ENERGY SECTOR INVENTORY

DISCLAIMER

PREPARED UNDER

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ABBREVIATIONS AND ACRONYMS

AD	Activity Data
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CH_4	Methane
DOCC	Department of Climate Change
EF	Emission Factor
GHG	Green House Gases
NCV	Net Calorific Value
N_2O	Nitrous oxide
NMVOCs	Non-methane Volatile Organic Compounds
NOx	Oxides of Nitrate
PM	Particulate matter
PLTA	Public Land Transport Authority
QA/QC	Quality Assurance/Quality Control
RA	Reference Approach
SO_2	Sulphur dioxide
TJ	Terajoules

1.1 ENERGY OVERVIEW

The energy sector is proven to be the predominant greenhouse gases (GHGs) emitter in almost every country in the world. The GHGs in this sector include emissions from fuel combustion activities, transportation, and other energy-generated activities in constructions, manufacturing, commercial, institutional, and residential sources. This manual focuses on the energy sector emissions from the combustion of petroleum or fossil fuels from mobile sources (Ministry of Climate Change, 2020).

Mobile sources create direct greenhouse gas emissions from the combustion of different fuel types. The greenhouse gases emitted include carbon dioxide (CO_2), Methane (CH_4) and Nitrous oxide (N_2O) with other pollutants, which are not direct greenhouse gases, as well involving such as carbon monoxide (CO), Non-methane Volatile Organic Compounds (NMVOCs), Sulphur dioxide (SO_2), particulate matter (PM) and oxides of nitrate (NO_x). All these gases contribute to the local and regional air pollution. This manual focuses on the development of estimating direct greenhouse gases - CO_2, CH_4, and N_2O - from mobile combustion that is described in the 2006 IPCC Guidelines as emissions from transport (category 1.A.3). Mobile combustion of fuels that generates greenhouse gas emissions can estimated by using transport activity such as road, air, off-road, water-borne navigation, and railways and applying relevant emission factors. Different mobile sources with their own range of characteristics have an impact on selecting or estimating the emission factors[1].

There is a need for more work to put into filling the numerous gaps to provide information on emissions from different vehicle types as well as the ageing effects in catalytic control of road vehicle emissions. Similarly, it is vital to strengthen the data and information on the appropriate emission factors intended for road transport in developing countries.

International bunker fuels refer to the fuels combusted in ships at sea and by airplanes engaged in international movements. The IPCC recommends that each country estimate emissions originating from international bunker fuels sold within national borders. However, these emissions should be reported separately and, to the extent feasible, excluded from national totals (IPCC Guidelines for National Greenhouse Has Inventories, 1996).

> *International maritime bunkers* refer to the quantities of fuels delivered to ships of all flags engaged in international navigation, encompassing operations at sea, on inland lakes and waterways, and in coastal waters. Consumption by ships engaged in domestic navigation, fishing vessels, and military forces is excluded from this definition.

[1] See Table 3.1.1 for Detailed sector split for the transport sector in the 2006 IPCC Guideline, Volume 2, Chapter 3 Mobile Combustion.

International aviation bunkers refer to the quantities of fuels delivered to aircraft specifically for international flights, determined by the departure and landing locations rather than the nationality of the airline. Fuels used by airlines for their road vehicles and military applications of aviation fuels are excluded from this definition.

The transport sub-categories that are most relevant for Vanuatu include road transport, domestic waterborne navigation, and domestic aviation.

1.1.1 TRANSPORT ACTIVITIES

Domestic waterborne navigation

This category focuses on domestic water-borne navigation in Vanuatu from cargo ships, ferry, fiberglass boats and private boats that are driven mostly by large, slow as well as medium diesel engines. Vanuatu has more than 20 vessels that services the locals from one island to another. This also include transporting heavy materials from one port to another within the country. Water-borne navigation emits direct GHGs as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O).

It also emits other air pollutants like carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), Sulphur dioxide (SO_2), particulate matter (PM) and oxides of nitrogen (NO_x). Note that these pollutants are not mandatory for reporting purposes in this manual (Waldron, et al., Chapter 3 Mobile Combustion , 2006).

Domestic aviation

Domestic aviation focuses on civil domestic passenger and freight traffic that departs and arrives within the same country. From one domestic airport to another. Vanuatu has five commercial operators with around 30 domestic aircraft to connect and service the nation's 65+ inhabited islands (PASO, 2023).

The emissions produced from aviation comes from the combustion of aviation gasoline and jet fuel such as jet kerosene and jet gasoline. Direct GHG emissions from aircraft engines include approximately 70% of CO_2. Modern gas turbines emit little to no N_2O. Modern engines emit little to no CH_4. However, older technology engines emit CH_4 by gas turbines during idle. Other pollutants resulting from the use of fossil fuels in civil aviation include approximately 30% H_2O, and less than 1% each of NO_x, CO, SO_x, NMVOC, particulates, and other trace components, including hazardous air pollutants. Unlike direct greenhouse gases such as CO_2, CH_4, and N_2O, these pollutants are not mandatory for reporting purposes. Emissions depends on the type and number of aircraft operations, the efficiency and type of aircraft engine, type of fuel used, length of flight from one airport to another, time spent at each stage of flight, power setting and, where appropriate, the altitude where exhaust gasses are emitted (Waldron, et al., Chapter 3 Mobile Combustion , 2006).

Road transportation

In IPCC road transportation is categorized under Transport (category 1.A.3b) that involves all types of light-duty and heavy-duty vehicles. Such vehicles compose of light trucks and automobiles, heavy duty vehicles such as buses and tractor trailers, and on-road motorcycles. All these vehicles function on several different fuel types, either gaseous or liquid (Waldron, et al., Chapter 3 Mobile Combustion , 2006). The transport sub-sector is known to be the largest GHG emitter as well as fossil fuel purchaser under the energy sector in Vanuatu. Land transport itself consumes more than 50% of petroleum products that is imported to the country for domestic transportation consumption. Petrol (Gasoline) and Diesel are mainly used in the road transport sector. Lubricants are also used for two-stroke engines. The road transport also includes the off-road transportation as part of GHGs emission sources (Ministry of Climate Change, 2020). Emissions can be estimated either based on fuel consumed (represented by fuel sold) or the distance traveled by the vehicles. Typically, the first approach (fuel sold) is suitable for estimating CO_2 emissions, while the latter (distance traveled by vehicle type and road type) is suitable for estimating CH_4 and N_2O emissions.

There is an estimation of 1,800 km of roads in Vanuatu – 234 km are sealed while 1,142km remain unsealed (gravel). The remaining are earth roads that cover about 4 km. Port Vila and Luganville account for most of the sealed roads in the urban areas. Sealed roads have been extended to rural areas as well as Efate and Santo Island. Most of the islands in Vanuatu road links are constructed to provide service to rural communities (MOCC, 2021). With more road construction occurring, the number of vehicles imported into the country will increase. The 2022 reports have stated that Vanuatu has become the 193rd largest car importer in the world.

Therefore, road transportation in Vanuatu is suitable for prioritizing data efforts, given the country's substantial data availability and information resources. This transport activity warrant prioritization for the energy sector manual due to its significant role as the largest emitter of greenhouse gases (GHGs) and primary consumer of fossil fuels in the country.

1.1.2 METHODS OF EMISSIONS ESTIMATION

Two methods can be employed to calculate CO2 emissions from the road transport subsector:

- The *sectoral approach (bottom-up)* involves estimating CO_2 emissions by analyzing data on the quantities of each fuel type consumed in the transport sector across different vehicle categories, multiplied by appropriate emission factors.
- The *reference approach (top-down)* substitutes actual fuel consumption data with the apparent national consumption of each fuel type, multiplied by the proportion of each fuel type used specifically within the transport subsector. This method is less

accurate compared to the sectoral approach, as it relies on approximate estimates of fuel usage proportions across different energy sectors.

According to the 2006 IPCC Guidelines, the sectoral approach is considered more precise and aligns with best practices. Conversely, the reference approach (top-down) is less accurate due to its reliance on generalized estimates of fuel proportions used by each energy subsector.

Non- CO_2 emissions within Tier 1 methodology can be estimated using fuel consumption data and default emission factors provided in the 2006 IPCC Guidelines.

1.1.3 REFERENCE APPROACH

The Reference Approach employs a top-down methodology that utilizes a country's energy supply data to compute carbon dioxide (CO_2) emissions resulting from the combustion of fossil fuels. This approach relies on national statistics regarding fuel imports, exports, and stock changes, drawing directly from the National Energy Balance without categorizing specific IPCC categories. It also accounts for the use of fossil fuels in international bunkers, such as international aviation and waterborne navigation.

Furthermore, the Reference Approach acknowledges that some portions of fossil fuels consumed within the country is not combusted but used for non-energy purposes. This component is referred to as "Excluded carbon," and its data are derived from the energy balance. This includes fossil fuels utilized in industrial processes as catalysts, feedstock, or lubricants.

The central concept of the Reference approach is Apparent Consumption. It shows the net consumption of fuels in the country excluding international bunkers and stock changes (equation 6.3 in the 2006 IPCC Guidelines[2]):

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

Please note that the term "Production" applies solely to the calculation of apparent consumption for primary fuels, which are naturally occurring fuels like coal, crude oil, and natural gas. For all other fuels categorized as "secondary" (or fuel products such as gasoline and lubricants derived from primary fuels), the production term is not considered (production = 0).

Apparent consumption and excluded carbon serve as the activity data for calculations under the reference approach. The emission factor utilized for estimating emissions under the reference approach is determined by the carbon content of the fuel, the oxidation factor of the fuel (defaulting to 1), and the ratio of the molar masses of carbon dioxide to carbon (44/12). The Reference Approach is created to

[2] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_6_Ch6_Reference_Approach.pdf

calculate CO_2 emissions from fuel combustion that starts from a high-level energy supply data. It does not split fuels by category but only calculates CO_2 emissions. (Treanton, et al., CHAPTER 6 REFERENCE APPROACH, 2006).

EQUATION 6.1

CO_2 EMISSIONS FROM FUEL COMBUSTION USING THE REFERENCE APPROACH

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

CO_2 Emissions	= CO_2 emissions (Gg CO_2)
Apparent Consumption	= production + imports – exports – international bunkers - stock change
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) Note that tonne C/TJ is identical to kg C/GJ
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. Lower values are used only to account for carbon retained indefinitely in ash or soot
44/12	= molecular weight ratio of CO_2 to C.

1.1.4 SECTORAL APPROACH

The Sectoral Approach is a bottom-up approach that uses the activity data from each IPCC category (in the transport subsector – by each type of transport) and the relevant emission factors to estimate emissions from that category for each fuel. The total GHG emissions using the sectoral approach, are obtained by summing up emissions by each type of transport by each fuel using a general equation

GHG emissions = Sum (Activity Data $_{\text{fuel, transport type}}$ x Emission Factor)

Unlike the Reference approach, the sectoral approach is category-specific and it allows estimating emissions of each GHG, not only CO_2. It is IPCC's good practice to apply, whenever possible, the sectoral approach for calculating emissions and use the Reference approach as verification of the CO_2 estimations from the energy sector.

For Tier 1 calculations for CO_2 from each type of transport, the activity data is fuel sold for that type of transport expressed in energy units (TJ). The emission factors are expressed as a mass of CO_2 per TJ of fuel consumed (kg/TJ) for each type of fuel. 2006 IPCC Guidelines provide default emission factors for different fuels[3].

Tier 1 calculations for non-CO_2 GHGs (CH_4 and N_2O) are very similar, they use the same activity data, but different values of the emission factor, which are also provided in the 2006 IPCC GLs[4].

Higher methodological tiers require more detailed activity data split by different environmental conditions and technology used and the relevant country-specific emission factors. For non-CO_2 emissions, additional data on vehicle-km traveled are also necessary.

Currently for Vanuatu, due to resource constraints and data availability, Tier 1 is used for all transport categories.

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[3] E.g., Table 3.2.1, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

[4] E.g., Table 3.2.2, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf

1.2 REFERENCE MANUAL

1.2.1A. TRANSPORT DATA COLLECTION FOR THE SECTORAL APPROACH

Table 1: below shows the Tier 1 activity data (AD) requirement to estimate CO2, N2O, and CH4 from the three transport activities, public road transport, domestic aviation, and domestic waterborne navigation

PUBLIC ROAD TRANSPORT	
ESTIMATING CO_2 EMISSION FROM ROAD TRANSPORT.	
Fuel Type	Diesel oil, motor gasoline, petrol etc.
Fuel consumption by **fuel type** using national data or, as an alternative, IEA, or UN international data sources	Terajoules, TJ
Default CO_2 emission factor (Refer to Annex, Table 2.2.1.1) This is equal to the carbon content of the fuel multiplied by 44/12[5].	kg/TJ
ESTIMATING N_2O AND CH_4 EMISSION FROM ROAD TRANSPORT.	
Fuel Type	Diesel oil, motor gasoline, petrol etc.
Distance Travelled by vehicle type on different road type.	Kilometer, Km
Fuel consumption by **fuel type** using national data or, as an alternative, IEA, or UN international data sources	Terajoules, TJ
Default N_2O and CH_4 emission factor (Refer to Annex, Table 2.2.1.2)	kg/TJ
(See 2006 IPCC Guidelines, Vol 2, Chap 3 Mobile Combustion, Section 3.2.1.1 for Equation 3.2.1, and Equation 3.2.3)	
DOMESTIC AVIATION	

[5] 44/12 is C/CO_2 ratio

ESTIMATING CO_2 EMISSION FROM DOMESTIC AVIATION	
Default CO_2 emission factor (See Annex Table 2.2.1.6a)	kg/TJ
Fuel Consumption	Terajoules, TJ
ESTIMATING N_2O AND CH_4 EMISSION FROM DOMESTIC AVIATION	
Default N_2O and CH_4 emission factor (See Annex Table 2.2.1.6b)	kg/TJ
Fuel Consumption	Terajoules, TJ
(See 2006 IPCC Guideline, Vol 2, Chap 3 Mobile Combustion for section 3.6.1.1 Choice of Method, Equation 3.6.1)	
DOMESTIC WATERBORNE NAVIGATION	
ESTIMATING CO_2 EMISSION FROM DOMESTIC WATERBORNE NAVIGATION	
Default CO_2 emission factor (See Annex Table 2.2.1.7a)	kg/TJ
Fuel Consumption	Terajoules, TJ
ESTIMATING N_2O AND CH_4 EMISSION FROM DOMESTIC WATERBORNE NAVIGATION	
Default CO_2 emission factor (See Annex Table 2.2.1.7b)	kg/TJ
Fuel Consumption	Terajoules, TJ
Note that the fuel consumption data and emission factors in the Tier 1 method are fuel-type-specific and should be applied to the corresponding activity data (e.g. gas/diesel oil used for domestic navigation). (See 2006 IPCC Guidelines, Chapter 3 "Mobile Combustion", Section 3.5.1.1 for Equation 3.5.1)	

1.2.1B. REFERNCE APPROACH DATA COLLECTION

A top-down approach to estimate CO_2 emissions from combustion of fossil fuels using national fuel supply data. The data requirement are as follows:

- The amounts of primary fuels **produced** (production of secondary fuels and fuel products is not included)
- The amounts of primary and secondary fuels **imported.**
- The amounts of primary and secondary fuels **exported**.
- The amounts of primary and secondary fuels used in **international bunkers.**
- The net increases or decreases in stocks (**stock change**) of primary and secondary fuels.
- Amount of fuels (carbon) **excluded from the energy** use.
- Basic parameters for each fuel (could be default values from the IPCC GLs): (*Refer to Annex, Table 2.2.1.3 – Table 2.2.1.5)*
    - Carbon content
    - Oxidation factor
    - Calorific value

1.2.2. DATA SOURCES (Departments, Stakeholders)

The country's specific data can be collected from the following departments/stakeholders/organization:

- Department of Energy
- Pacific (Pacific Petroleum Company)
- Public Land Transport Authority (PLTA)
- Department of Climate Change (DOCC)

Once a data set is selected, a more detailed formal specification of data should be created. A clear clarity of data requirements will allow data that is requested from the different departments/organizations to be delivered upon expectation (Goodwin, Woodfield, Ibnoaf, Koch, & Yan, 2006). The specification should include details such as:

- Definition of the data set (E.g. time series, sectors and sub-sector detail, national coverage, requirements for uncertainty data, emission factors and/or activity data units).

