GHG Inventory – Stationary combustion

Training on 2006 IPCC Guidelines for preparing National GHG Inventory:

Jaypalsinh Chauhan

Organized by the Capacity Building Initiative for Transparency
Global Support Programme (CBIT-GSP)

Contents

1. Stationary combustion coverage in 2006 IPCC guideline
2. Analysis of 2006 IPCC Guidelines and 2019 Refinement
3. Stationary Combustion in GHGI, 2010
    - Data collection
    - Tier selection - EF, Activity data
    - Emissions - Philippines
4. Sample calculation

Outline of Energy Sector

1. **Energy Sector: scope and importance**
2. **Fuel Combustion (stationary and mobile): CO2 emissions**
3. **Fuel Combustion: CH4 and N2O emissions**
4. **Methodological issues:**
    - 4.1 Biomass
    - 4.2 Road Transport
    - 4.3 International bunker
    - 4.4 Waste as a fuel
    - 4.5 Reference Approach
    - 4.6 Excluded carbon
5. **Fugitive Emissions**
    - 5.1 Coal mines
    - 5.2 Oil and gas systems
6. **Carbon Dioxide Transport, Injection and Geological Storage**
7. **Summary**

Reference: UNFCCC CGE Training material

Energy Sector: Scope

1. **Exploration and exploitation of primary energy sources**

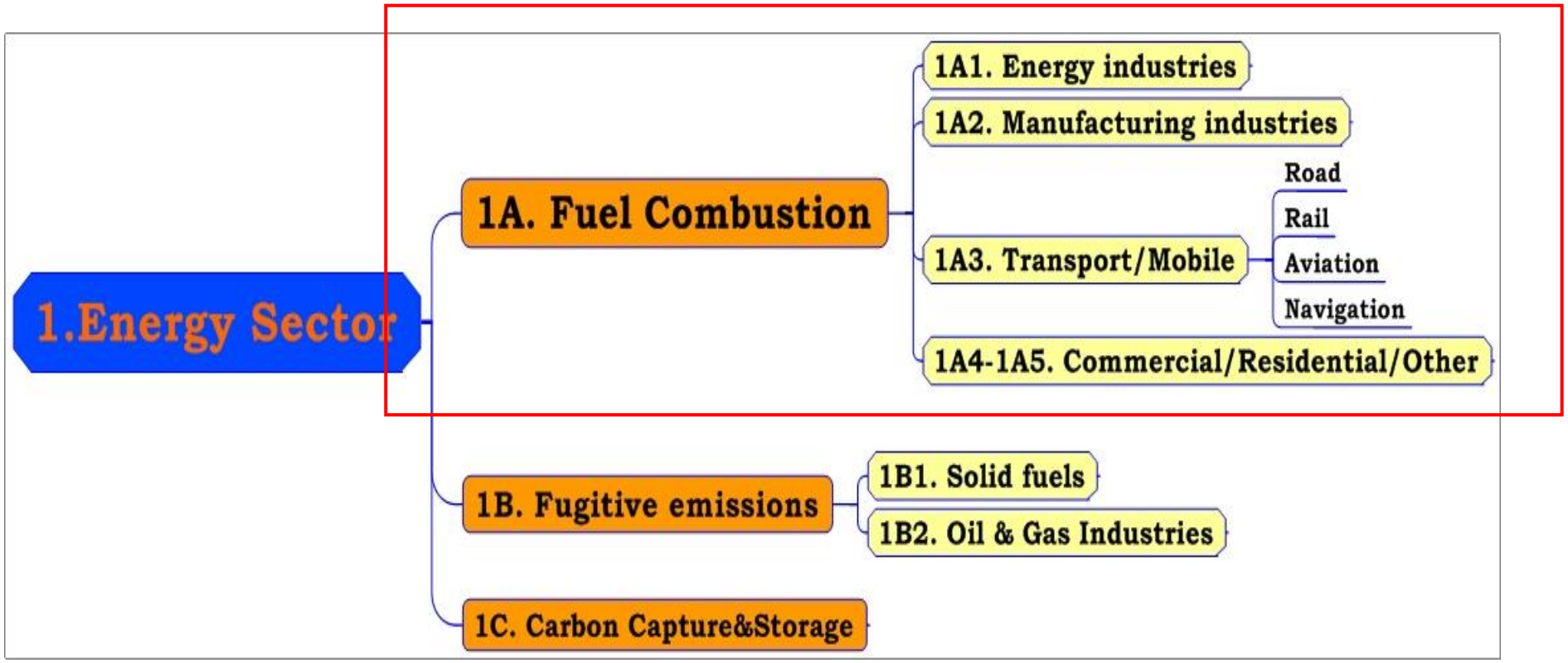
2. **Conversion of primary energy sources into more useable energy forms in refineries and power plants**

