumen (asphalt)	road paving and roofing	5.4
	white spirit[2], some aromatics	as solvent (paint, dry cleaning)	5.5

1. Also used in secondary steel production (in electric arc furnaces) (see Chapter 4.2).
2. Also known as mineral turpentine, petroleum spirits, industrial spirit ("SBP").

Oxidation factors – points to remember

- Oxidation factor is used to account for the small amount of unoxidized carbon that is left in ash or soot.
- Default Oxidation factor = 1 (2006 IPCC GLs), but this is an approximation
- Amount of carbon remaining unoxidized should be low for oil and natural gas combustion
- It can be larger and more variable for coal combustion
- When national oxidation factors are not available, use IPCC default factors

Oxidation factor values for different fuel types

Natural gas

- Less than 1% left unburned
- Remains as soot in the burner, stack or environment
- Higher for flares in the oil and gas industry
- Closer to 100% for efficient turbines.

Oil

- 1.5 ± 1 per cent left unburned
- Closer to 100% in efficient devices with catalytic converters.

Coal

- Range from 0.6% to 6.6% unburned
- Primarily in the form of bottom and fly ash

Biomass

- Can range widely, especially for open combustion
- For closed combustion (e.g. boiler), the range is from 1% to 10%
- No IPCC default.

Quiz

Calculate CO_2 emissions from the use of natural gas in country X using the data below and the Reference approach:

Please note:

- *Consider that fraction of oxidized carbon = 1;*
- *1 kt = 1000 t*
- *To convert C emissions to CO_2 emissions: $E(CO_2) = E(C) \bullet 44/12 = E(C) \bullet 3.667$*

CO_2 emissions = (Apparent Consumption - Excluded Carbon) * EF
Apparent consumption = Production + Import - Export - International bunker - Stock change

Production (TJ)	Imports (TJ)	Exports (TJ)	International Bunkers (TJ)	Stock Change (TJ)	Apparent Consumption (TJ)	Carbon EF (t C/TJ)	Carbon Emissions (kt C)	Carbon excluded (kt C)	Net C Emissions (kt C)	CO_2 emissions (kt CO_2)
21000	NO	NO		1000	**20,000**	15	**300**	200	**100**	**366.7**

Thank you