- The format (e.g., spreadsheet) and structure (e.g., what different tables are needed and their structure) of the data set,
- Description of any assumptions made regarding national coverage, the sectors included, representative year, technology/management level, and emission factors or uncertainty parameters.
- Identification of the routines and timescales for data collection activities (e.g., how often is the data set updated and what elements are updated).
- Reference to documentation and QA/QC procedures.
- Contact name and department/ organization.
- Date of availability.

Flow chart 1.2.2.1: Details of access to data sources by the Department of Climate Change (DOCC)

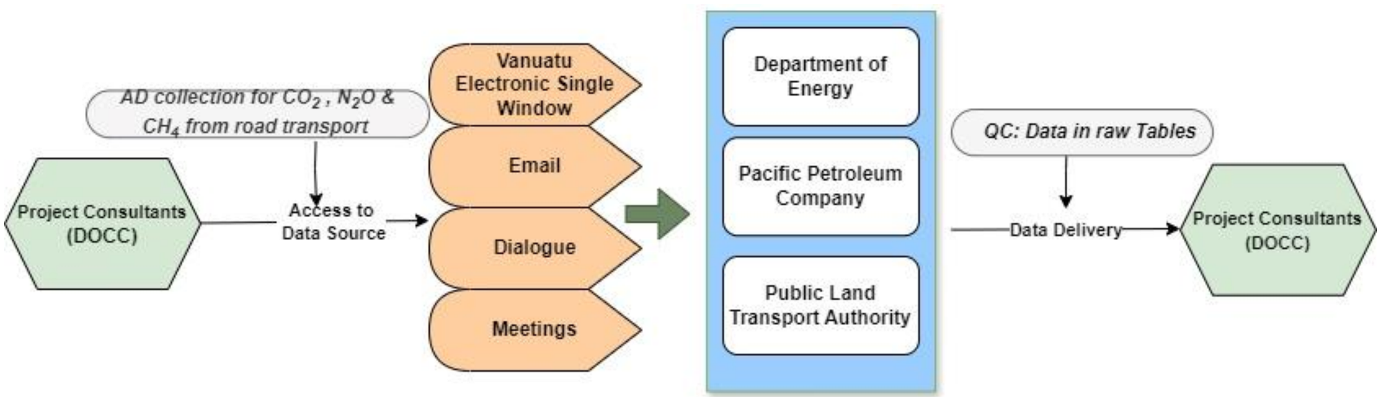


Table 2: Detailed Information of Collecting Activity Data from Sources.

Department/ Organization	Roles and Responsibility	Dates	Relevant Governing Arrangement	Contact Person	Comments
Department of Energy	To provide relevant data and information on CO_2, CH_4 and N_2O emission from road transport. To deliver activity data on imports, exports, international bunkers, and stock change.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between Department of energy and DOCC	Serah T Chilia Email: schilia@vanuatu.gov.vu	For significant information and data requirements, DOCC needs to send a prompt letter to the Department of Energy two months prior. A follow-up email or call is crucial as well.
Pacific Petroleum Company	To provide relevant data on the quantity of different fuel type distributed or sold for public road transport, domestic aviation, and domestic waterborne navigation purposes. This data is crucial for	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between Pacific Petroleum Company and DOCC	Pacific Petroleum Tel: (+678) 22901	For significant information and data collection, DOCC needs to send a prompt letter to Pacific Petroleum two months prior. A follow-up email or call is crucial as well.

	estimating emissions based on fuel consumption.				
Public Land Transport Authority (PLTA)	To provide relevant data and information on the quantity of vehicle types currently operating, vehicle fleets, average annual distance travelled per vehicle, km, to estimate ghg emission.	First week of April– First week of May every year	A Memorandum of understanding or Right to Information (RTI) can be provided between PLTA and DOCC	Lisa Malwosi (Shefa Permit Officer Public Land Transport Authority) Port Vila, Tel: (+678) 23100 Email: lmalwosi@plta.com.vu	For significant information and data collection, DOCC needs to send a prompt letter to PLTA two months prior. A follow-up email or call is crucial as well.
Department of Climate Change (DOCC)	DOCC is responsible to send a formal letter requesting relevant data and information on CO_2, CH_4 and N_2O emission on public road transport, domestic aviation, and domestic waterborne navigation.	February – March every year	Provide a Memorandum of understanding or Right to Information (RTI) to the Department of Energy, PLTA and Pacific Petroleum.	Name: Nelson Kalo (Director of Climate Change) Email: nekalo@vanuatu.gov.vu	DOCC is responsible for doing a follow-up to the departments/companies for the required data to be delivered upon schedule.

1.2.3. DATA ASSUMPTIONS

ROAD TRANSPORT

The following assumptions are made where data is unavailable for greenhouse gas emissions on road transport focusing on Tier 1 approach.

- Vanuatu is using Net Calorific Value (NCV) basis,
  - Calorific value (NCV), diesel = 43.00 (TJ/Gg) - 2006 IPCC default
  - Calorific value (NCV), petrol = 44.3 (TJ/Gg) - 2006 IPCC default

- In Tier 1, all carbon in the fuel is fully oxidized and converted into carbon dioxide, that is, carbon oxidation factor (COF) = 1.

- Uncertainty information on fuel combustion statistics or energy balance can be obtained from national data. If no uncertainty data is available, the recommended default uncertainty range for fossil fuel combustion data should be assumed to be **plus or minus 5 percent**.

VEHICLE DATA ASSUMPTIONS

Apart from Liquefied petroleum gas (LPG) and ethanol vehicles, the default values are determined using the sources referenced in the Energy Volume Introduction chapter. These include NCV values from the sources mentioned, density values from the U.S. Energy Information Administration, and assumed typical fuel consumption rates:

- 10 km/l for gasoline vehicles
- 5 km/l for diesel vehicles
- 9 km/l for natural gas vehicles (considered equivalent to gasoline vehicles

If specific actual fuel economy figures are available, it is recommended to utilize them along with total fuel consumption data to estimate total distance traveled, which should then be multiplied by Tier 2 emission factors for N_2O and *CH_4 (See 2006 IPCC Guidelines, Chapter 3 "Mobile Combustion", Table 3.2.2).*

REFERENCE APPROACH

The Reference Approach assumes that once carbon is brought into a national economy as fuel, it is either released into the atmosphere as a greenhouse gas, or it is diverted (e.g., in increases of fuel stocks, stored in products, left unutilized in ash) and does not insert into the atmosphere as a greenhouse gas. (See 2006 IPCC Guidelines Volume 2, Chapter 1, Sector 1.6.1 on Reference Approach)

1.3 CALCULATING GREENHOUSE GAS EMISSION

1.3.1 USING TIER 1 APPROACH WITH SCARES DATA ON FUEL SALES.

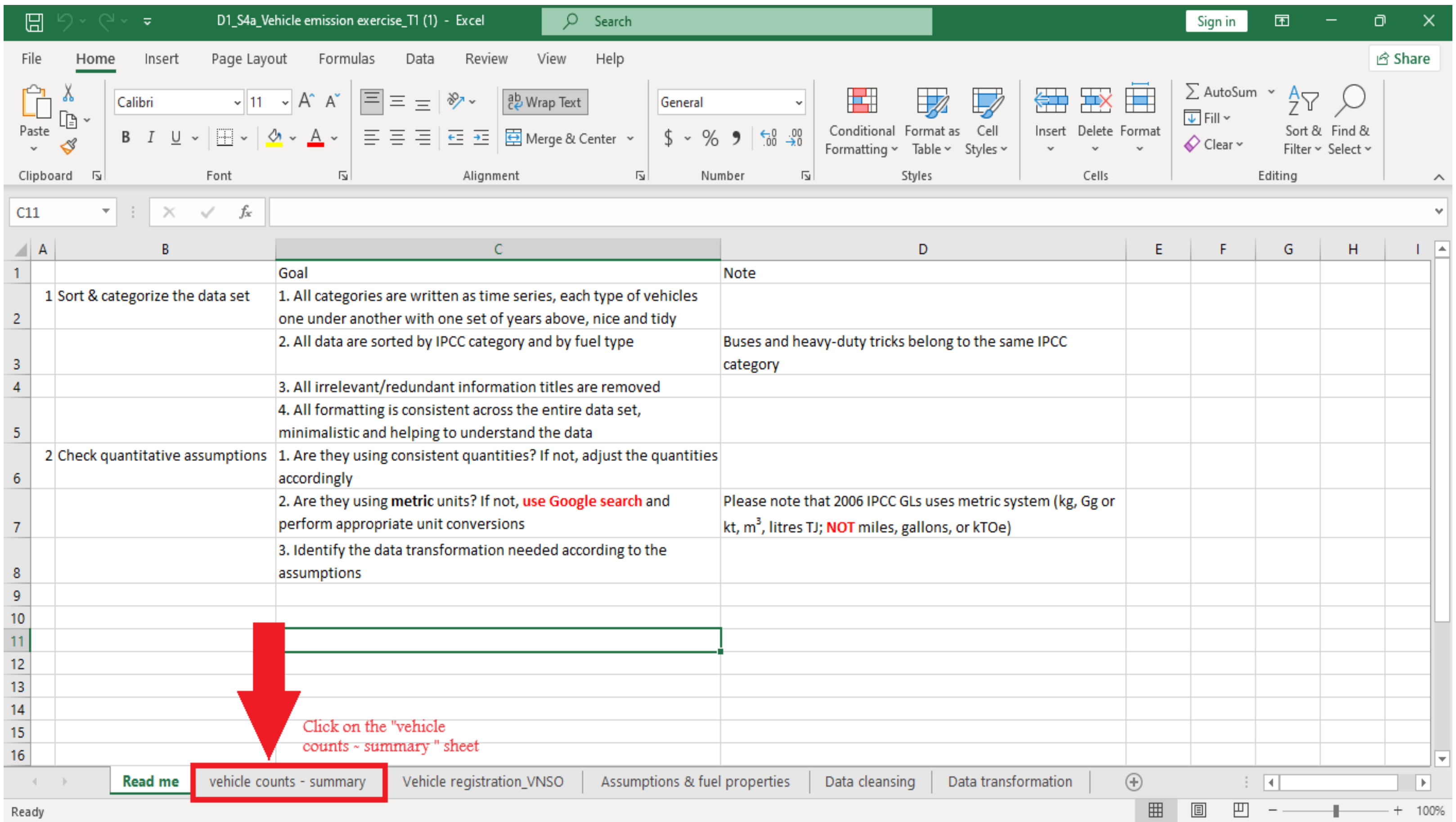
- The accurate values for fuel sales by each type of fuel for each type of transport are not available in Vanuatu
- However, some data are available (or elucidated from the expert judgment) on the vehicle counts (VNSO), the approximate annual distance traveled, and the fuel consumption per km traveled (from vehicle specification)
- Therefore, an approximate estimate of fuel consumption by each type of vehicles could be prepared and used for a rough estimate of GHG emissions in the sectoral approach:

Fuel used (TJ) = km traveled x fuel consumption (L)/1000 x fuel density (kg/m^3) x NCV(TJ/Gg) / 1,000,000

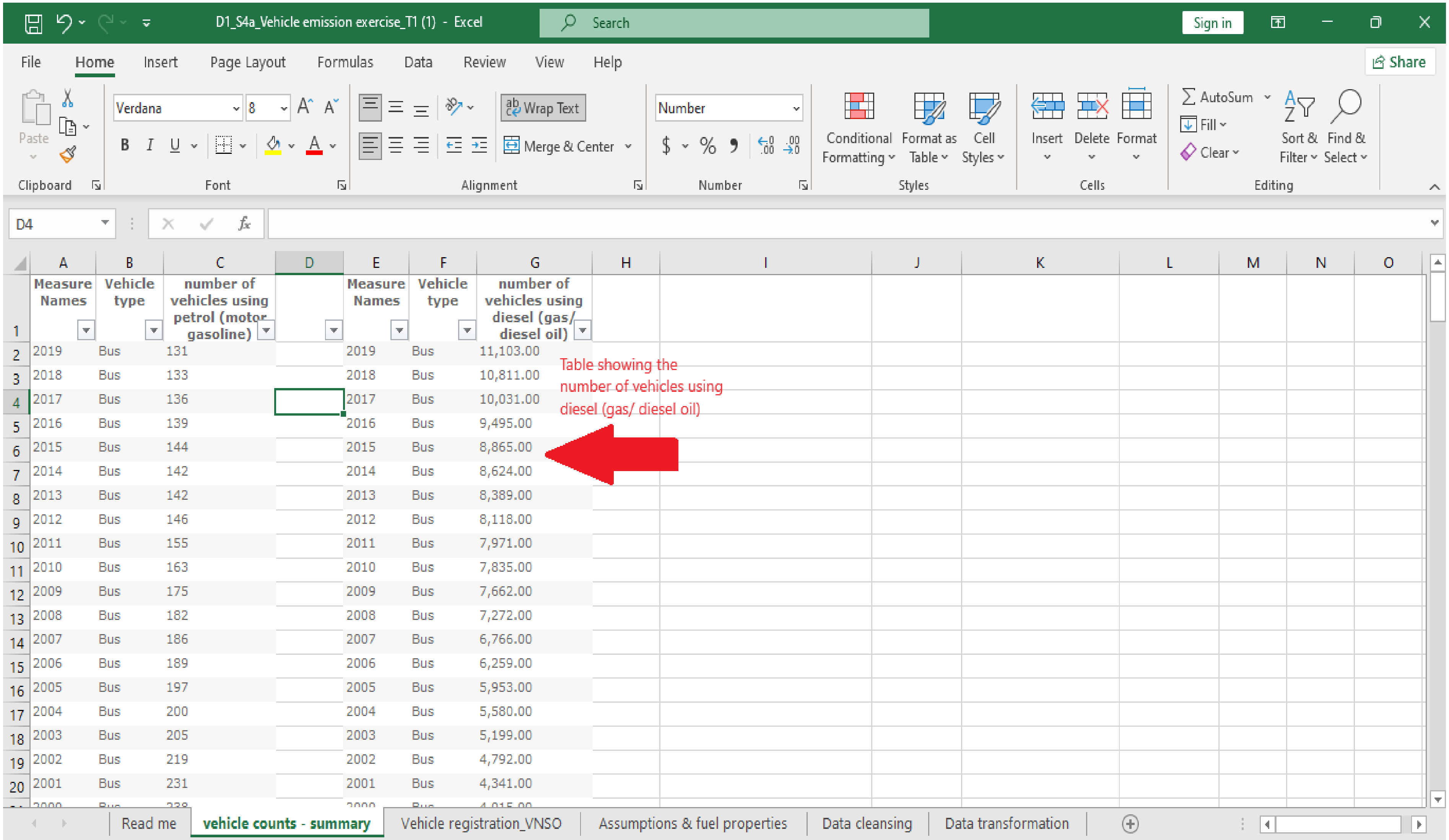
CALCULATING THE TOTAL FUEL CONSUMPTION BY VEHICLES USING THE Excel file D1_S4a_Vehicle emission exercise_T1