3. **Transmission and distribution of fuels**

4. **Use of fuels in stationary and mobile applications**

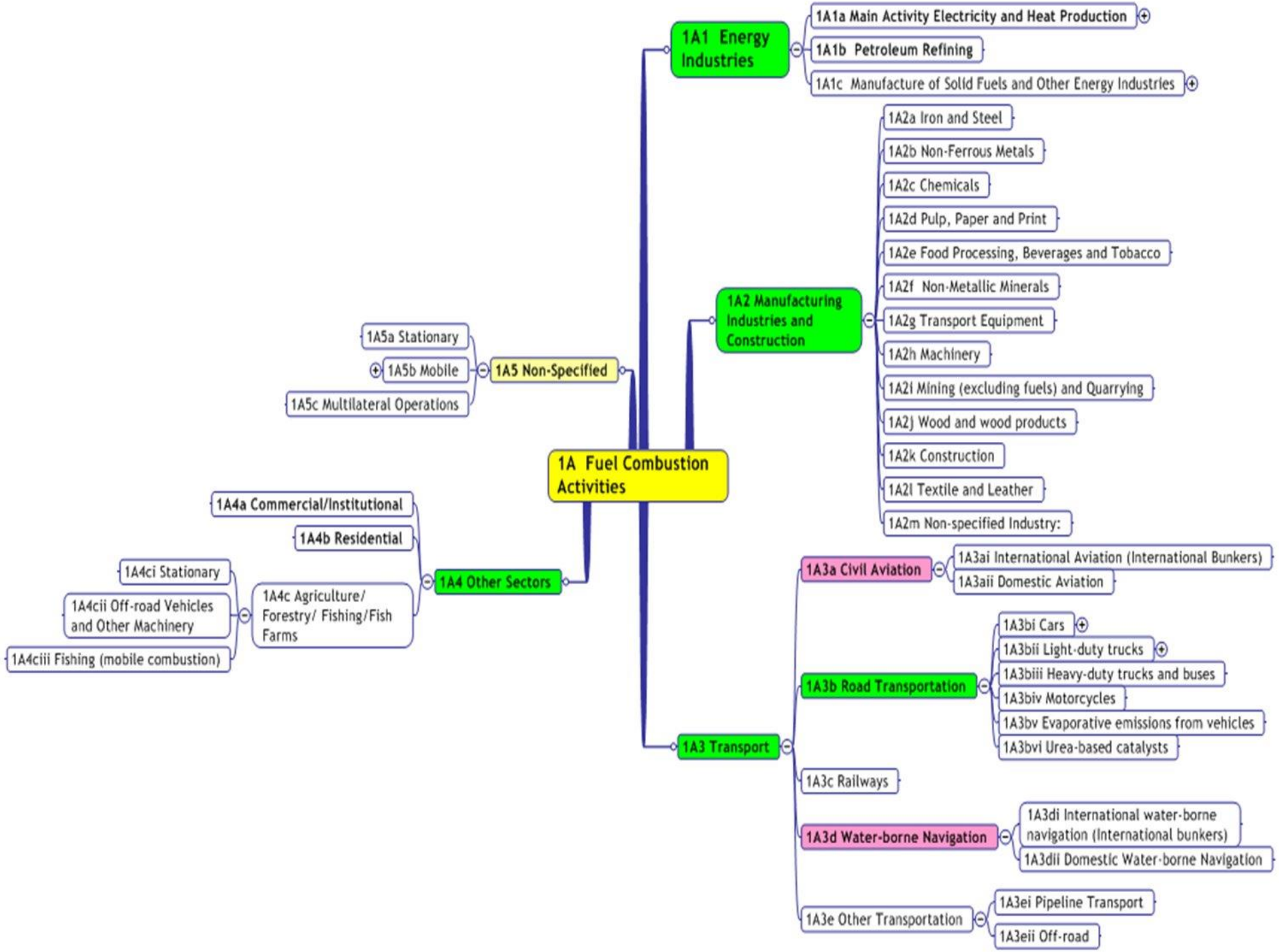
Reference: UNFCCC CGE Training material

Energy Sector



Reference: UNFCCC CGE Training material

1. Stationary combustion coverage in 2006 IPCC guideline


1A Fuel Combustion Activities
1A1 Energy Industries
1A1a Main Activity Electricity and Heat Production
1A1b Petroleum Refining
1A1c Manufacture of Solid Fuels and Other Energy Industries
1A2 Manufacturing Industries and Construction
1A2a Iron and Steel
1A2b Non-Ferrous Metals
1A2c Chemicals
1A2d Pulp, Paper and Print
1A2e Food Processing, Beverages and Tobacco
1A2f Non-Metallic Minerals
1A2g Transport Equipment
1A2h Machinery
1A2i Mining (excluding fuels) and Quarrying
1A2j Wood and wood products
1A2k Construction
1A2l Textile and Leather
1A2m Non-specified Industry:
1A3 Transport
1A3a Civil Aviation
1A3ai International Aviation (International Bunkers)
1A3aii Domestic Aviation
1A3b Road Transportation
1A3bi Cars
1A3bii Light-duty trucks
1A3biii Heavy-duty trucks and buses
1A3biv Motorcycles
1A3bv Evaporative emissions from vehicles
1A3bvi Urea-based catalysts
1A3c Railways
1A3d Water-borne Navigation
1A3di International water-borne navigation (International bunkers)
1A3dii Domestic Water-borne Navigation
1A3e Other Transportation
1A3ei Pipeline Transport
1A3eii Off-road
1A4 Other Sectors
1A4a Commercial/Institutional
1A4b Residential
1A4c Agriculture/ Forestry/ Fishing/Fish Farms
1A4ci Stationary
1A4cii Off-road Vehicles and Other Machinery
1A4ciii Fishing (mobile combustion)
1A5 Non-Specified
1A5a Stationary
1A5b Mobile
1A5c Multilateral Operations

1A. Fuel 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

✓ ***Not Energy Sector:***

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

✓ ***Coal mines fires, Gas flaring are in Fugitive Emissions***

Reference: UNFCCC CGE Training material

1A. Fuel Combustion. CO_2

- **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%).**

- **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)**

C + O2 = CO2

1 tonne C => 3.667 tonne CO2

(44/12)

Reference: UNFCCC CGE Training material

Exercise 1: CO_2 emissions - ?

Anthracite (80-98% of Carbon, by mass):

1. **"Hypothetical Anthracite": 100% of Carbon, 100% combustion**
2. **Anthracite: 85% of Carbon, 100% combustion**
3. **Anthracite: 85 % of Carbon, 99% combustion**
4. **Anthracite: 85% of Carbon, 95% combustion**
5. **Anthracite: 80% of Carbon, 99% combustion**

CO2 emissions = Amount of Fuel * Emission Factor

EF = Carbon content * Oxidation fraction * 44/12

Anthracite - 1 tonne:

1. **CO_2 emissions = 1 * 1* 1 * 44/12 = 3.667 tonne**
2. **CO_2 emissions = 1 * 0.85 * 1 * 44/12 = 3.117 tonne**
3. **CO_2 emissions = 1 * 0.85 * 0.99 * 44/12 = 3.086 tonne**
4. **CO_2 emissions = 1 * 0.85 * 0.95 * 44/12 = 2.961 tonne**
5. **CO_2 emissions = 1 * 0.80 * 0.99 * 44/12 = 2.904 tonne**

Reference: UNFCCC CGE Training material

1A. Fuel Combustion. Fuels

- **SOLID** (Coal and Coal Products)
  - including Coal, Coke and Derived Gases
- **LIQUID** (Crude Oil and Petroleum Products)
  - Including Fuel Oil, Gasoline, LPG, Ethane and Petroleum Coke
- **GAS** (Natural Gas)
- **OTHER FOSSIL FUELS** (Non-biomass municipal & Industrial wastes, waste oils)
- **PEAT**
  - treated as fossil fuel
- **BIOMASS** (Wood, Charcoal, Biofuels, Biomass fraction of MSW)
  - CO_2 emissions not included in total Energy emissions

✓ ***See definition of fuel types in Table 1.1, Volume 2, 2006 IPCC Guidelines***

Reference: UNFCCC CGE Training material

1A. Fuel Combustion. Units

The carbon content may vary considerably both among and within primary fuel types on a per mass or per volume basis. By converting to energy units this variability is reduced.

Fuel units:

- **Volume:** barrels (gallons), cubic feet, cubic meters, litres
- **Mass:** tonnes, kg
- **Energy (*expressed as either NCV or GCV*):** oil/coal-equivalent, calories, kW, MJ, BTU

The 2006 IPCC Guidelines - SI units :

1. Fuel – Gg (TJ)
2. NCV – TJ/Gg
3. Carbon content – kg/GJ
4. CO_2 EF – kg/TJ (*per energy basis*)

Reference: UNFCCC CGE Training material

IPCC Energy Units

	NCV, TJ/Gg	Carbon Content, kg/GJ	Default CO_2 EF, kg/TJ
Biomass (Wood)	15.6	30.5	112 000
Peat	9.76	28.9	106 000
Lignite	8.9	27.6	101 000
Anthracite	26.7	26.8	98 300
Coking Coal	28.2	25.8	94 600
Residual Fuel Oil	40.4	21.1	77 400
Diesel Oil	43	20.2	74 100
Motor Gasoline	44.3	18.9	69 300
Natural Gas	48	15.3	56 100

Reference: UNFCCC CGE Training material

NCV vs. GCV

- **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:**
  - 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:**

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

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

Reference: UNFCCC CGE Training material

Exercise 2: CO_2 emissions - ?

1. Diesel burnt by:

- **Stationary source – a diesel-generator**
- **Mobile source – a car**

2. Amount of diesel burnt - 1 Giga-gram (or 1 201 923 litres, or 317 561 gallons)*

3. Assuming complete combustion

$$CO_2 \text{ emissions} = \text{Amount of Fuel} * NCV * EF$$

$$CO_2 \text{ emissions} = 1 * 43 * 74\,100 = 3\,186\,300 \text{ kg } CO_2$$

$$= 3.19 \text{ Gg } CO_2$$

Reference: UNFCCC CGE Training material

Non-CO_2: CH_4 and N_2O

- **Emission factors for non-CO_2 gases from fuel combustion are dependent on fuel and technology used** (operating conditions, control technologies, quality of maintenance, age of 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**

Reference: UNFCCC CGE Training material

Non-CO_2: CH_4 and N_2O

TABLE 2.7
INDUSTRIAL SOURCE EMISSION FACTORS

		Emission factors[1] (kg/TJ energy input)	
Basic technology	**Configuration**	**CH_4**	**N_2O**
Liquid Fuels			
Residual Fuel Oil Boilers		3	0.3
Gas/Diesel Oil Boilers		0.2	0.4
Large Stationary Diesel Oil Engines >600hp (447 kW)		r 4	NA
Liquefied Petroleum Gases Boilers		n 0.9	n 4
Solid Fuels			
Other Bituminous/Sub-bit. Overfeed Stoker Boilers		1	r 0.7
Other Bituminous/Sub-bit. Underfeed Stoker Boilers		14	r 0.7
Other Bituminous/Sub-bituminous Pulverised	Dry Bottom, wall fired	0.7	r 0.5
	Dry Bottom, tangentially fired	0.7	r 1.4
	Wet Bottom	0.9	r 1.4
Other Bituminous Spreader Stokers		1	r 0.7
Other Bituminous/Sub-bit. Fluidised Bed Combustor	Circulating Bed	1	r 61
	Bubbling Bed	1	r 61
Natural Gas			
Boilers		r 1	n 1
Gas-Fired Gas Turbines[2] >3MW		4	1
Natural Gas-fired Reciprocating Engines[3]	2-Stroke Lean Burn	r 693	NA
	4-Stroke Lean Burn	r 597	NA
	4-Stroke Rich Burn	r 110	NA
Biomass			
Wood/Wood Waste Boilers[4]		n 11	n 7

Reference: UNFCCC CGE Training material

Non-CO_2: CH_4 and N_2O

TABLE 3.2.2
ROAD TRANSPORT N_2O AND CH_4 DEFAULT EMISSION FACTORS AND UNCERTAINTY RANGES [a]