1. Open the Excel file D1_S4a_Vehicle emission exercise_T1

1.1 Click on the sheet at the bottom of the page entitled “Vehicle counts – summary” (see illustration below).

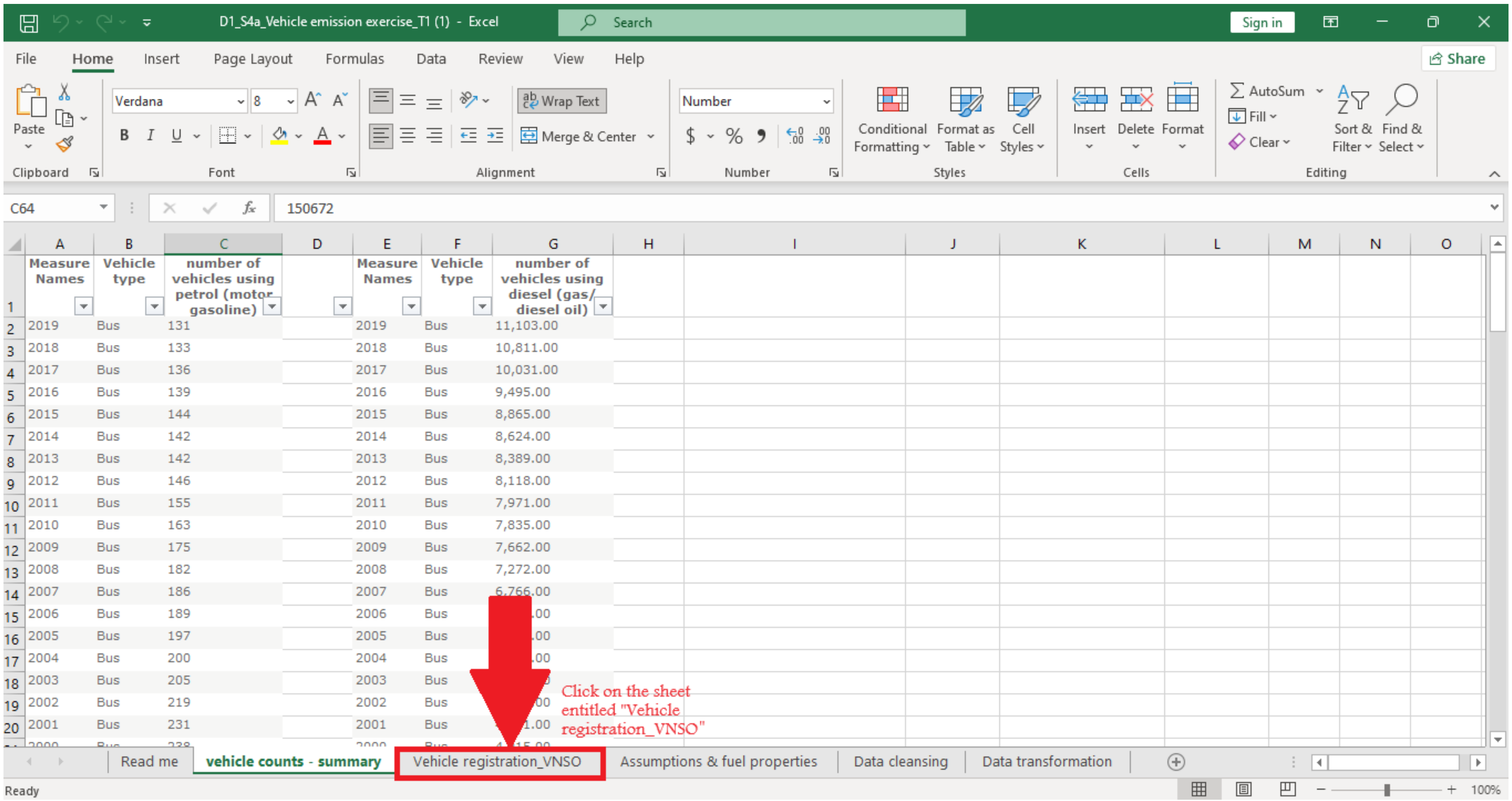


1.2 Find the number for each type of vehicle present in the specific year containing the data as seen below in the table

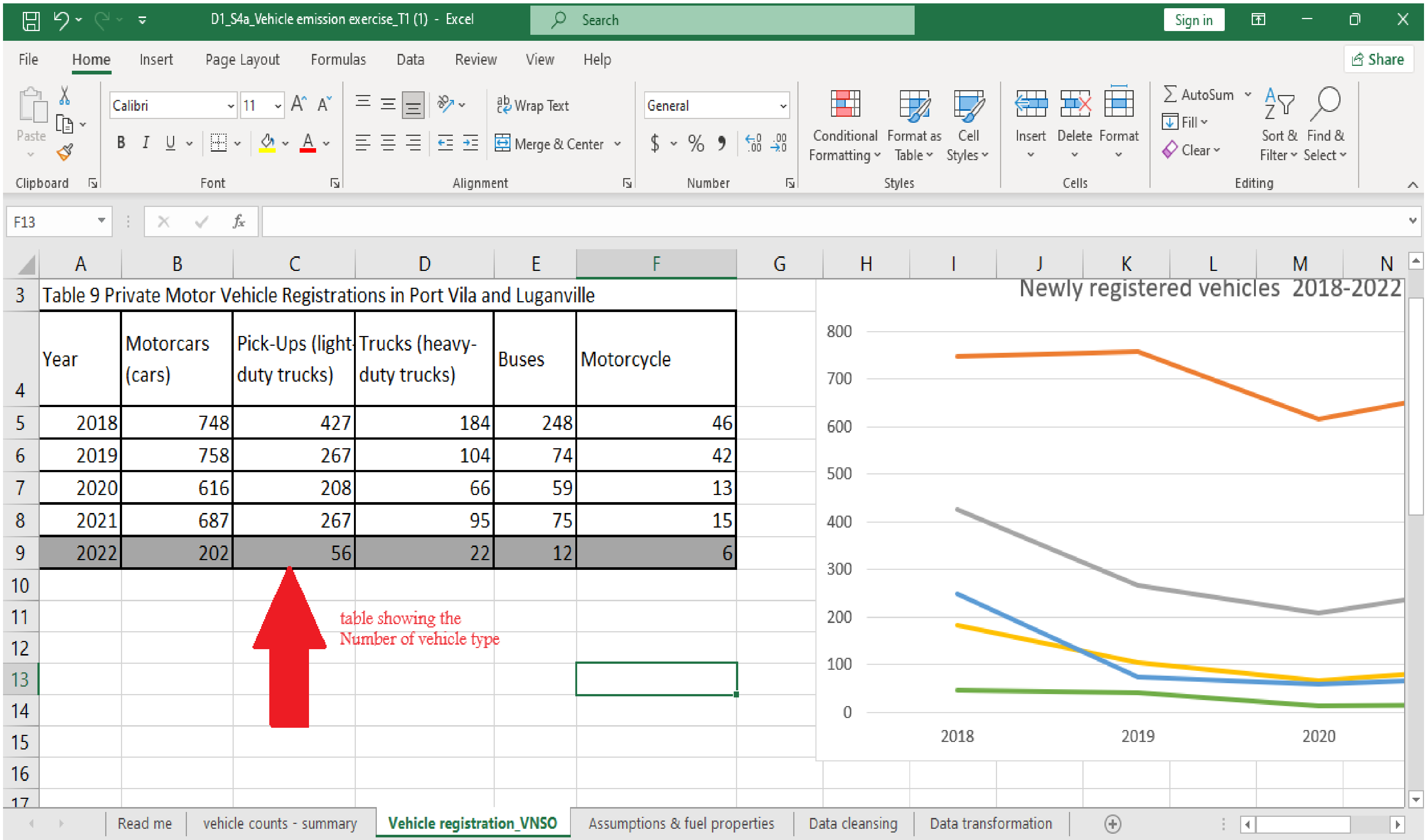


Measure Names	Vehicle type	number of vehicles using petrol (motor gasoline)		Measure Names	Vehicle type	number of vehicles using diesel (gas/ diesel oil)
2019	Bus	131		2019	Bus	11,103.00
2018	Bus	133		2018	Bus	10,811.00
2017	Bus	136		2017	Bus	10,031.00
2016	Bus	139		2016	Bus	9,495.00
2015	Bus	144		2015	Bus	8,865.00
2014	Bus	142		2014	Bus	8,624.00
2013	Bus	142		2013	Bus	8,389.00
2012	Bus	146		2012	Bus	8,118.00
2011	Bus	155		2011	Bus	7,971.00
2010	Bus	163		2010	Bus	7,835.00
2009	Bus	175		2009	Bus	7,662.00
2008	Bus	182		2008	Bus	7,272.00
2007	Bus	186		2007	Bus	6,766.00
2006	Bus	189		2006	Bus	6,259.00
2005	Bus	197		2005	Bus	5,953.00
2004	Bus	200		2004	Bus	5,580.00
2003	Bus	205		2003	Bus	5,199.00
2002	Bus	219		2002	Bus	4,792.00
2001	Bus	231		2001	Bus	4,341.00

1.3 Click on the sheet entitled “Vehicle registrations”

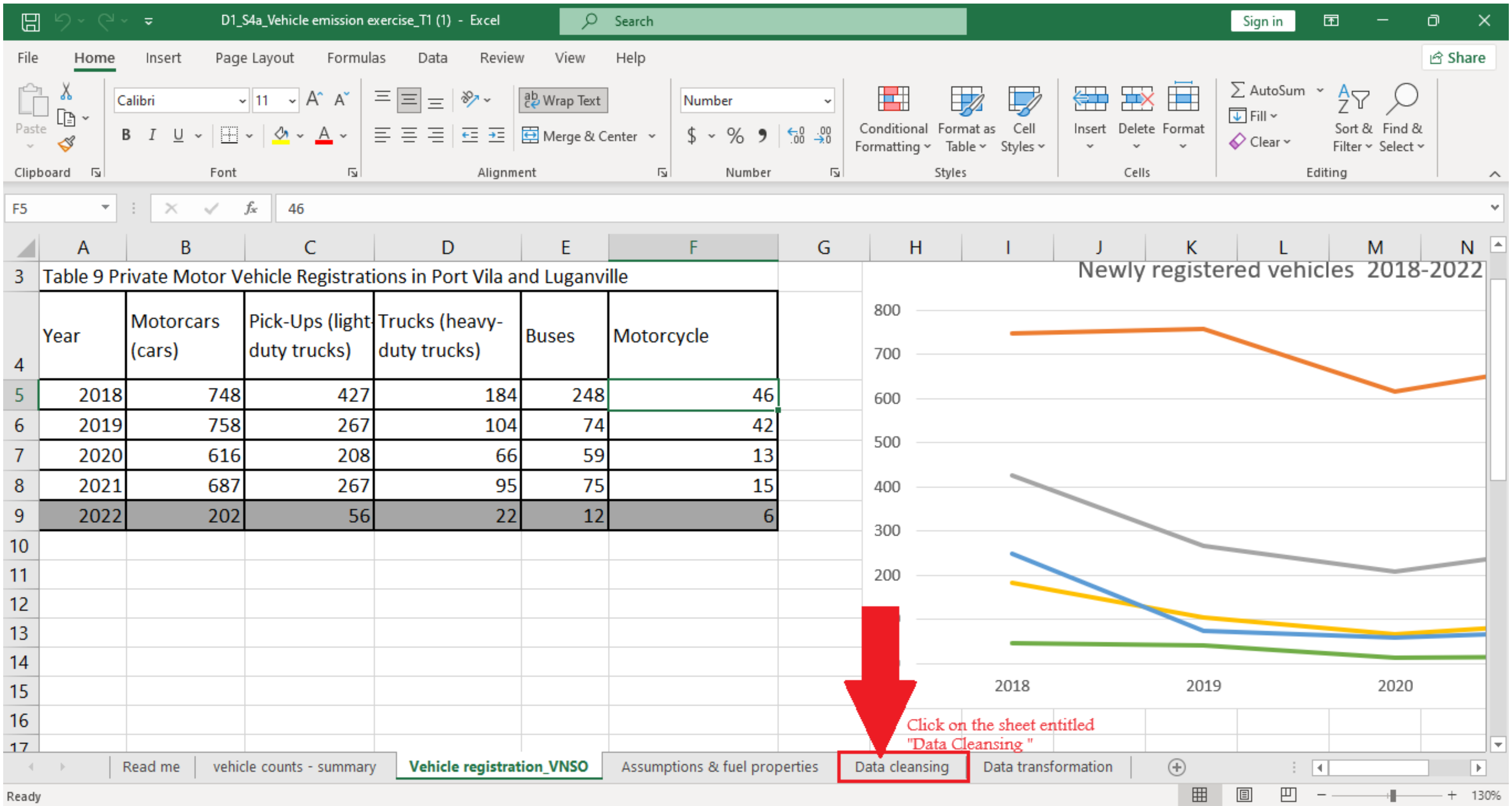


1.4 Enter the number of total vehicle type into the specific year as recorded. (See illustration below)

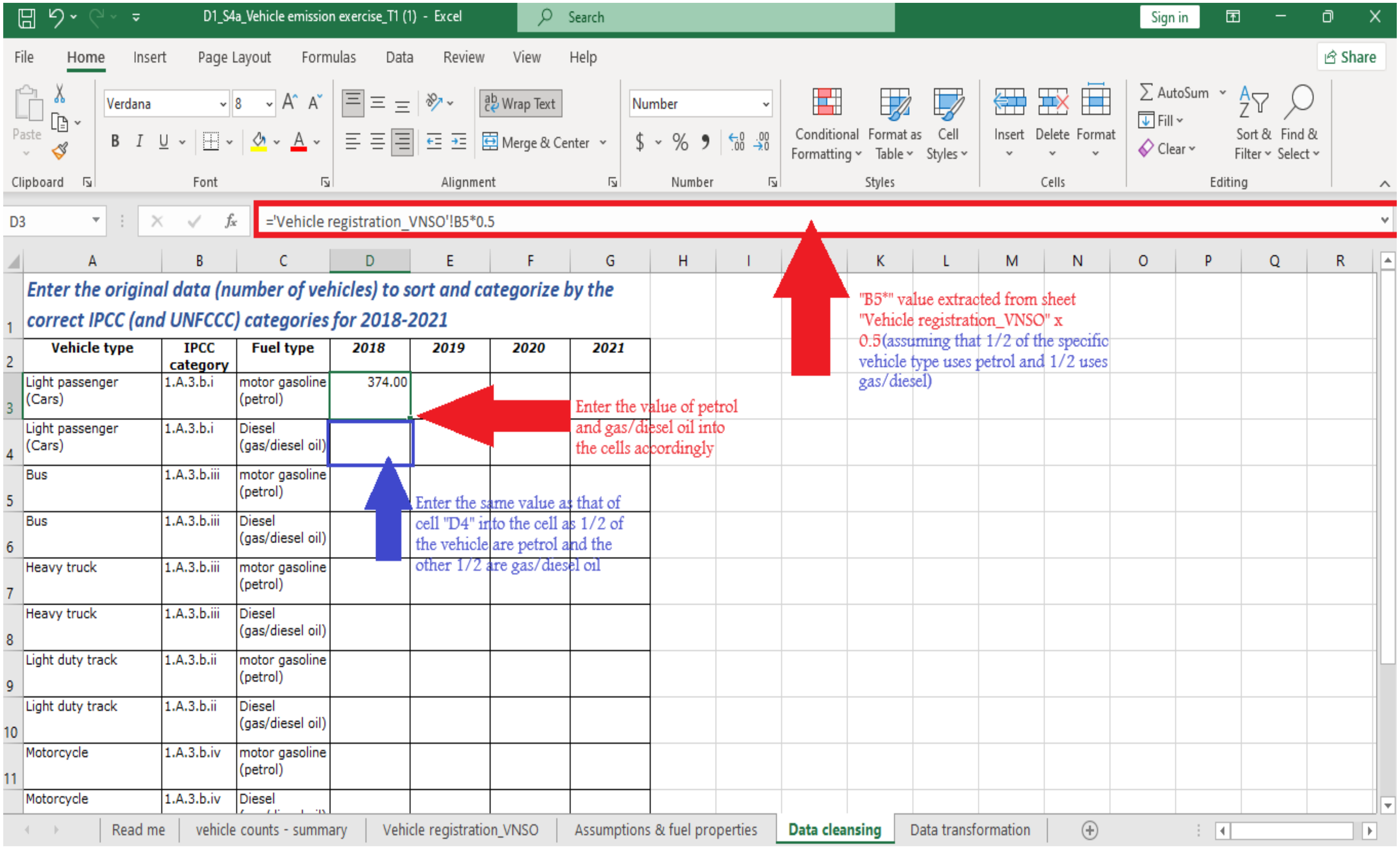


Year	Motorcars (cars)	Pick-Ups (light-duty trucks)	Trucks (heavy-duty trucks)	Buses	Motorcycle
2018	748	427	184	248	46
2019	758	267	104	74	42
2020	616	208	66	59	13
2021	687	267	95	75	15
2022	202	56	22	12	6

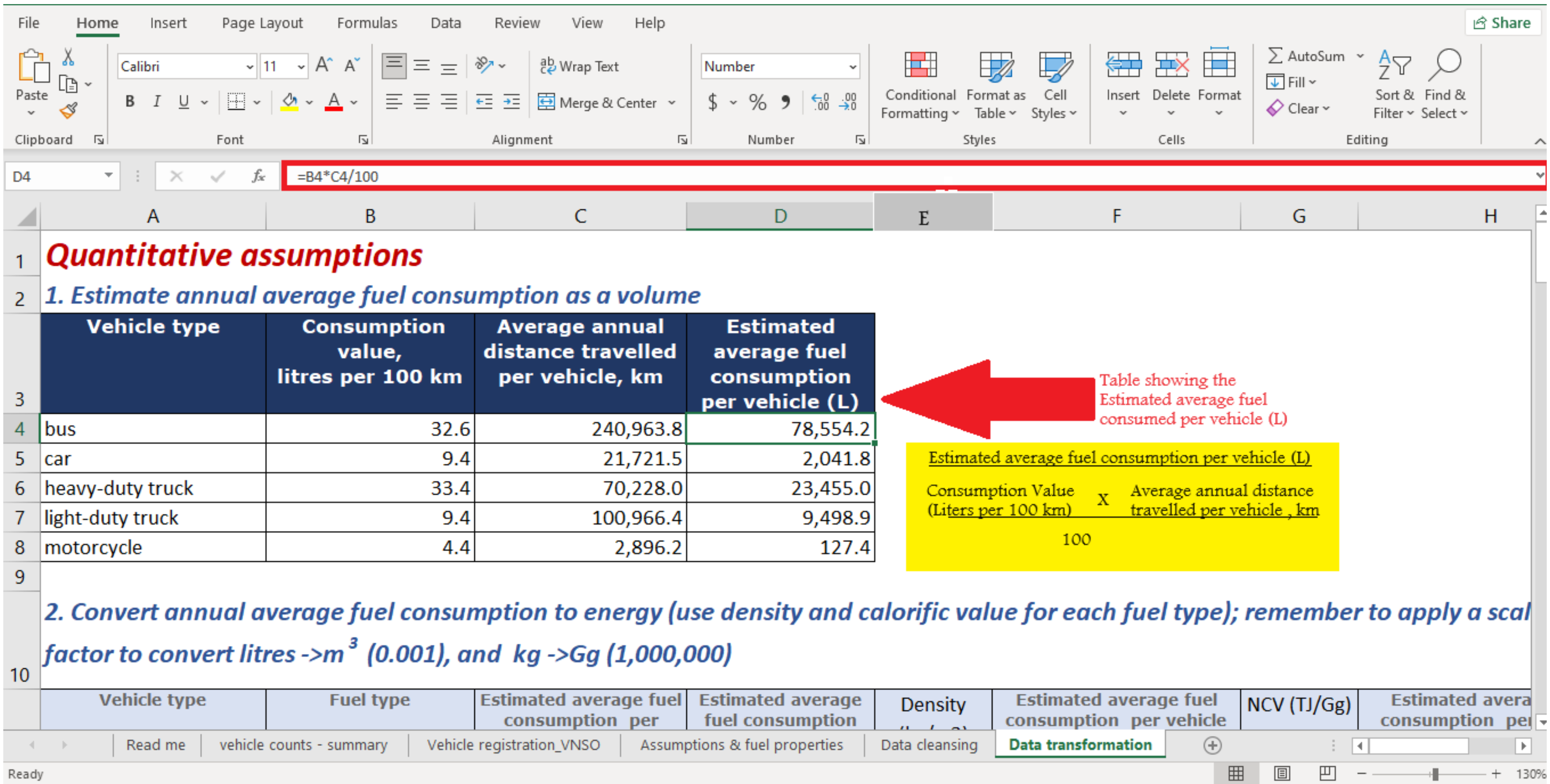
1.5 Click on the sheet entitled "Data Cleansing"



1.6 Using the assumption that half of the total vehicle type uses petrol and the other half uses gas/diesel, further divide the vehicles into the types of fuels used. (See illustration below)

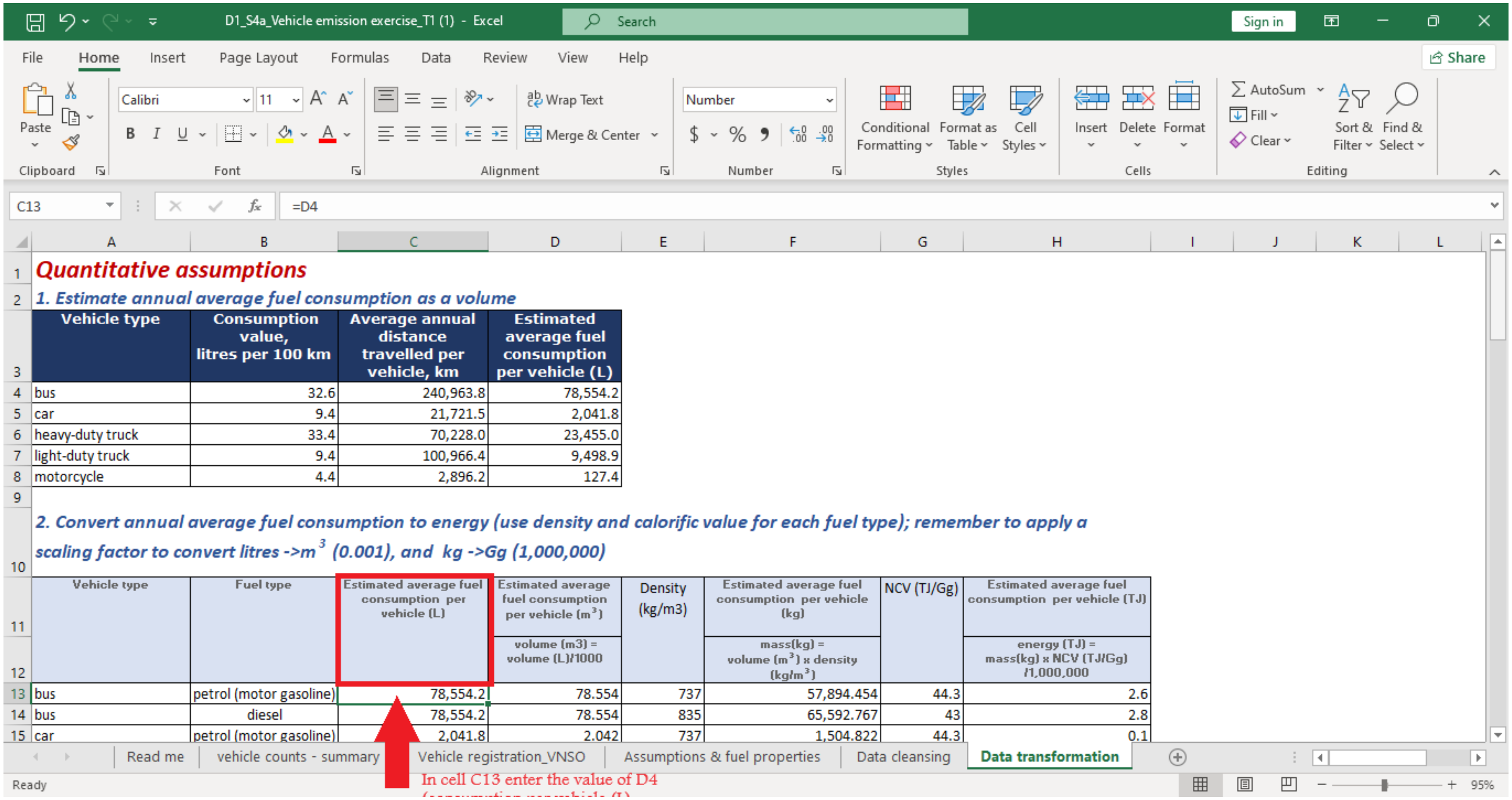


1.7 Find the Estimated average fuel consumption per vehicle (L), by using the equation (Consumption value liters per 100km X Average annual distance travelled per vehicle, km)/100. (See illustration below)



Vehicle type	Consumption value, litres per 100 km	Average annual distance travelled per vehicle, km	Estimated average fuel consumption per vehicle (L)
bus	32.6	240,963.8	78,554.2
car	9.4	21,721.5	2,041.8
heavy-duty truck	33.4	70,228.0	23,455.0
light-duty truck	9.4	100,966.4	9,498.9
motorcycle	4.4	2,896.2	127.4

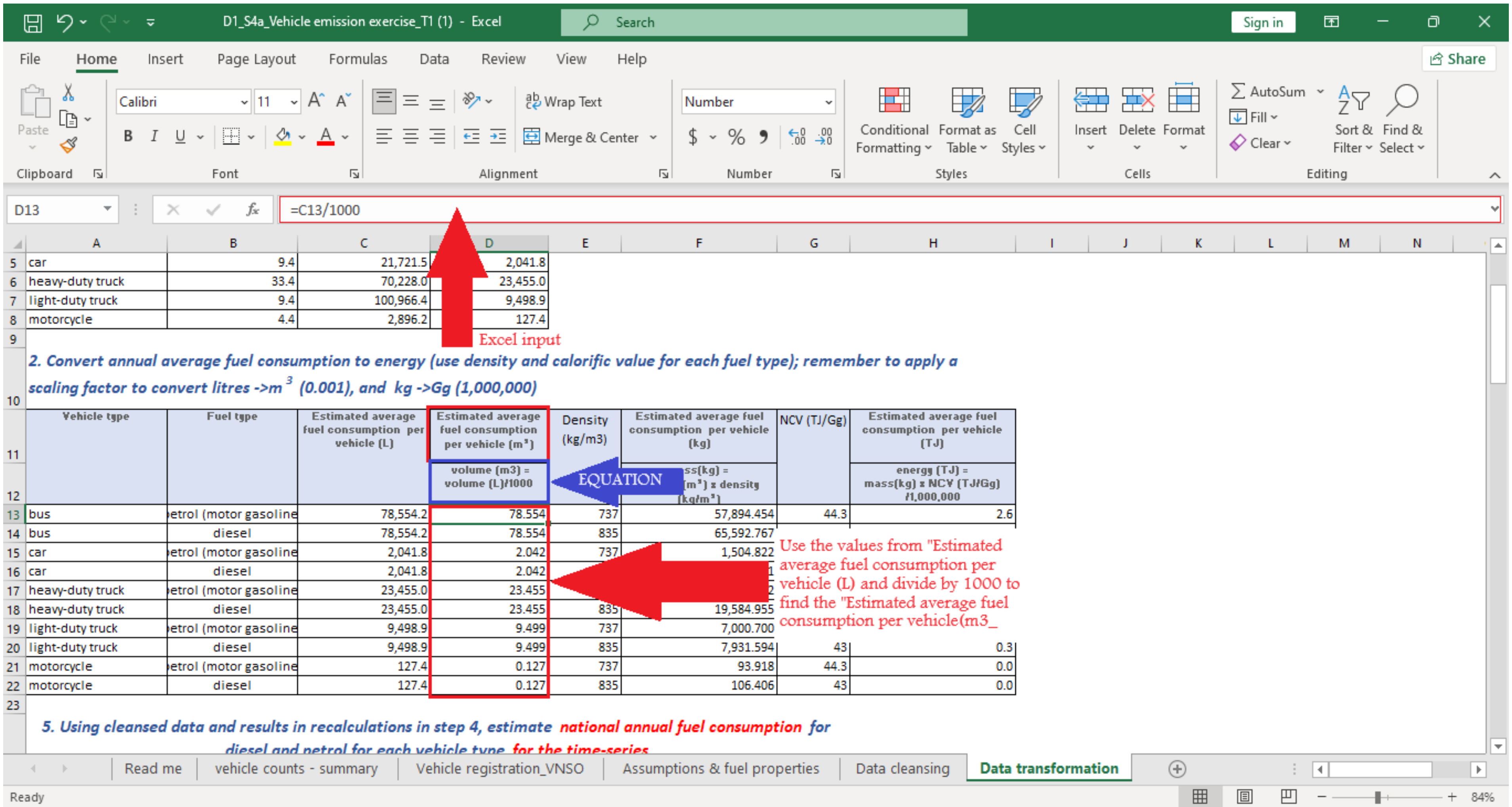
1.8 Enter the values from the Table 1 in sheet "Data Transforamation" into the Table 2 under the Tab "Estimated average fuel consumption per vehicle (L) (See illustration below).



1.9 Convert the value of fuel consumption in litres to m^3 by using the equation:

Estimated average Fuel consumption per vehicle (m^3) = Volume (L) / 1000.