Fuel Type/Representative Vehicle Category	CH_4 (kg /TJ)			N_2O (kg /TJ)		
	Default	Lower	Upper	Default	Lower	Upper
Motor Gasoline -Uncontrolled [b]	33	9.6	110	3.2	0.96	11
Motor Gasoline –Oxidation Catalyst [c]	25	7.5	86	8.0	2.6	24
Motor Gasoline –Low Mileage Light Duty Vehicle Vintage 1995 or Later [d]	3.8	1.1	13	5.7	1.9	17
Gas / Diesel Oil [e]	3.9	1.6	9.5	3.9	1.3	12
Natural Gas [f]	92	50	1 540	3	1	77
Liquified petroleum gas [g]	62	na	na	0.2	na	na
Ethanol, trucks, US [h]	260	77	880	41	13	123
Ethanol, cars, Brazil [i]	18	13	84	na	na	na

Reference: UNFCCC CGE Training material

Combustion Emissions – Higher Tiers

Tier 1

Amount of fuel combusted, default NCV, carbon content, CO_2 EF (complete combustion)

Emissions = AD * EF

Tier 2

Amount of fuel, country-specific NCV, carbon content and CO_2 EF (oxidation rate), N_2O EF, CH_4 EF

Tier 3

Emissions depend on fuel type used, combustion technology, operating conditions, control technology, quality of maintenance, age of the equipment used to burn the fuel – plant-specific EFs (measurements)

Reference: UNFCCC CGE Training material

Biomass

Biomass is a special case:

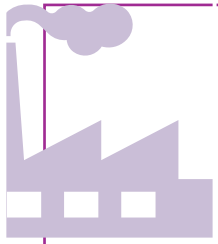
- **CO_2 emissions from biomass combustion are not included in the national total. They are reported separately (*information item*)**
- **Non-CO_2 emissions are reported in the national total**
- **Net carbon emissions are accounted for in the LULUCF/AFOLU sector**
- **Peat is treated as a fossil fuel**

Reference: UNFCCC CGE Training material

Avoiding Double Counting Activity Data With Other Sectors as per IPCC 2006 guidelines

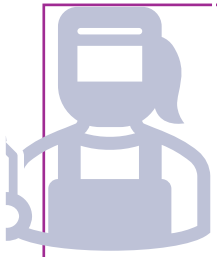
Fuel Combustion Sector:

- Use fuel combustion statistics instead of fuel delivery statistics.
- Be cautious about incomplete combustion data and potential double counting.
- Coordinate estimates between stationary source categories to avoid inaccuracies.



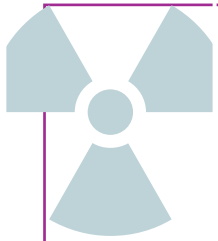
Industrial Processes and Product Use (IPPU) Sector:

- Account for emissions from synthesis gas production in IGCC under fuel combustion.
- Consider emissions from carbide production, especially when using carbon-rich fuels.



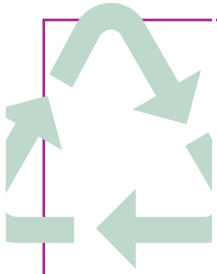
Metal Production (IPPU and AFOLU Sectors):

- Include emissions from the use of coal, coke, natural gas, and by-product fuels in metal production.
- Differentiate between fossil carbon materials and biogenic content for wood chips and charcoal.



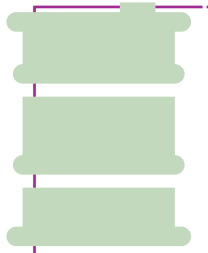
Energy and Waste Sectors:

- Ensure consistency between stationary combustion and fugitive emissions accounting for methane from coal mine waste, landfill gas, and sewage gas.
- Report emissions from waste incineration with energy recovery in the Energy sector.



Waste Sector (Incineration):

- Distinguish between waste incineration with and without energy recovery.
- Assess and differentiate between fossil-carbon and biogenic content for accurate emissions reporting.



Waste Sector (Used Oils):

- Coordinate with those recovering used oils to assess the extent of burning.
- Estimate and report emissions in the Energy sector if used oils are used as fuel.

Summary

- **Energy Sector = Fuel combustion (mobile and stationary) + Fugitive emissions + CCS**
- **Energy emissions are usually the most important**
  - CO_2 from fuel combustion is major source
  - CH_4 mainly comes from fugitive emissions
- **CO_2 emission factor depends on carbon content of fuel, non-CO_2 – on the technology used**
- **Methodological issues** (biomass, international bunker, excluded carbon/fuels in other sectors)
- **Reference approach is used for checking** (CO_2)

Reference: UNFCCC CGE Training material

2. Analysis of 2006 IPCC Guidelines and 2019 Refinement

- According to the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories no refinements has occurred in stationary combustion except treatment of biomass

Comparative Analysis of 2006 IPCC Guidelines and 2019 Refinement

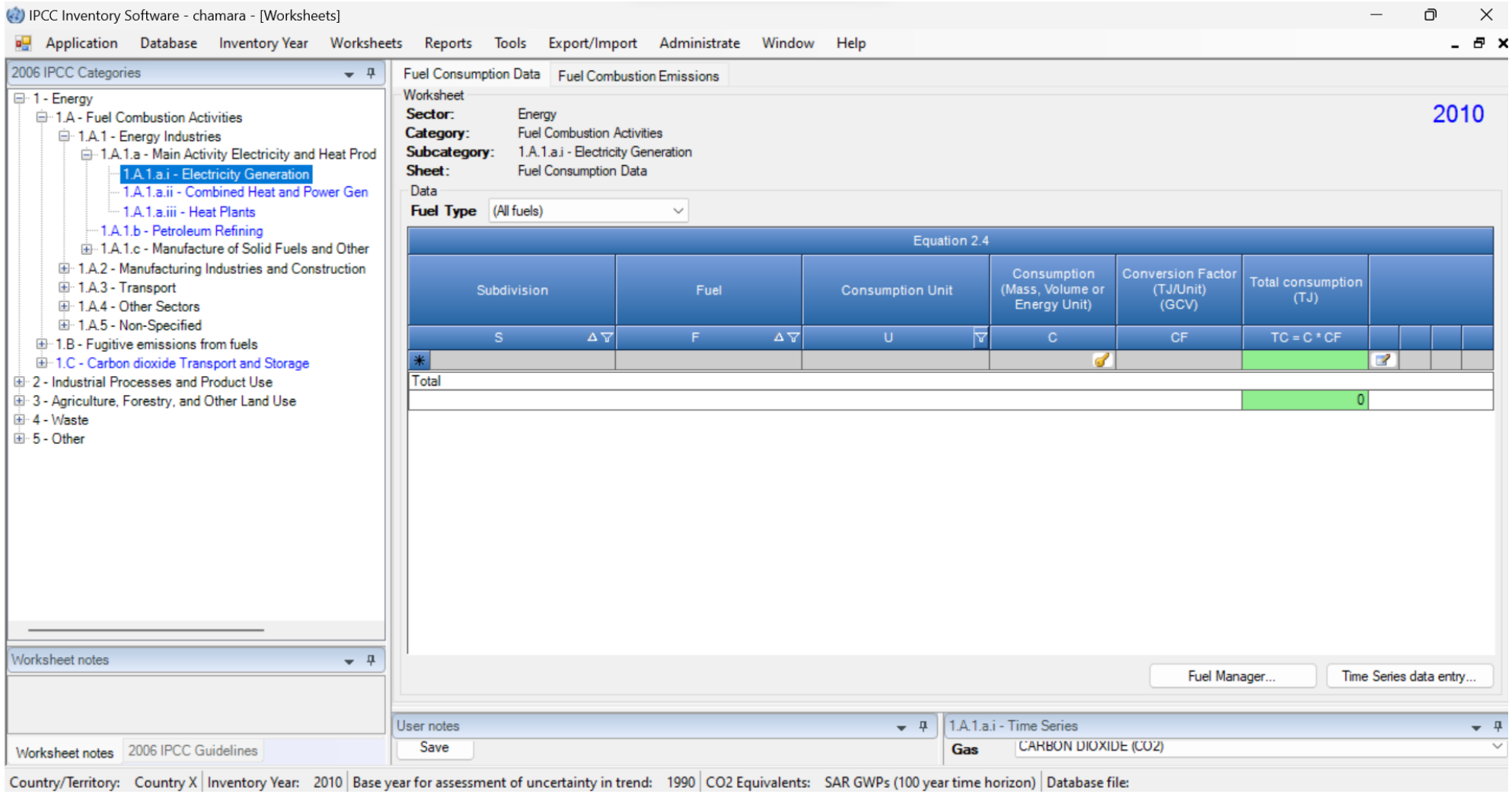
Treatment of biomass

	2006 IPCC Guideline	2019 Refinement
CO_2 Emissions from Biomass Fuels	Reported in AFOLU sector; not included in sectoral totals.	Reported as information items; not included in sectoral or national totals to avoid double counting. Default CO_2 emission factors provided.
CH4 and N2O Emissions	Included in sectoral and national totals.	Included in sectoral and national totals, in addition to stock changes estimated in AFOLU sector.
Estimation for Energy Sector	Only that part combusted for energy estimated.	Only the part combusted for energy estimated for inclusion as an information item in the Energy sector.
Fuel Wood Activity Data	Data available from IEA or FAO.	Data available from IEA or FAO; compilers encouraged to contact national statistical agencies for better understanding.
Biofuels Combustion	Not mentioned	Biofuels combustion mentioned; recommended to establish split between fossil and non-fossil fractions for emission factor application.