Take the values from " volume (L)" under the cell C column and divide by 1000 to get the value for m^3 under the cell D column (See illustration below)



A	B	C	D
car	9.4	21,721.5	2,041.8
heavy-duty truck	33.4	70,228.0	23,455.0
light-duty truck	9.4	100,966.4	9,498.9
motorcycle	4.4	2,896.2	127.4

2. Convert annual average fuel consumption to energy (use density and calorific value for each fuel type); remember to apply a scaling factor to convert litres ->m³ (0.001), and kg ->Gg (1,000,000)

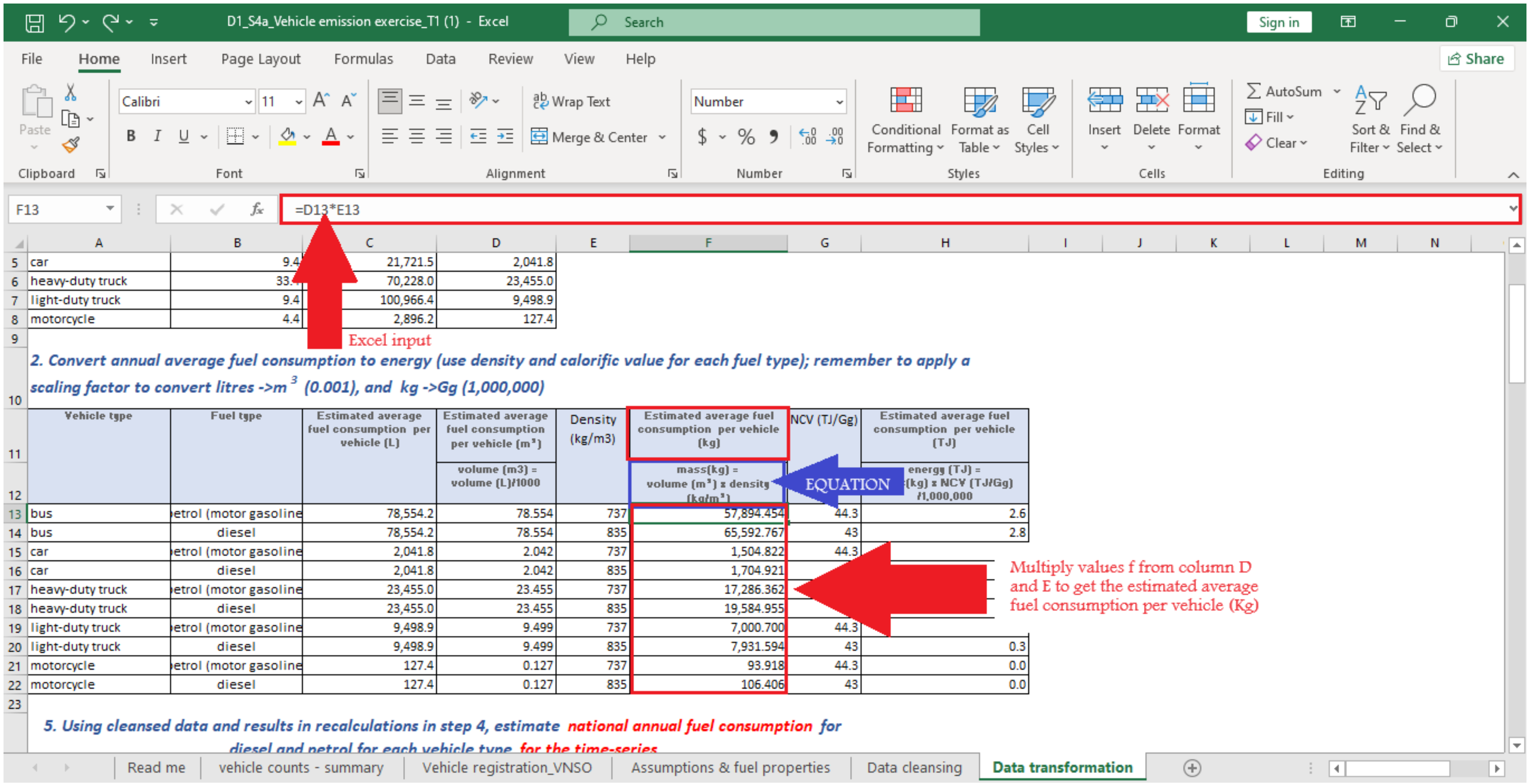
Vehicle type	Fuel type	Estimated average fuel consumption per vehicle (L)	Estimated average fuel consumption per vehicle (m³)	Density (kg/m3)	Estimated average fuel consumption per vehicle (kg)	NCV (TJ/Gg)	Estimated average fuel consumption per vehicle (TJ)
			volume (m3) = volume (L)/1000		ss(kg) = (m³) x density (kg/m³)		energy (TJ) = mass(kg) x NCV (TJ/Gg) /1,000,000
bus	etrol (motor gasoline	78,554.2	78.554	737	57,894.454	44.3	2.6
bus	diesel	78,554.2	78.554	835	65,592.767		
car	etrol (motor gasoline	2,041.8	2.042	737	1,504.822		
car	diesel	2,041.8	2.042				
heavy-duty truck	etrol (motor gasoline	23,455.0	23.455				
heavy-duty truck	diesel	23,455.0	23.455	835	19,584.955		
light-duty truck	etrol (motor gasoline	9,498.9	9.499	737	7,000.700		
light-duty truck	diesel	9,498.9	9.499	835	7,931.594	43	0.3
motorcycle	etrol (motor gasoline	127.4	0.127	737	93.918	44.3	0.0
motorcycle	diesel	127.4	0.127	835	106.406	43	0.0

5. Using cleansed data and results in recalculations in step 4, estimate national annual fuel consumption for diesel and petrol for each vehicle type for the time-series

2 Convert the value Fuel consumption (m^3) to (Kg) by using th equation.

Estimated average fuel consumption per vehicle (Kg) = Volume (m^3) x Density (Kg/m^3)

Multiply the values from column D and E to get the value of Estimated average fuel consumption per vehicle (Kg) (See illustration below)



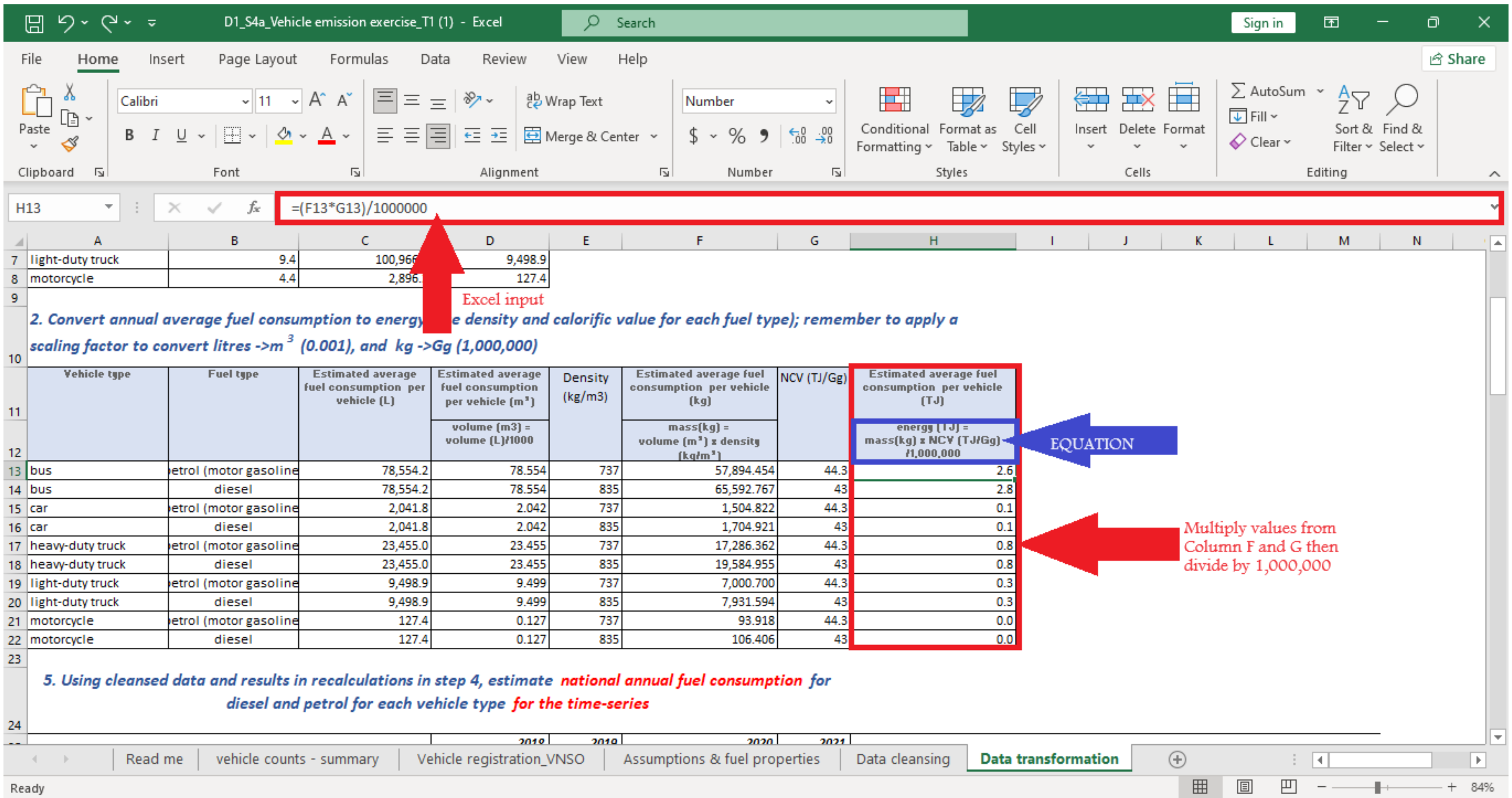
	A	B	C	D
5	car	9.4	21,721.5	2,041.8
6	heavy-duty truck	33.	70,228.0	23,455.0
7	light-duty truck	9.4	100,966.4	9,498.9
8	motorcycle	4.4	2,896.2	127.4

	Vehicle type	Fuel type	Estimated average fuel consumption per vehicle (L)	Estimated average fuel consumption per vehicle (m³)	Density (kg/m3)	Estimated average fuel consumption per vehicle (kg)	NCV (TJ/Gg)	Estimated average fuel consumption per vehicle (TJ)
12				volume (m3) = volume (L)/1000		mass(kg) = volume (m³) x density (kg/m³)		energy (TJ) = (kg) x NCV (TJ/Gg) /1,000,000
13	bus	etrol (motor gasoline	78,554.2	78.554	737	57,894.454	44.3	2.6
14	bus	diesel	78,554.2	78.554	835	65,592.767	43	2.8
15	car	etrol (motor gasoline	2,041.8	2.042	737	1,504.822	44.3	
16	car	diesel	2,041.8	2.042	835	1,704.921		
17	heavy-duty truck	etrol (motor gasoline	23,455.0	23.455	737	17,286.362		
18	heavy-duty truck	diesel	23,455.0	23.455	835	19,584.955		
19	light-duty truck	etrol (motor gasoline	9,498.9	9.499	737	7,000.700	44.3	
20	light-duty truck	diesel	9,498.9	9.499	835	7,931.594	43	0.3
21	motorcycle	etrol (motor gasoline	127.4	0.127	737	93.918	44.3	0.0
22	motorcycle	diesel	127.4	0.127	835	106.406	43	0.0

2.2 Convert the value of vehicle consumption (Kg) to (TJ) using the equation:

Estimated average fuel consumption per vehicle = Mass (Kg) X NCV (TJ/Gg) / 1,000,000

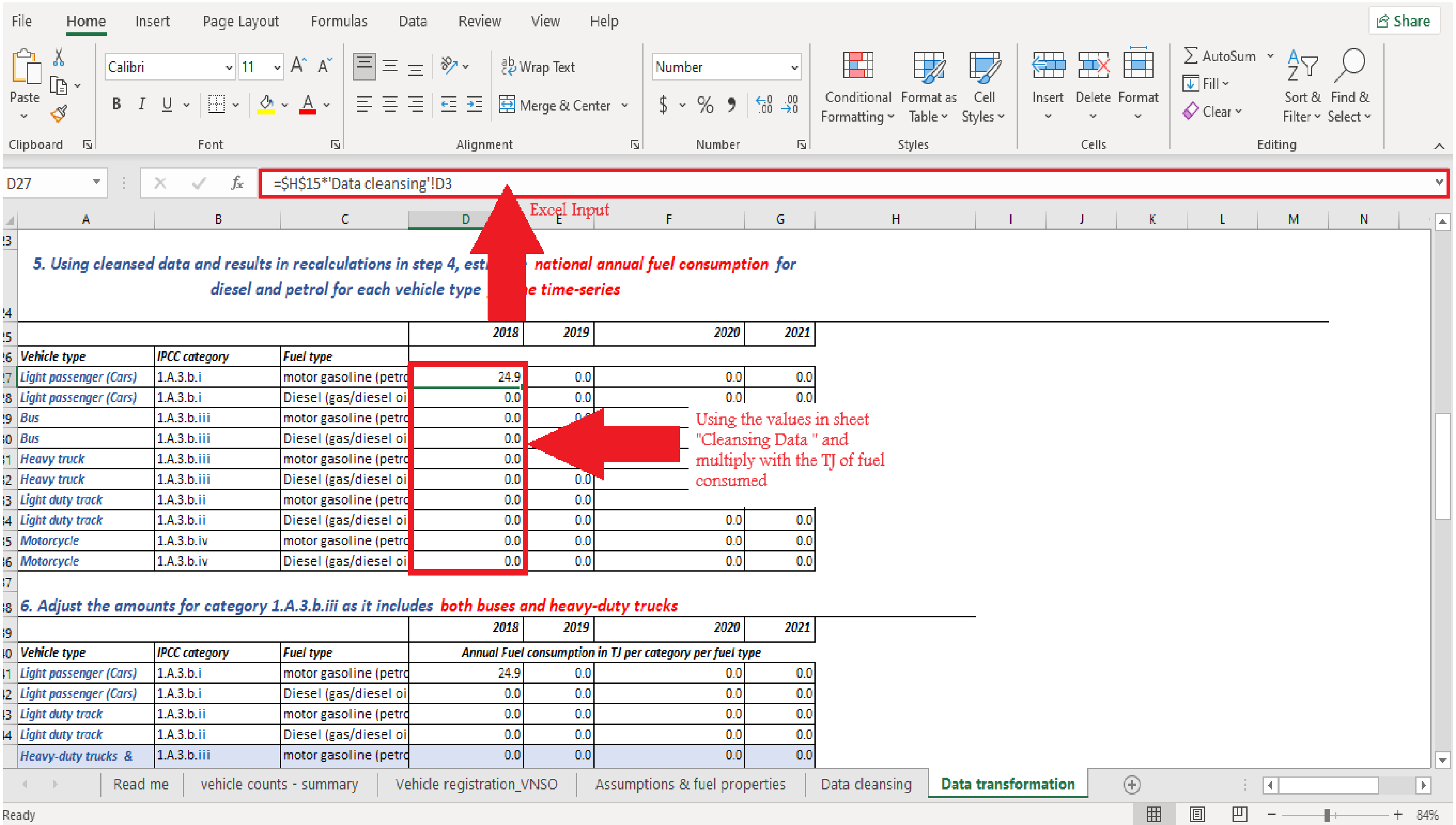
Under the cell H (Estimation average fuel consumption per vehicle (TJ)), multiply values from column F and G and divide by 1,000,000 (See illustration below)



Vehicle type	Fuel type	Estimated average fuel consumption per vehicle (L)	Estimated average fuel consumption per vehicle (m³) volume (m3) = volume (L)/1000	Density (kg/m3)	Estimated average fuel consumption per vehicle (kg) mass(kg) = volume (m³) x density (kg/m³)	NCV (TJ/Gg)	Estimated average fuel consumption per vehicle (TJ) energy (TJ) = mass(kg) x NCV (TJ/Gg) /1,000,000
bus	etrol (motor gasoline	78,554.2	78.554	737	57,894.454	44.3	2.6
bus	diesel	78,554.2	78.554	835	65,592.767	43	2.8
car	etrol (motor gasoline	2,041.8	2.042	737	1,504.822	44.3	0.1
car	diesel	2,041.8	2.042	835	1,704.921	43	0.1
heavy-duty truck	etrol (motor gasoline	23,455.0	23.455	737	17,286.362	44.3	0.8
heavy-duty truck	diesel	23,455.0	23.455	835	19,584.955	43	0.8
light-duty truck	etrol (motor gasoline	9,498.9	9.499	737	7,000.700	44.3	0.3
light-duty truck	diesel	9,498.9	9.499	835	7,931.594	43	0.3
motorcycle	etrol (motor gasoline	127.4	0.127	737	93.918	44.3	0.0
motorcycle	diesel	127.4	0.127	835	106.406	43	0.0

2.3 In table 3 in sheet “Data transformation” under the year tab, Cell D, calculate the national annual fuel consumption for diesel and petrol for each vehicle type for the time-series using the equation:

National annual fuel consumption for diesel and petrol for each vehicle type = Estimated average fuel consumption per vehicle (TJ) X Number of specific vehicle (See illustration below).



5. Using cleansed data and results in recalculations in step 4, est... national annual fuel consumption for diesel and petrol for each vehicle type ...e time-series

Vehicle type	IPCC category	Fuel type	2018	2019	2020	2021
Light passenger (Cars)	1.A.3.b.i	motor gasoline (petr	24.9	0.0	0.0	0.0
Light passenger (Cars)	1.A.3.b.i	Diesel (gas/diesel oi	0.0	0.0	0.0	0.0
Bus	1.A.3.b.iii	motor gasoline (petr	0.0	[illegible]		
Bus	1.A.3.b.iii	Diesel (gas/diesel oi	0.0			
Heavy truck	1.A.3.b.iii	motor gasoline (petr	0.0			
Heavy truck	1.A.3.b.iii	Diesel (gas/diesel oi	0.0	0.0		
Light duty track	1.A.3.b.ii	motor gasoline (petr	0.0	0.0		
Light duty track	1.A.3.b.ii	Diesel (gas/diesel oi	0.0	0.0	0.0	0.0
Motorcycle	1.A.3.b.iv	motor gasoline (petr	0.0	0.0	0.0	0.0
Motorcycle	1.A.3.b.iv	Diesel (gas/diesel oi	0.0	0.0	0.0	0.0

6. Adjust the amounts for category 1.A.3.b.iii as it includes both buses and heavy-duty trucks

Vehicle type	IPCC category	Fuel type	2018	2019	2020	2021
			Annual Fuel consumption in TJ per category per fuel type			
Light passenger (Cars)	1.A.3.b.i	motor gasoline (petr	24.9	0.0	0.0	0.0
Light passenger (Cars)	1.A.3.b.i	Diesel (gas/diesel oi	0.0	0.0	0.0	0.0
Light duty track	1.A.3.b.ii	motor gasoline (petr	0.0	0.0	0.0	0.0
Light duty track	1.A.3.b.ii	Diesel (gas/diesel oi	0.0	0.0	0.0	0.0
Heavy-duty trucks &	1.A.3.b.iii	motor gasoline (petr	0.0	0.0	0.0	0.0

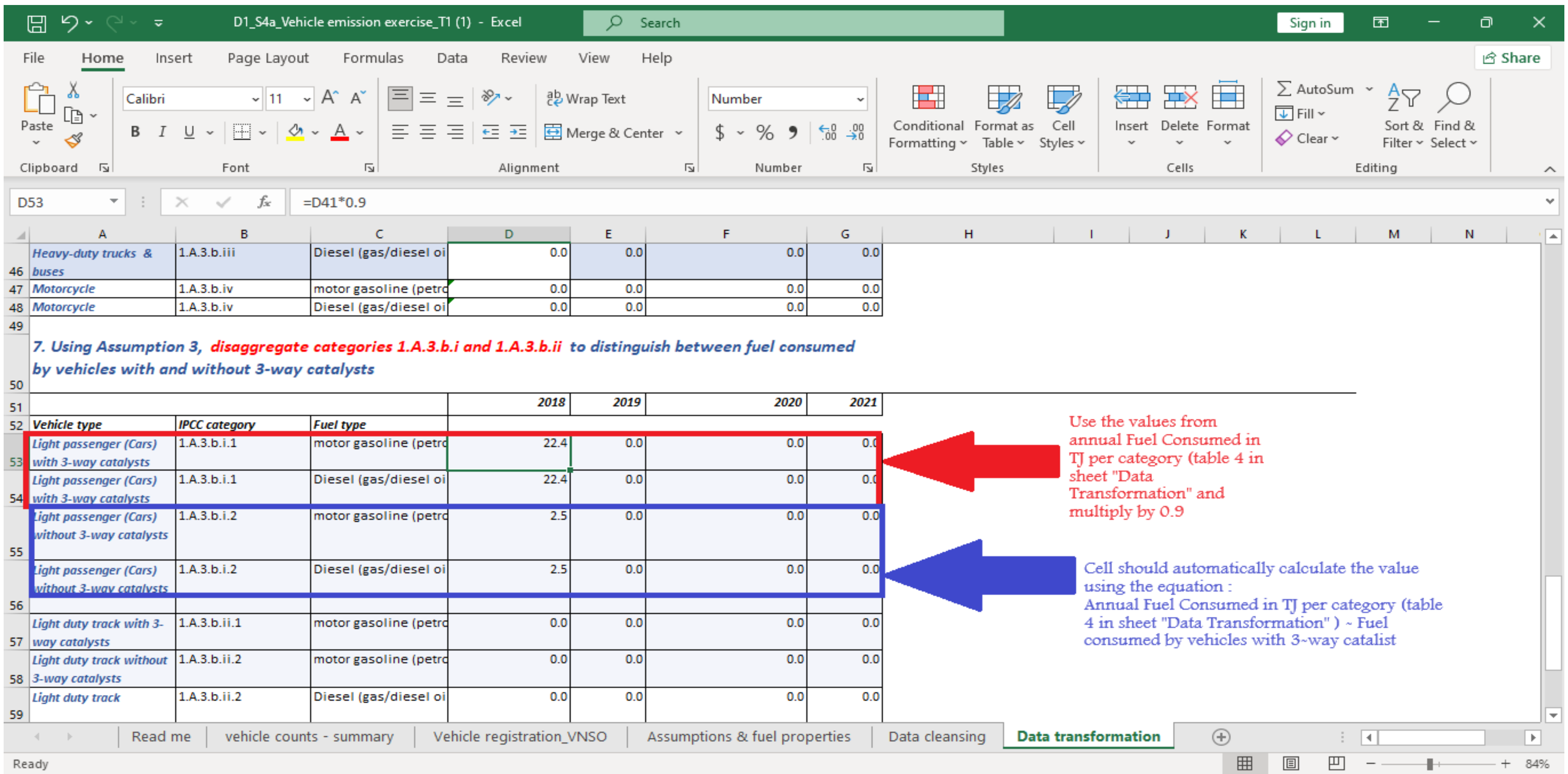
2.4 For table 4 in Sheet "Data Transformation" repeat the same approach as in step 2.3.

2.5 In table 5 in sheet "Data Transformation" Distinguish between fuel consumed by vehicles with and without 3-way catalysts using the equation:

i. Fuel Consumed by Vehicles with 3-way catalysts = Annual Fuel Consumed in TJ per category X 0.9

ii. Fuel Consumed by Vehicles without 3-way catalyst = Annual Fuel Consumed in TJ per category - Fuel Consumed by Vehicles with 3-way catalysts.

See illustration below



1.3.2 STEP- BY- STEP CALCULATION, DOCUMENTING RESOURCES USED (sectoral approach)

Water-Borne Calculation for Emissions for Total Consumption:

1.0 Calculate the total consumption suing the stepwise example below

i. Convert Tonnes to Kilotonnes using the equation:
Fuel Consumed (kilo tonnes (kt)) = Fuel Consumed (tonnes) / 1000

Table 3: showing an example of the conversion Tonnes to Kilo Tonnes.

SHIP TYPE	FUEL TYPE	Fuel Consumption (Tonnes)	Fuel Consumption (kt)
CONTAINER SHIPS	Diesel Oil	131,800	131.8
HIGH SPEED FERRY	Diesel Oil	117,384	117.384

(The consumption figures utilized don't correspond to any published data.)

ii. Convert Kilo Tonnes to TJ using the equation:
Fuel consumption (TJ) = Fuel Consumption (kt) X NCV (TJ/Gg (fuel)

Table 4: showing as example of the conversion of Fuel Consumption (kt) to Fuel consumption (TJ).

SHIP TYPE	FUEL TYPE	Fuel Consumption (Tonnes)	Fuel Consumption (kt)	NCV (TJ/Gg (fuel)	Fuel consumption (TJ)
CONTAINER SHIPS	Diesel Oil	131,800	131.8	43	5667.4
HIGH SPEED FERRY	Diesel Oil	117,384	117.384	43	5047.512

Note: kt = Gg

iii. Calculate the total Diesel Oil fuel consumed (TJ) by adding the Fuel consumption (TJ) for both the Container ship and high-speed ferry.

Table 5: below shows and example of the total fuel consumed (TJ) from the addition of both Container ship and high-speed ferry.

SHIP TYPE	FUEL TYPE	Fuel Consumption (Tonnes)	Fuel Consumption (kt)	NCV (TJ/Gg (fuel)	Fuel consumption (TJ)	TOTAL FULE CONSUMED (TJ)
CONTAINER SHIPS	Diesel Oil	131,800	131.8	43	5667.4	10714.912
HIGH SPEED FERRY	Diesel Oil	117,384	117.384	43	5047.512	

USING THE IPCC SOFTWARE VER. 2.901 IPCC INVENTORY SOFTWARE - 64BIT

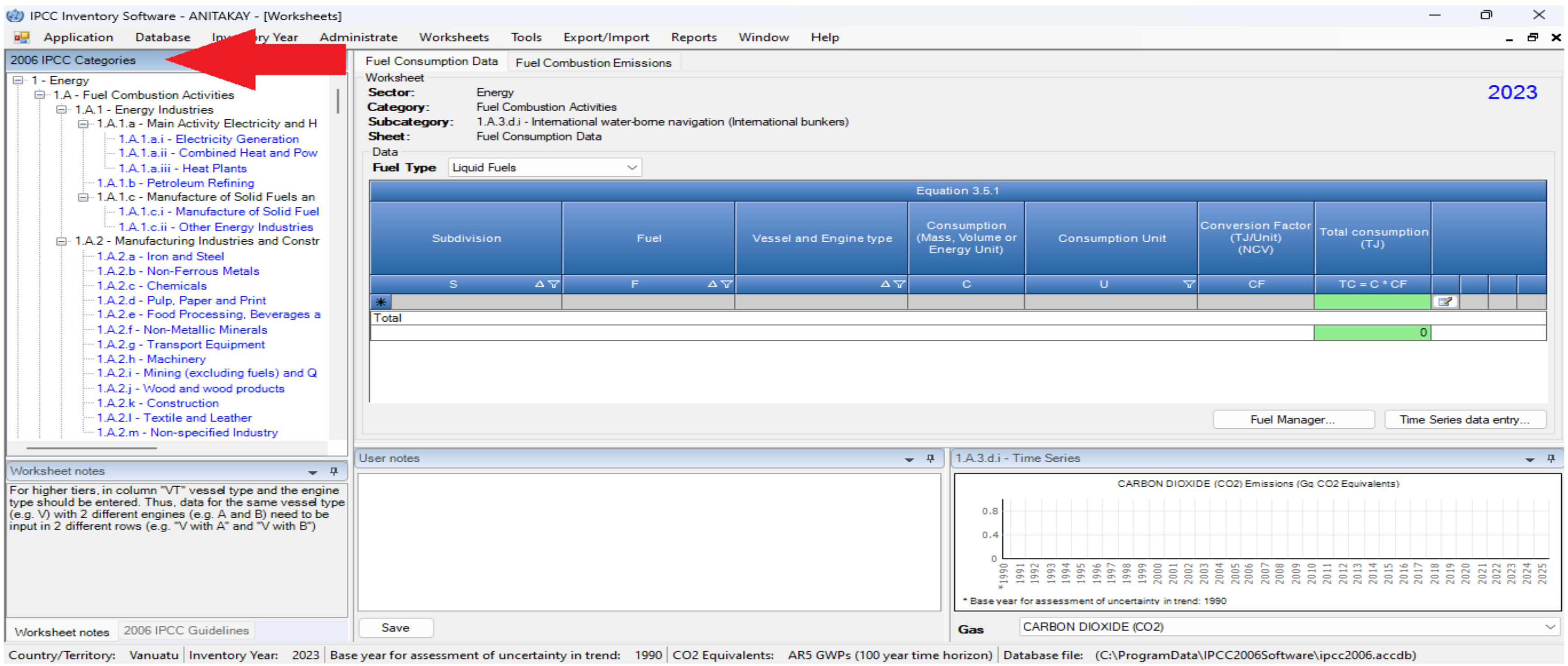
INTERNATIONAL WATER-BORNE NAVIGATION

1.1 Launch the IPCC software ver. 2.901 IPCC Inventory software - 64bit for national GHG inventories.

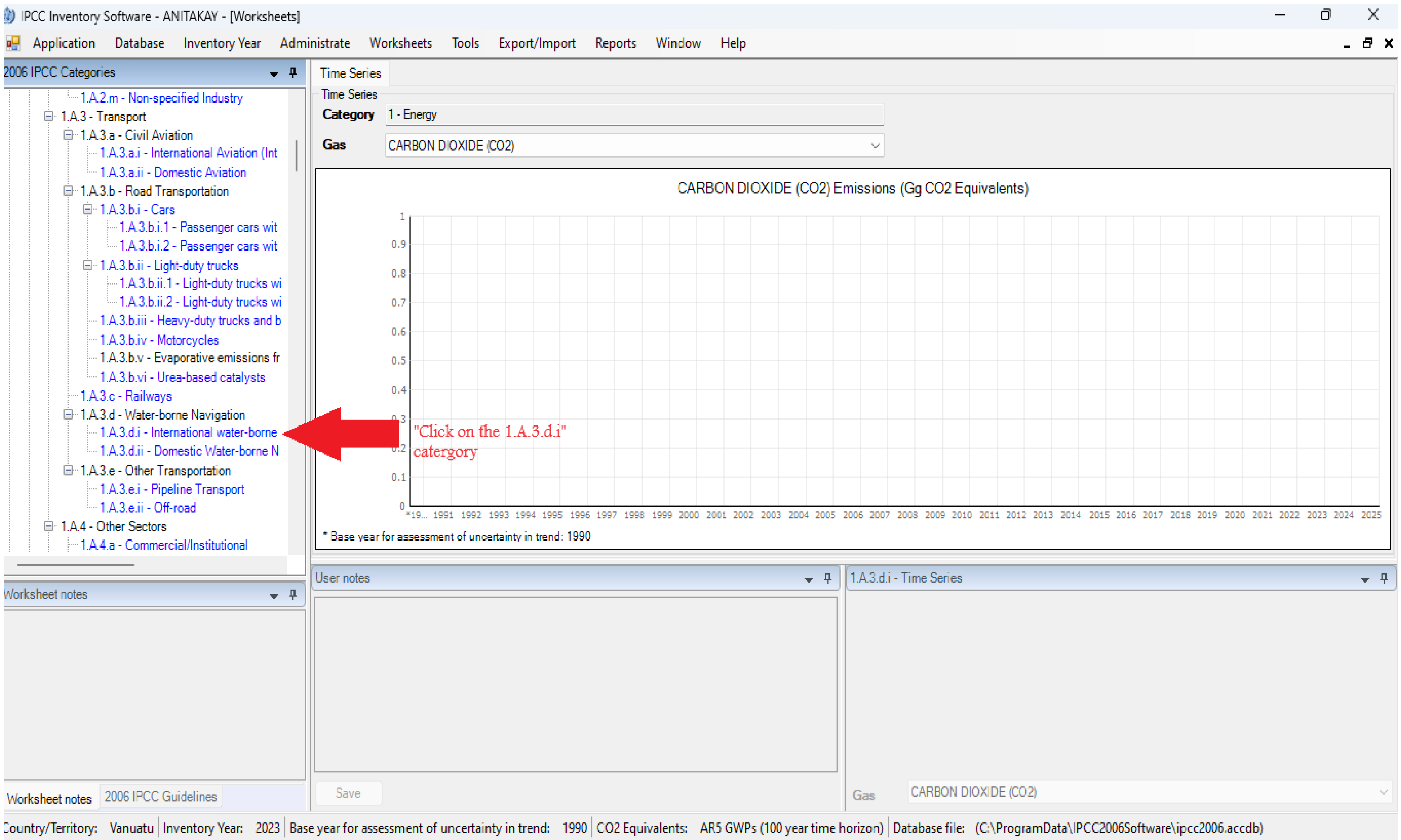
1.2 Type in your password and username.