How do we conduct GHG emission estimation for electricity generation using IPCC software?

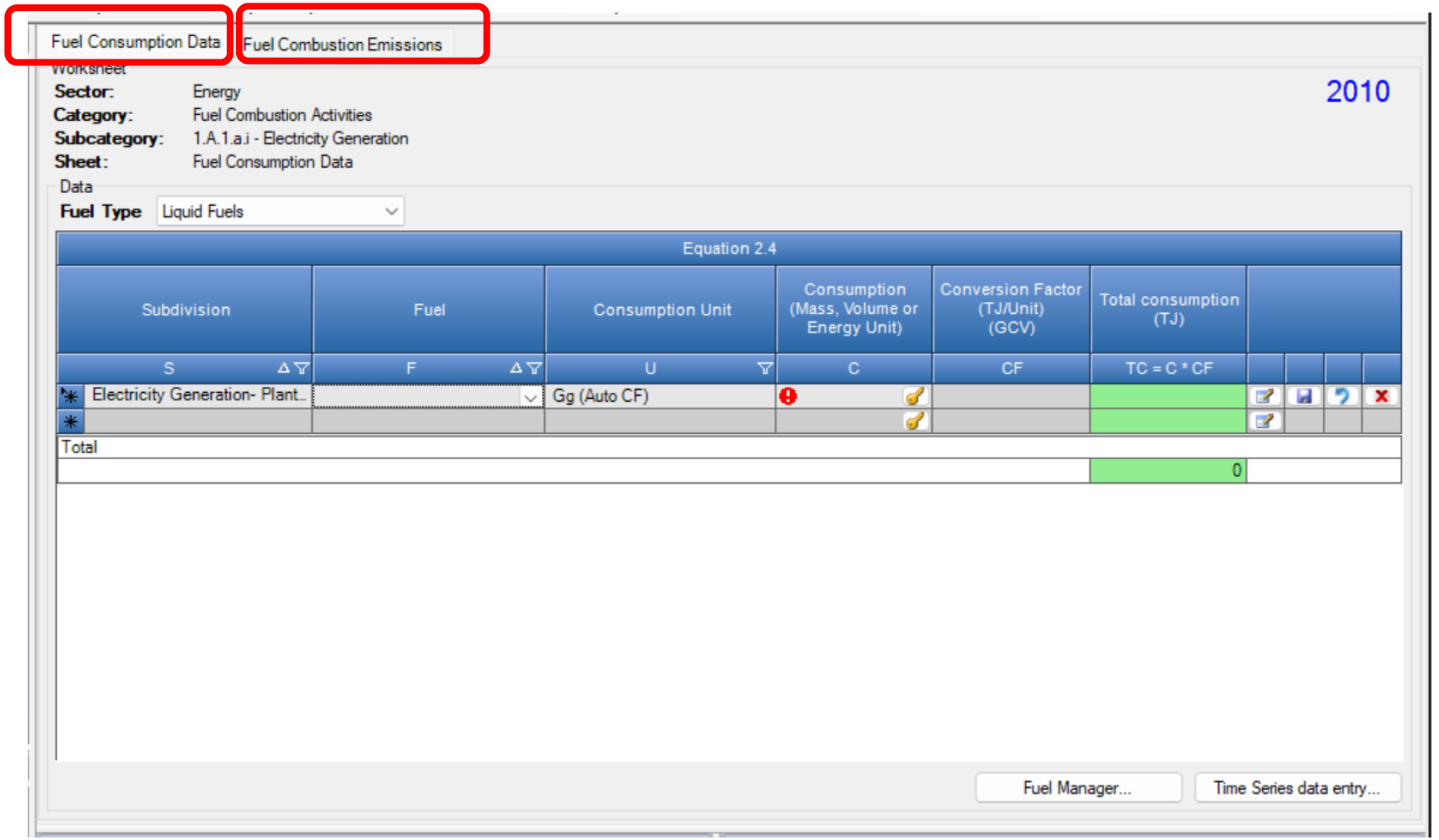
1.A.1.a.i - Electricity Generation

This the work sheet for Electricity Generation



Activities at worksheet

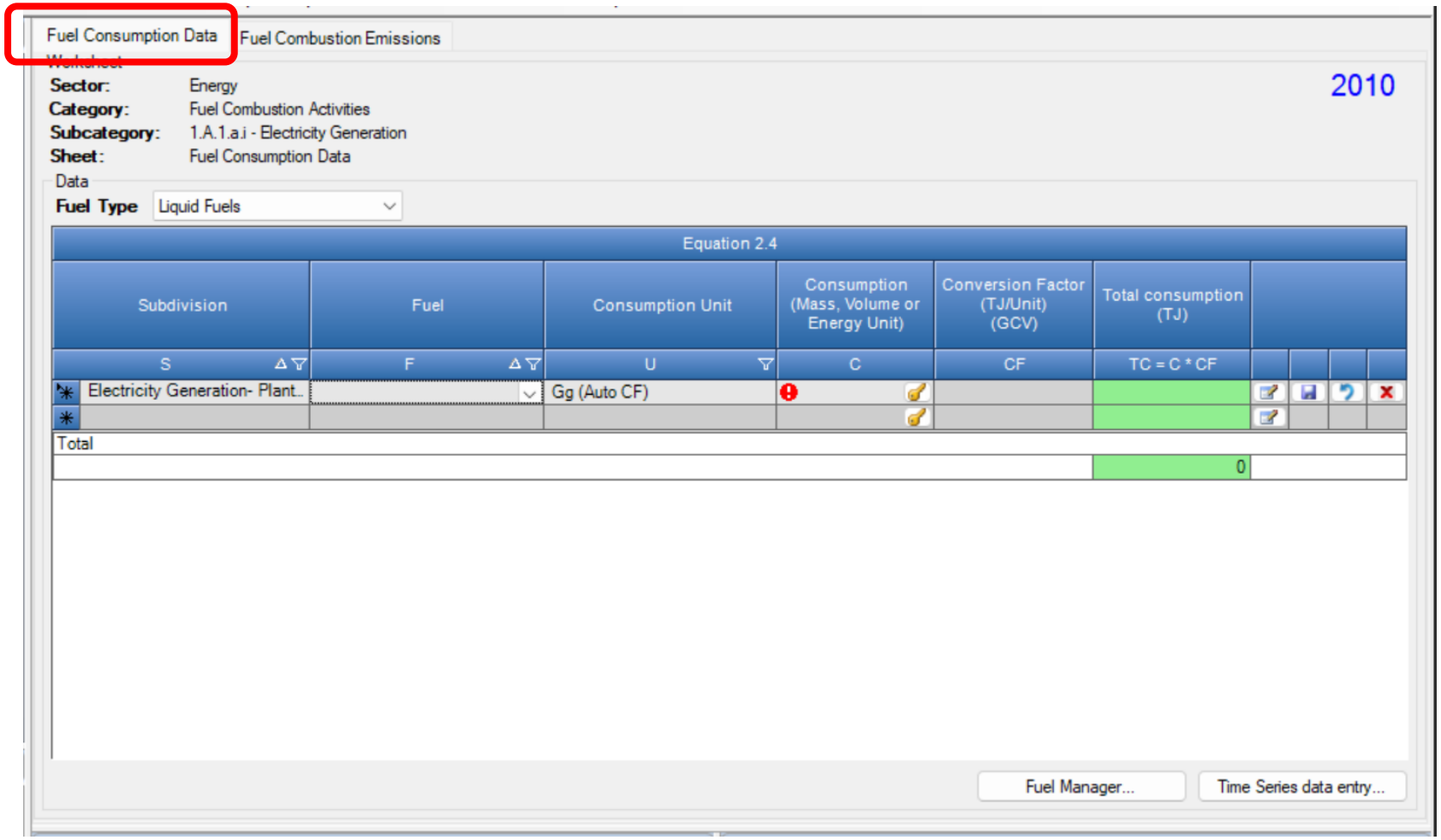
When compiling a greenhouse gas (GHG) inventory for the electricity sector using IPCC software, the process is divided into two main sections.