1.3 Type in the year of your choosing or the current inventory year.

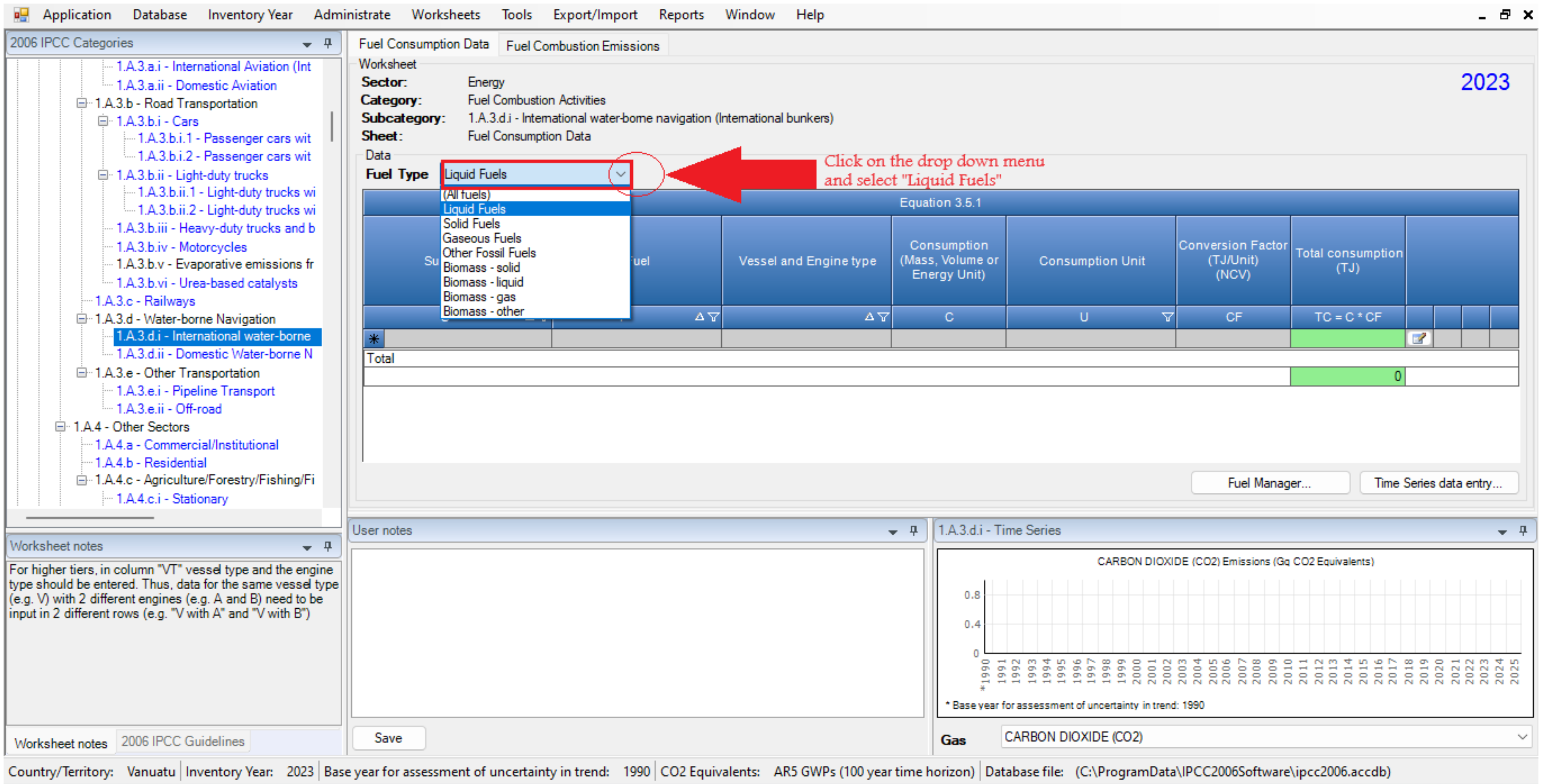
1.4 Locate the bar on the left-hand corner of the page labeled "2006 IPCC categories" (See illustration below).



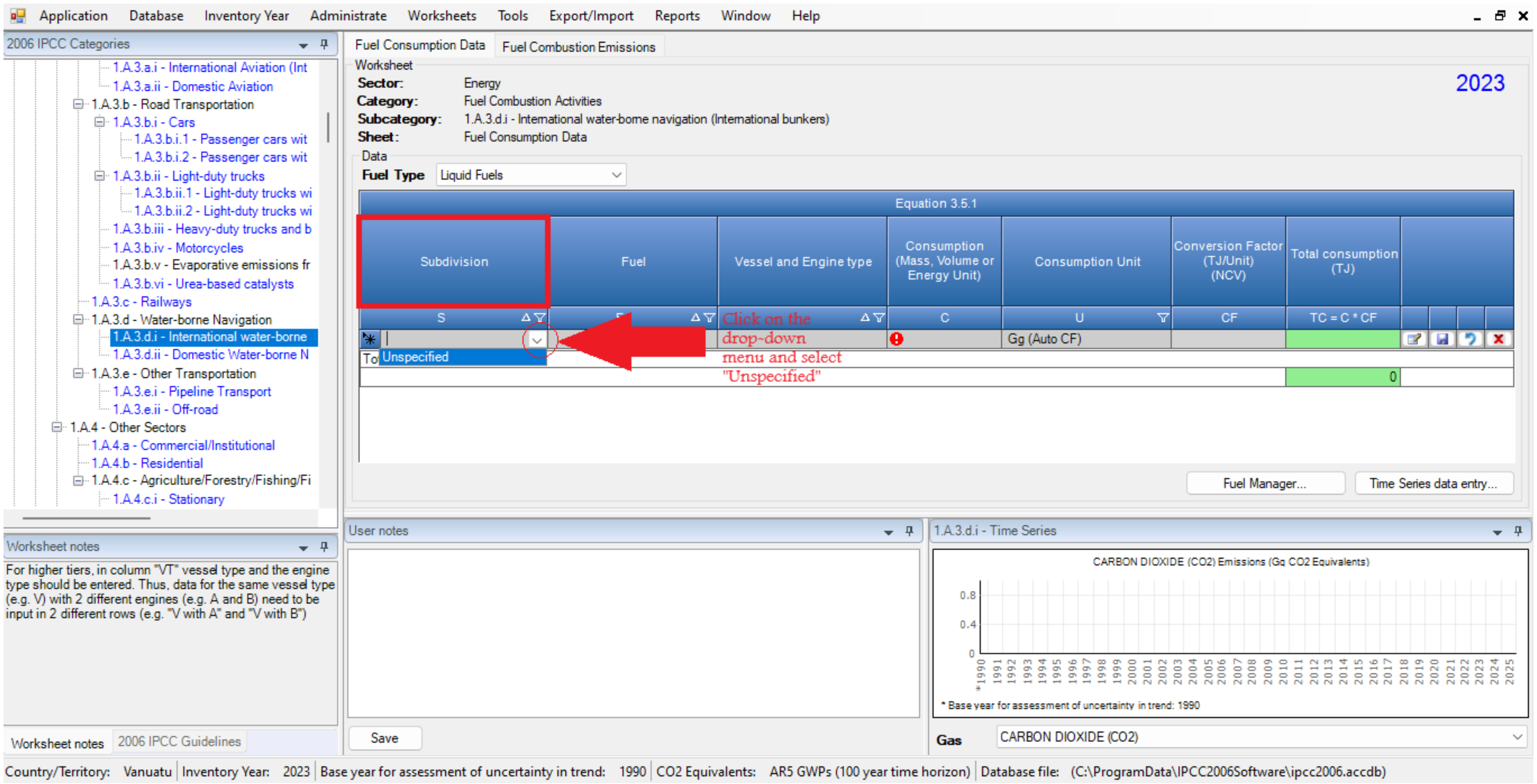
1.5 Scroll down the “2006 IPCC Categories” tab and select the subcategory “1.A.3.d.i – International water-borne”



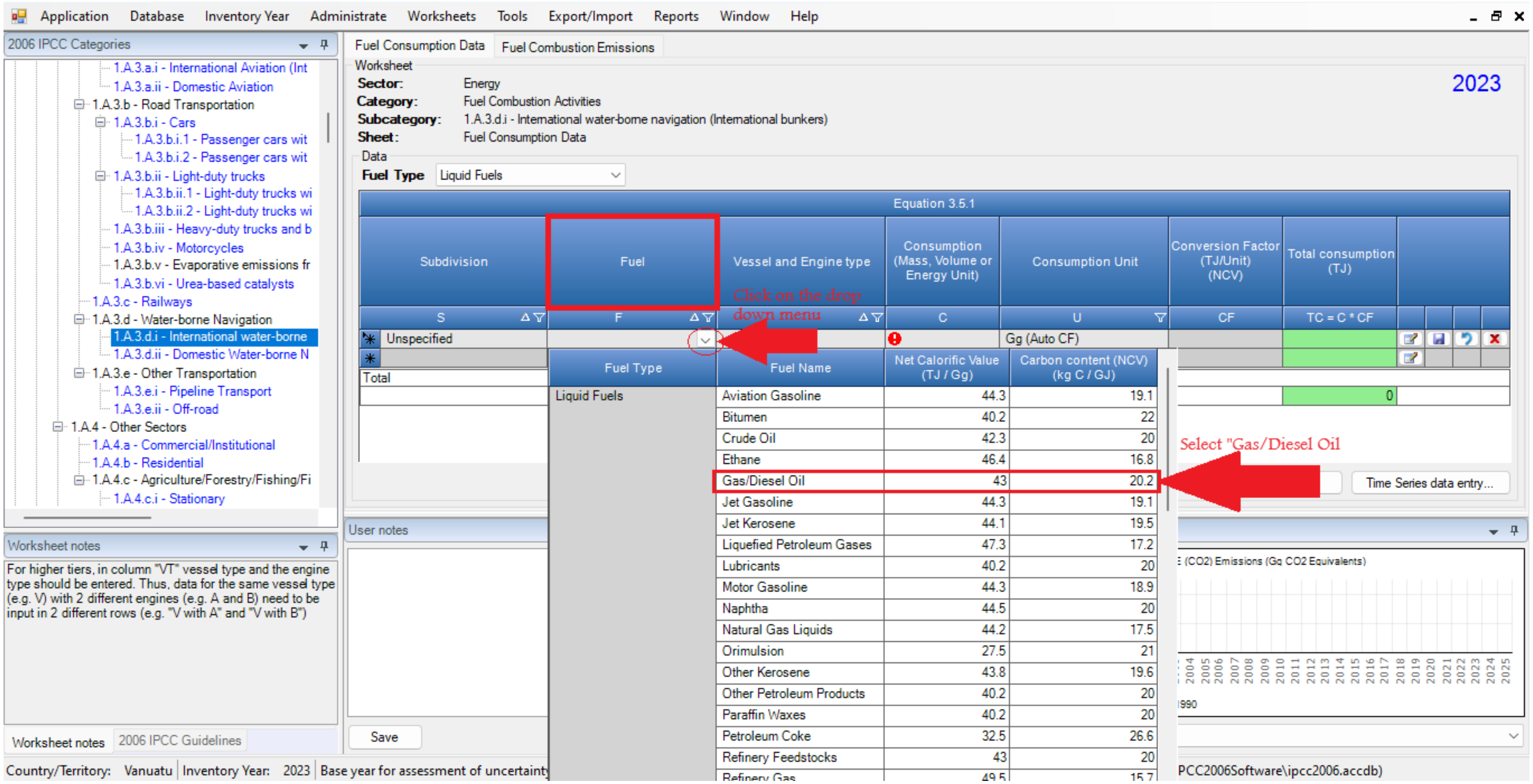
1.6 Click on the drop-down menu from the “Fuel Type” and select “Liquid Fuels” (See illustration below).



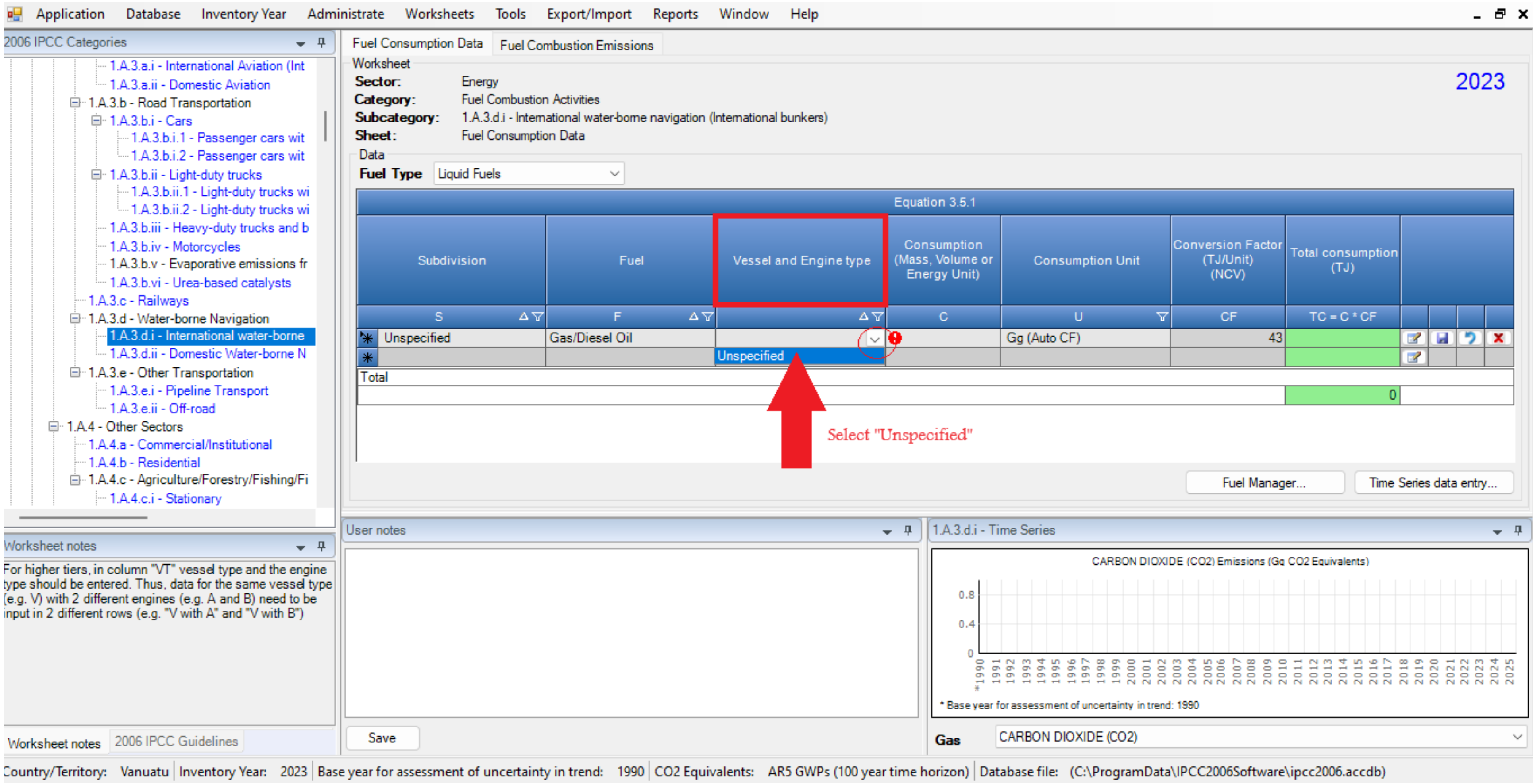
1.7 Click on the drop-down menu under the “Subdivision” tab an select “Unspecified”