Activities at worksheet

- **Fuel Consumption Data:**

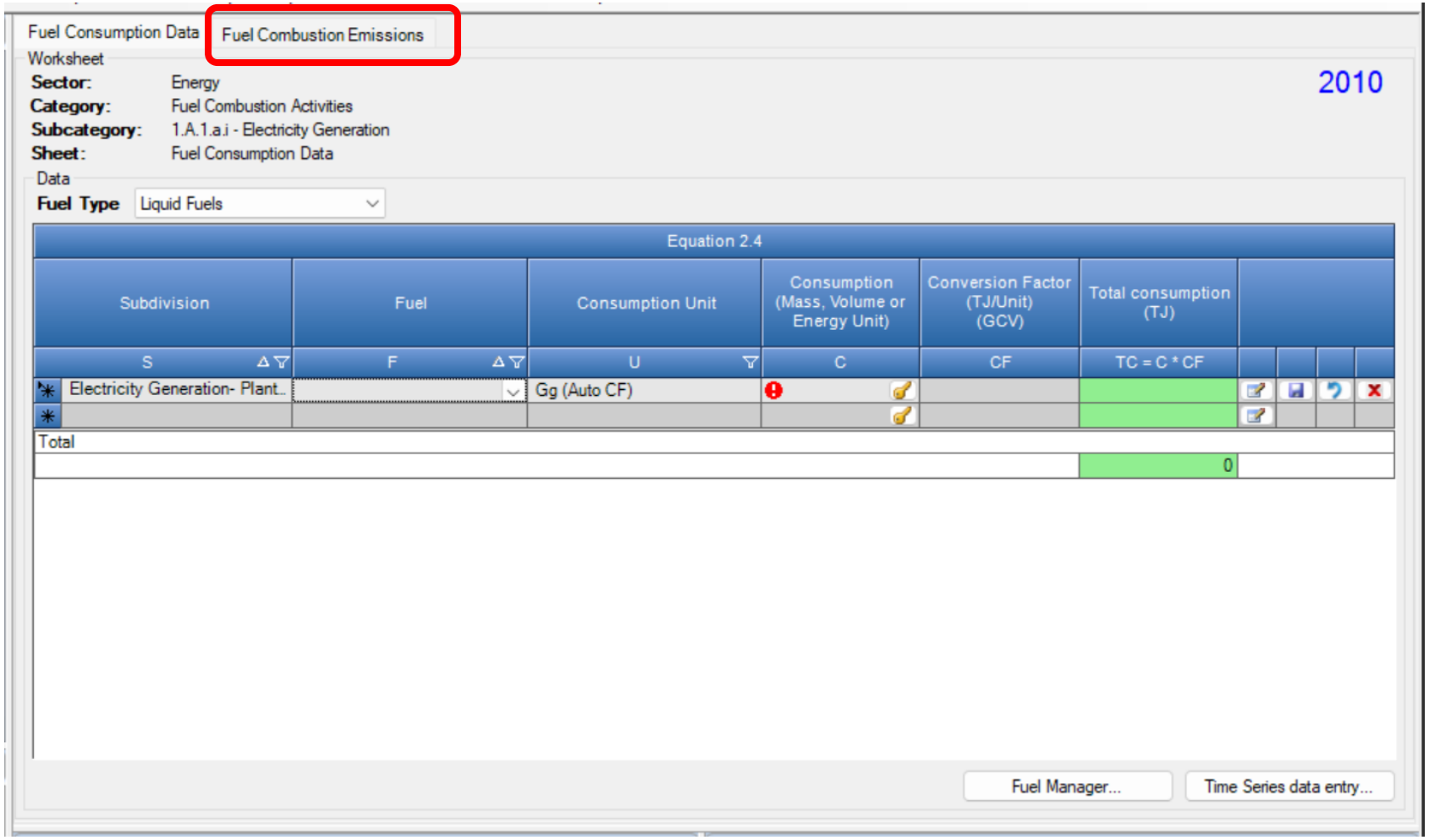
This part is all about gathering details on how much fuel is being used. We need precise records of the types and amounts of fuel used within the electricity sector.



Activities at worksheet

- **Fuel Combustion Data:**

Fuel Combustion Data involves examining the emissions generated through the combustion process and accurately measuring and assessing their quantities.



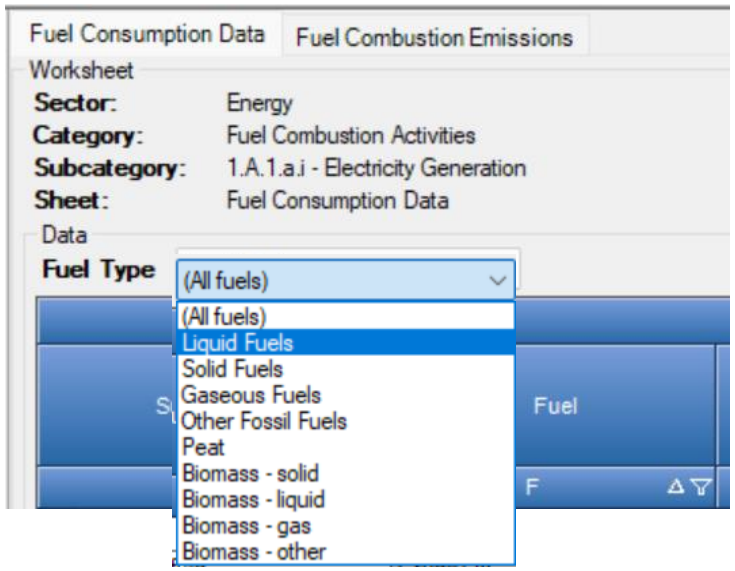
Entering Data in the Fuel Combustion Section

Let's walk through an example of how to input data into the Fuel Consumption section

- Item : Electricity generation - plant-01
- Fuel Type : Crude Oil
- Fuel consumption : 4500 TJ/year

Entering Data in the Fuel Combustion Section

Frist select the “Fuel Type”



Other fuel types

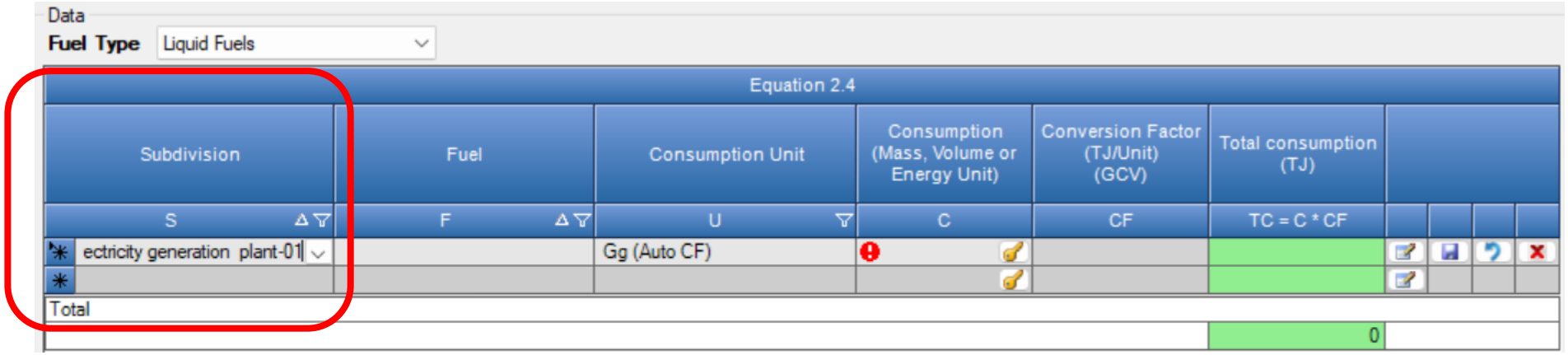
These are the fuel types

Fuel Types

- Liquid Fuels
- Solid Fuels
- Gaseous Fuels
- Other Fossil Fuels
- Peat
- Biomass – solid
- Biomass- liquid

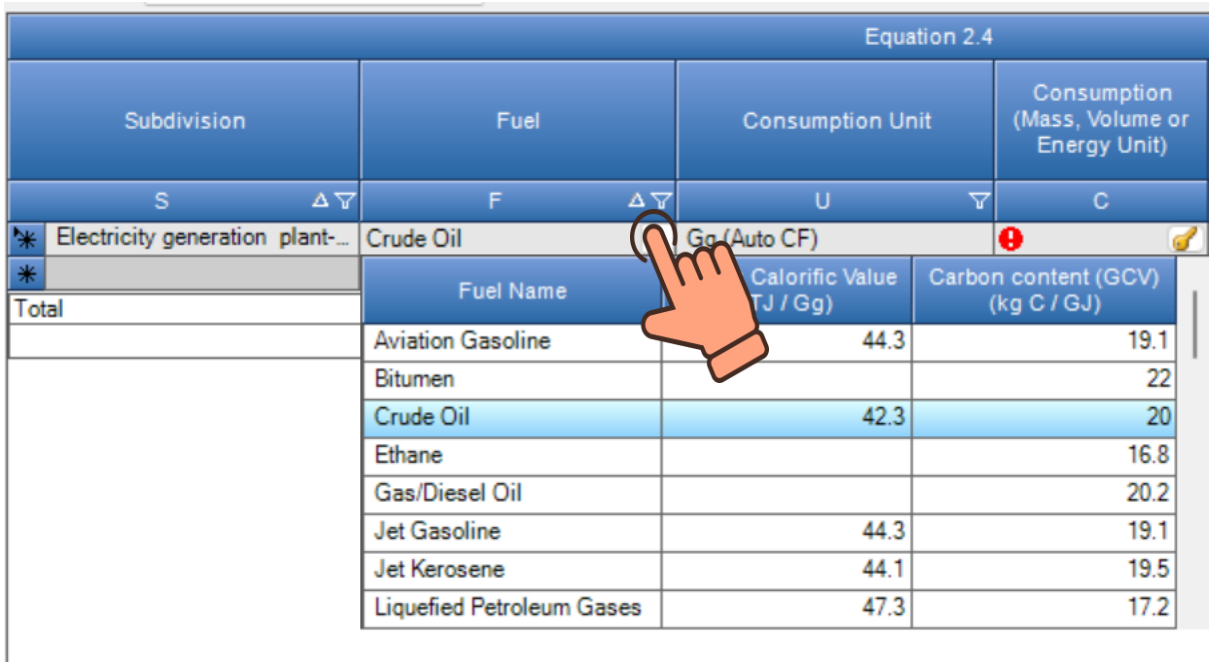
Entering Data in the Fuel Consumption Section

Enter the name or code of your electricity generation plant under the 'Subdivision' column.



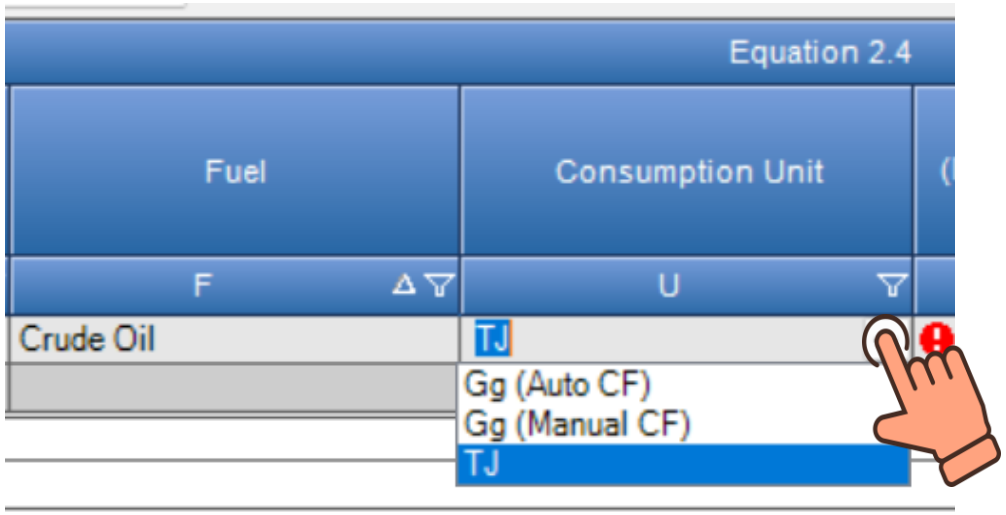
Entering Data in the Fuel Consumption Section

Next, choose "crude oil" from the dropdown menu in the Fuel column.



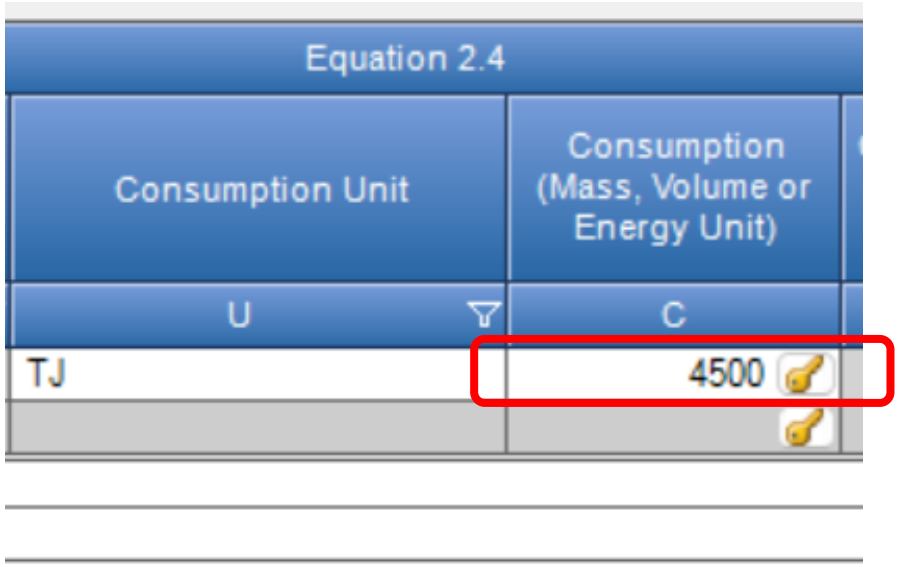
Entering Data in the Fuel Consumption Section

Next, select "TJ" as the Consumption unit



Entering Data in the Fuel Consumption Section

Afterward, input the consumption quantity in the Consumption column



Equation 2.4	
Consumption Unit	Consumption (Mass, Volume or Energy Unit)
U	C
TJ	4500

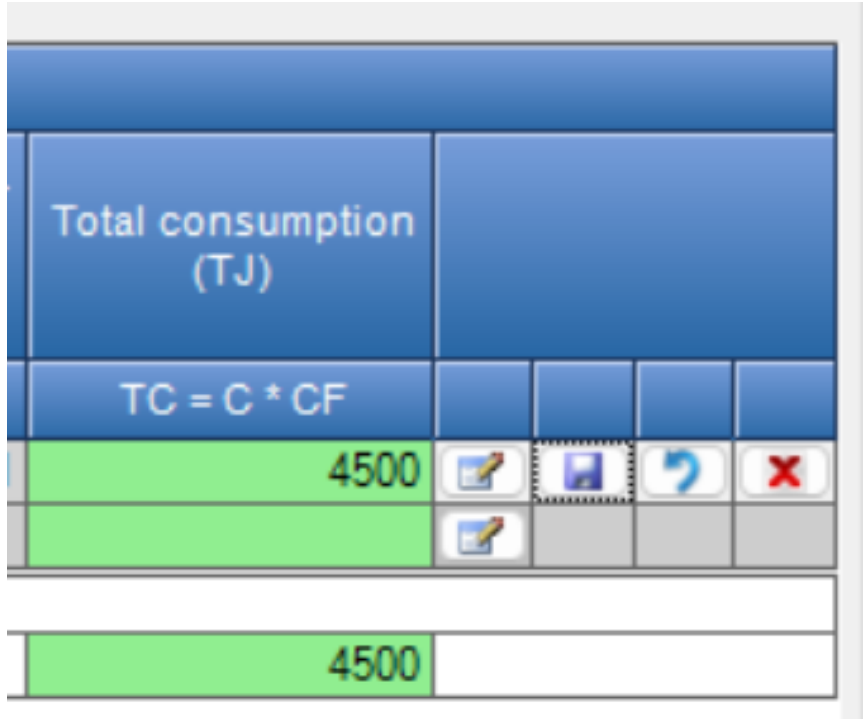
Entering Data in the Fuel Consumption Section

All right, those fields you see are the only ones available for input within the Fuel Consumption section

Towards the end, you've got some options in the last column:

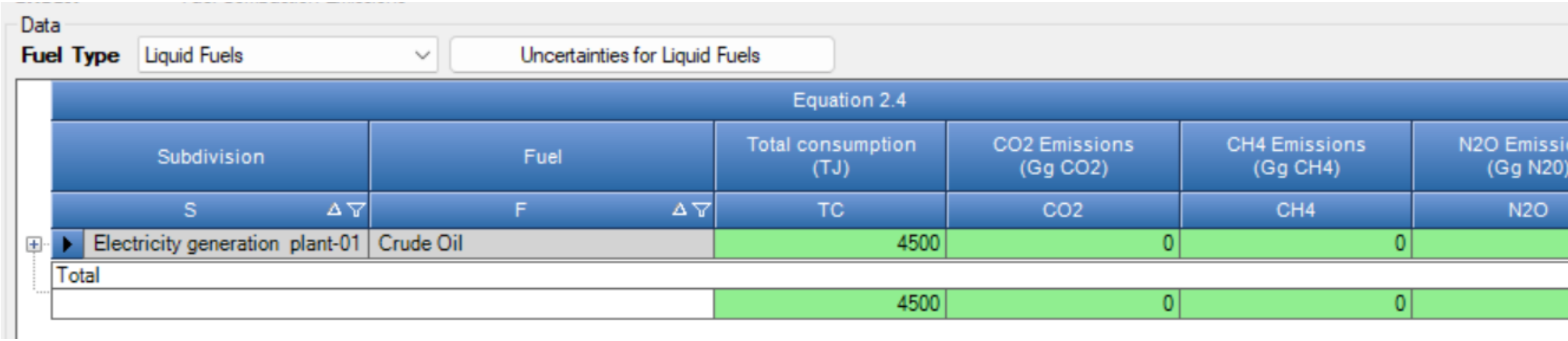
- you can jot down any remarks
- save your progress
- undo changes
- delete entries if needed.

Once done here, we'll move over to the Fuel Combustion Emission section.



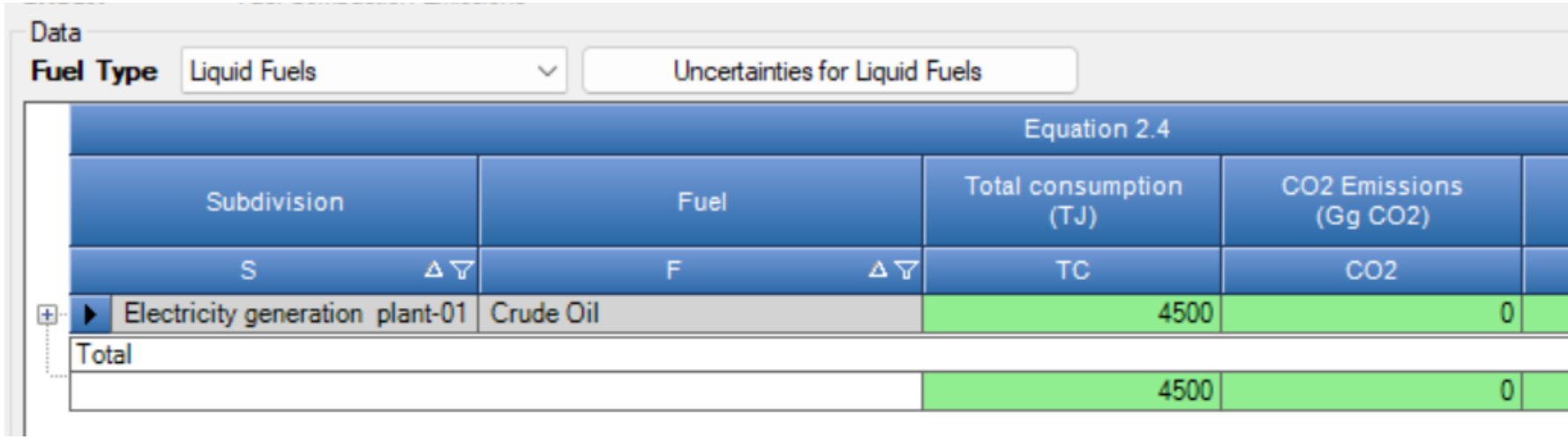
Entering Data in the Fuel Combustion Section

Let’s select for "Liquid fuels" as the fuel type



Entering Data in the Fuel Combustion Section

Next, click on the small "+" icon.

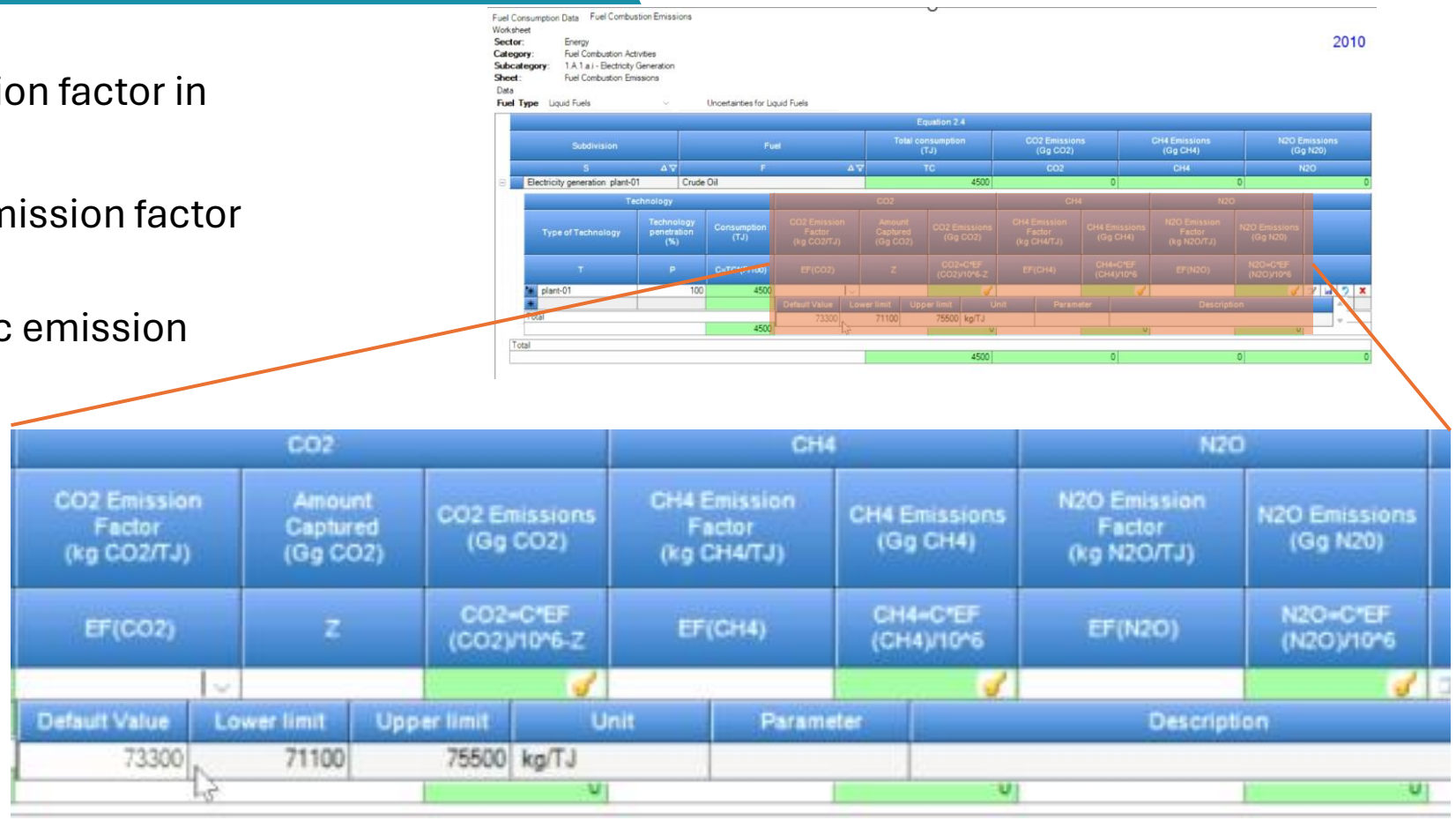


Tier consideration using IPCC tool

Tier 1 Approach: Select IPC default emission factor in IPCC software

Tier 2 Approach: Enter country specific emission factor values

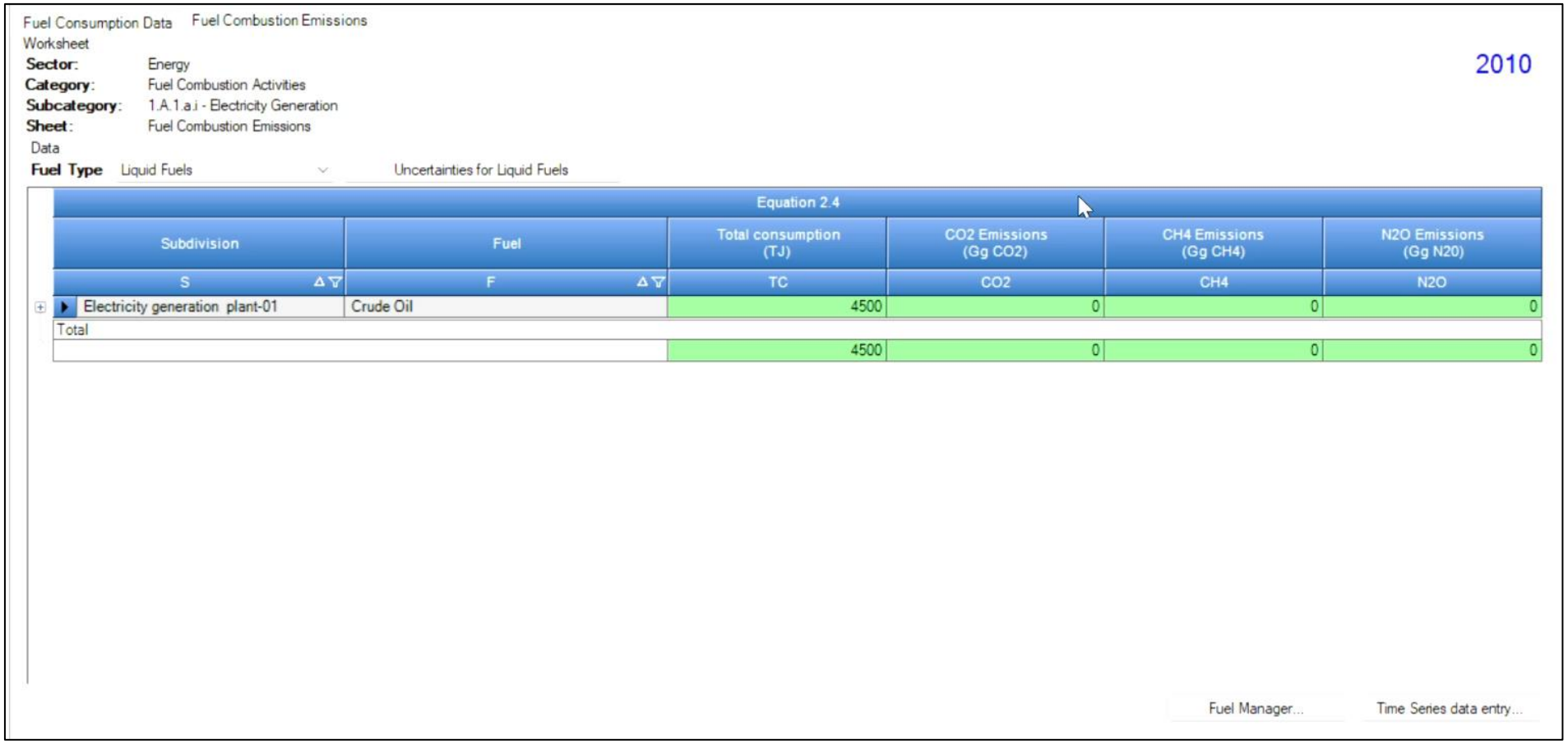
Tier 3 Approach: Enter technology specific emission factor values



Entering Data in the Fuel Combustion Section

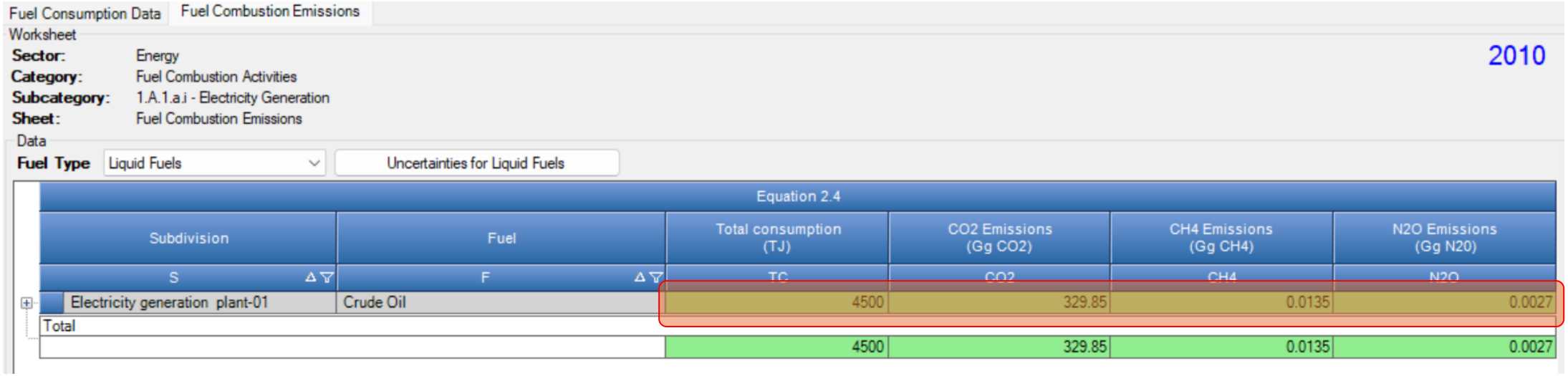
If you have specific values for each column, you can input them. Otherwise, you can select the default values and finally, click the "Save" button.

Tier 1 approach is used in this example



Entering Data in the Fuel Combustion Section

This is how the first entry looks once you're done. You'll follow the same steps to add new entries under electricity generation.



Fuel Consumption Data | Fuel Combustion Emissions

Worksheet

Sector: Energy
Category: Fuel Combustion Activities
Subcategory: 1.A.1.a.i - Electricity Generation
Sheet: Fuel Combustion Emissions

2010

Data

Fuel Type Liquid Fuels | Uncertainties for Liquid Fuels

Equation 2.4					
Subdivision	Fuel	Total consumption (TJ)	CO2 Emissions (Gg CO2)	CH4 Emissions (Gg CH4)	N2O Emissions (Gg N20)
S	F	TC	CO2	CH4	N2O
Electricity generation plant-01	Crude Oil	4500	329.85	0.0135	0.0027
Total					
		4500	329.85	0.0135	0.0027

Exercise-01

1.A.1.a.i - Electricity Generation

Step 01: Open the Worksheet 1: Fuel Consumption Data.

Step 02: Enter following data accordingly

Input parameter	Entry	Note
Subdivision	Gas –fired Plant-01	
Fuel Type	Gaseous Fuels	
Fuel	Natural Gas(Dry)	
Consumption	10,000	User defined
Consumption Unit	Gg (Auto CF)	Selection

Step 03: Save entered data

Exercise-01 Cont.

1.A.1.a.i - Electricity Generation

Step 04: Open the Worksheet 2: Fuel Combustion Emissions

Step 05: Enter following data accordingly

Input parameter	Entry	Note
Type of Technology	Gas –fired Plant-01	
Technology penetration	100%	
CO_2 Emission factor	56100 $kgCO_2/TJ$	Default
Amount Captured	0	
CH_4 Emission factor	1 $kgCH_4/TJ$	Default
N_2O Emission factor	0.1 kgN_2O/TJ	Default

Step 06: Save entered data

Exercise-01 Cont.

Fuel Consumption data

Data

Fuel Type Gaseous Fuels

Equation 2.4						
Subdivision	Fuel	Consumption Unit	Consumption (Mass, Volume or Energy Unit)	Conversion Factor (TJ/Unit) (NCV)	Total consumption (TJ)	
S	F	U	C	CF	TC = C * CF	
Gas -fired Plant-01	Natural Gas (Dry)	Gg (Auto CF)	10000	48	480000	
Total						
					480000	

Exercise-01 Cont.

Fuel Combustion data

Data

Fuel Type (All fuels)

Equation 2.4					
Subdivision	Fuel	Total consumption (TJ)	CO2 Emissions (Gg CO2)	CH4 Emissions (Gg CH4)	N2O Emissions (Gg N20)
S	F	TC	CO2	CH4	N2O
Gas -fired Plant-01	Natural Gas (Dry)	480000	26928	0.48	0.048

Technology			CO2			CH4		N2O		
Type of Technology	Technology penetration (%)	Consumption (TJ)	CO2 Emission Factor (kg CO2/TJ)	Amount Captured (Gg CO2)	CO2 Emissions (Gg CO2)	CH4 Emission Factor (kg CH4/TJ)	CH4 Emissions (Gg CH4)	N2O Emission Factor (kg N2O/TJ)	N2O Emissions (Gg N20)	
T	P	C=TC*(P/100)	EF(CO2)	Z	CO2=C*EF(CO2)/10^6-Z	EF(CH4)	CH4=C*EF(CH4)/10^6	EF(N2O)	N2O=C*EF(N2O)/10^6	
Gas-Fired Plant-1	100	480000	56100	0	26928	1	0.48	0.1	0.048	
Total										
		480000			26928		0.48		0.048	

Total				
480000	26928	0.48	0.048	


Q&A