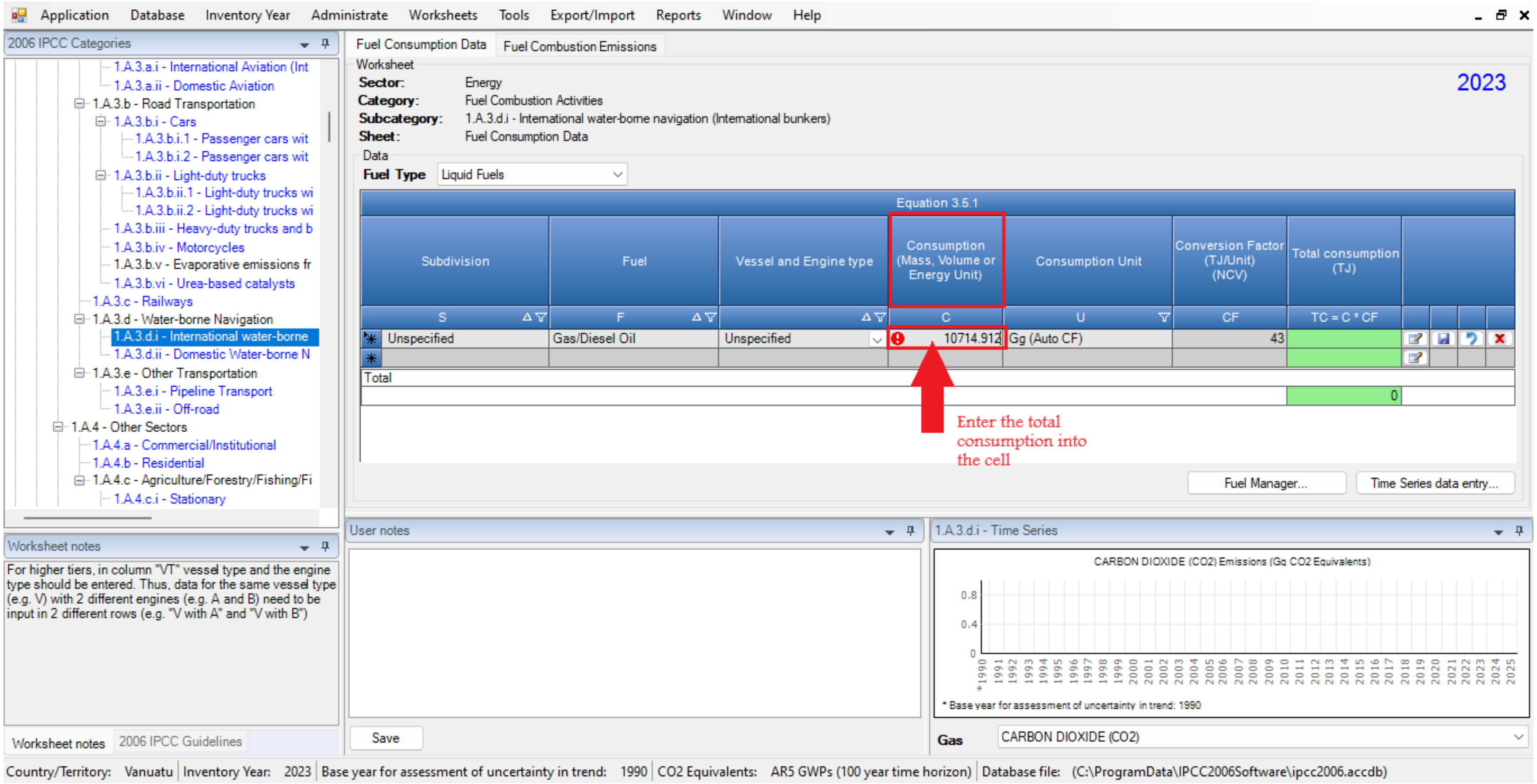
1.8 Under the "Fuel" tab in the table click on the drop-down menu and select "Gas/Diesel Oil"



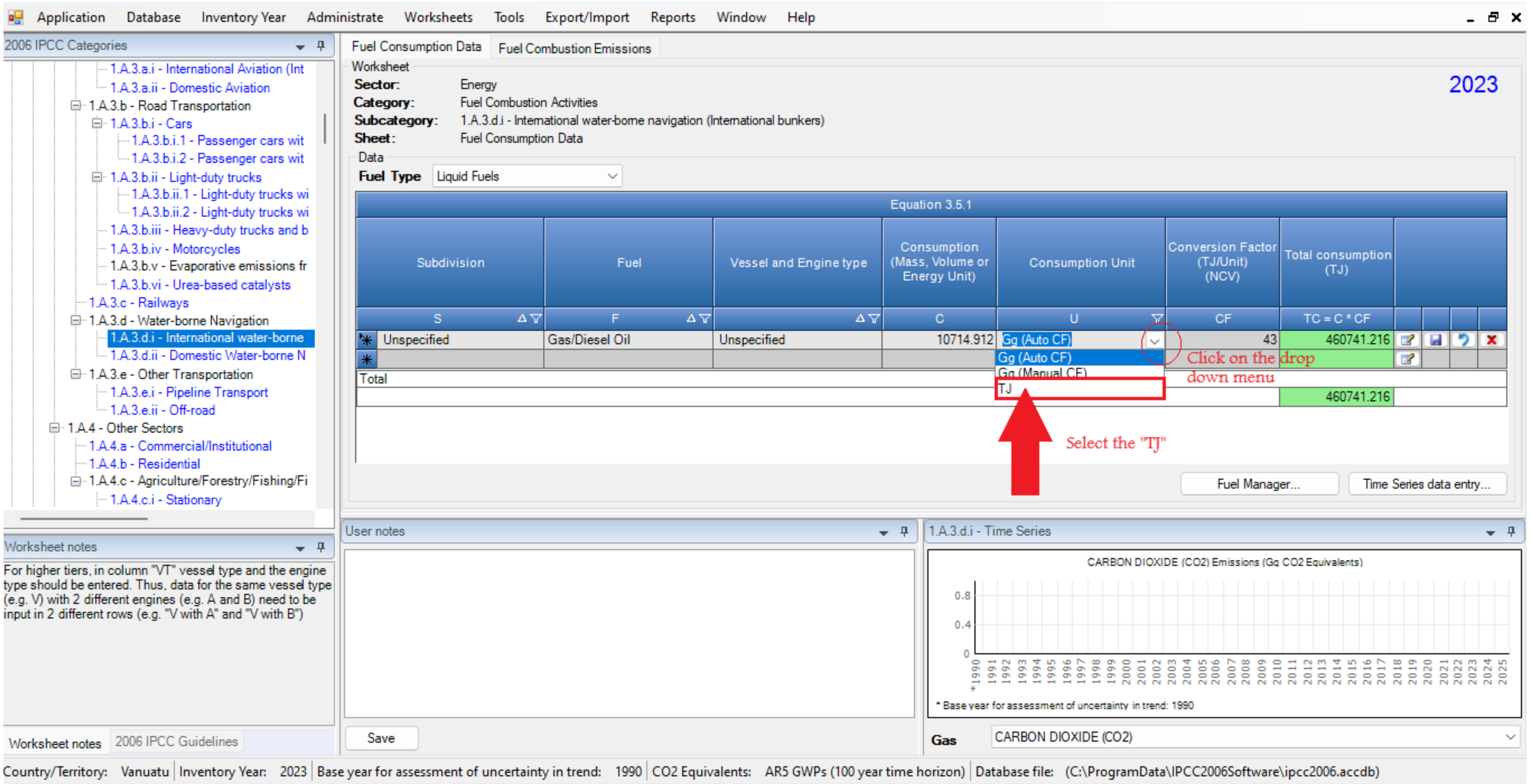
1.9 Under the "Vessel and Engine type" click on the drop-down menu and select "Unspecified" (See illustration below).



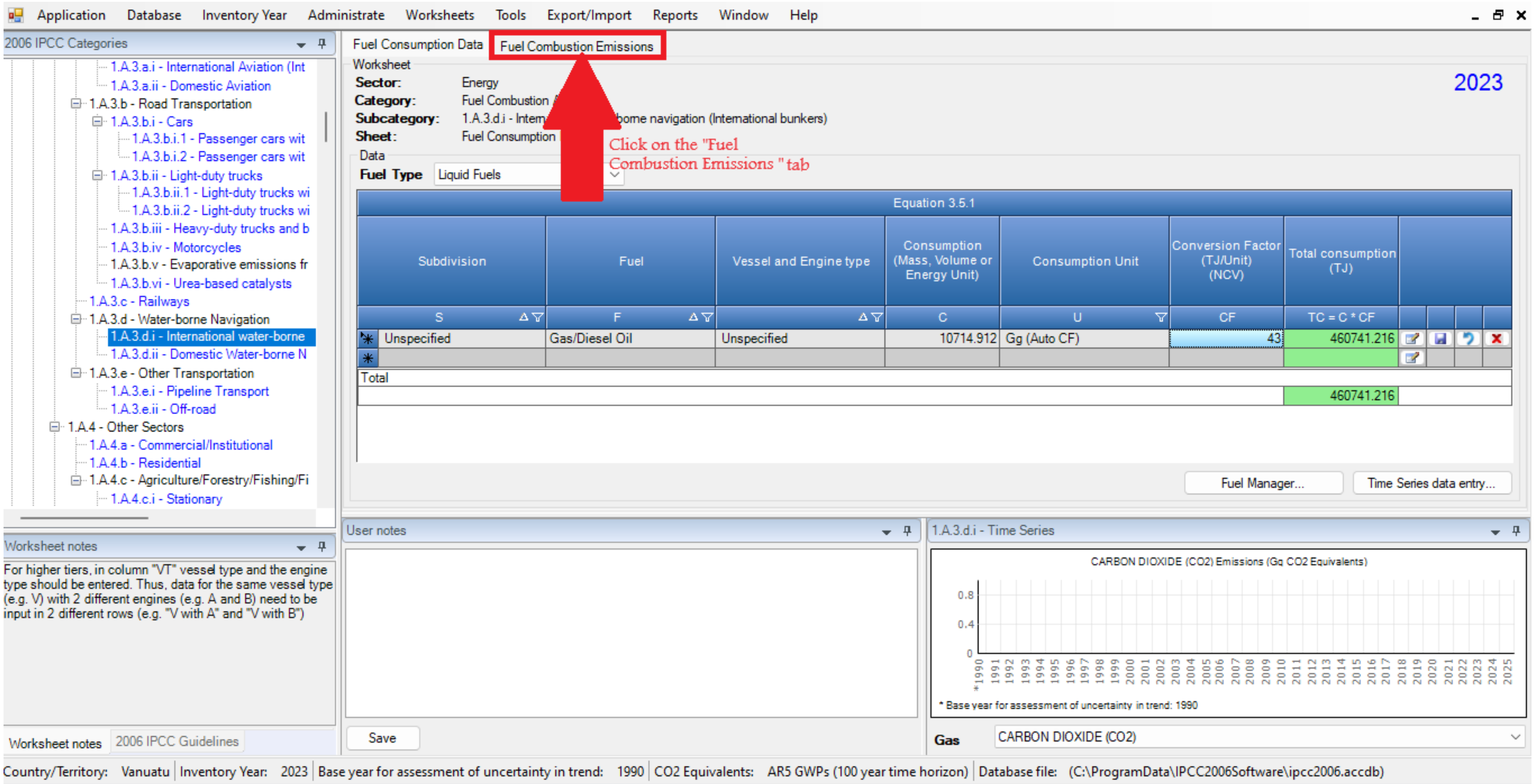
2. Under the “Consumption” tab in the table, enter the total consumption into the cell (See illustration below).



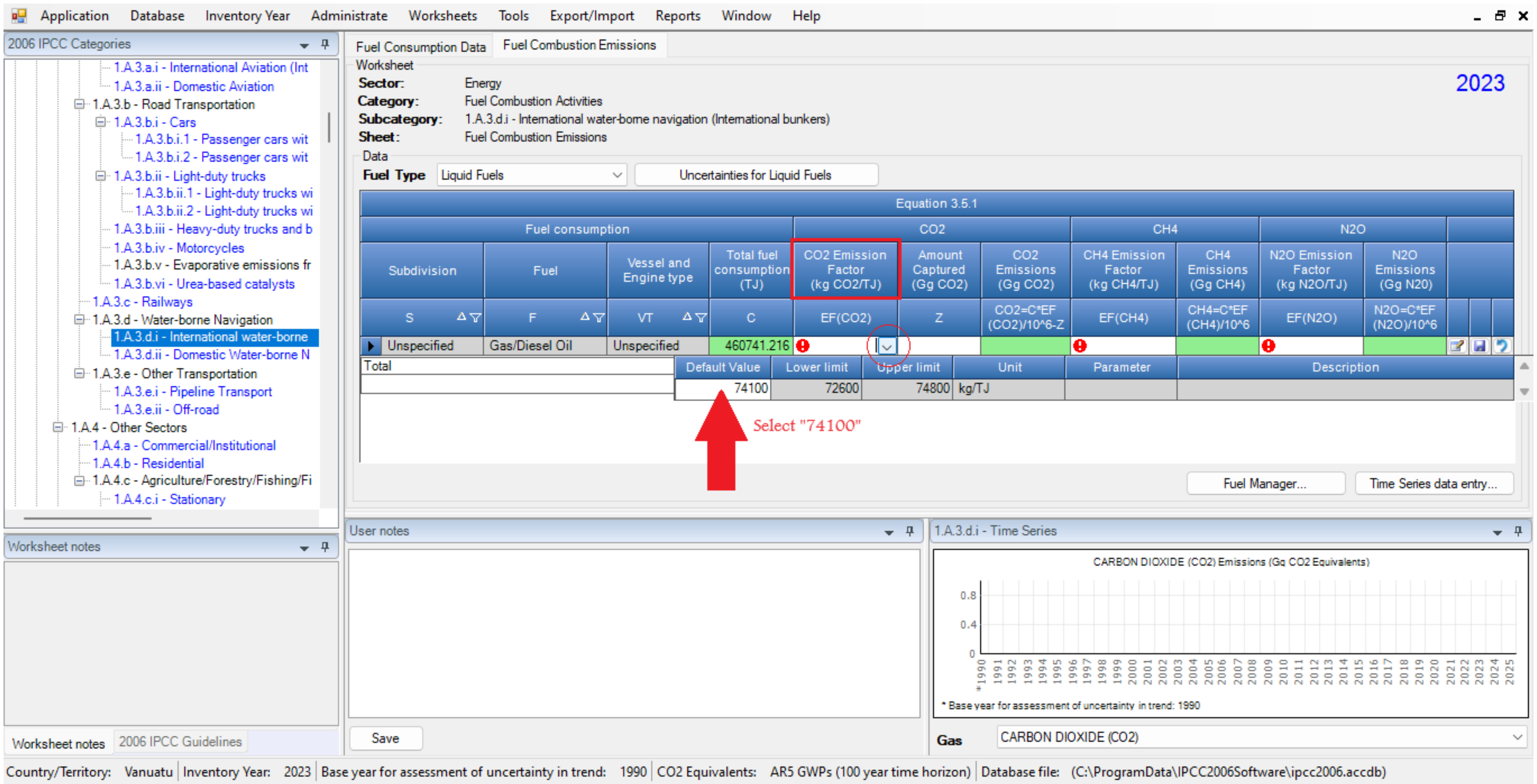
2.1 Click on the drop-down menu under the “Consumptions Unit” tab in the table, and select “TJ” (See illustration below).



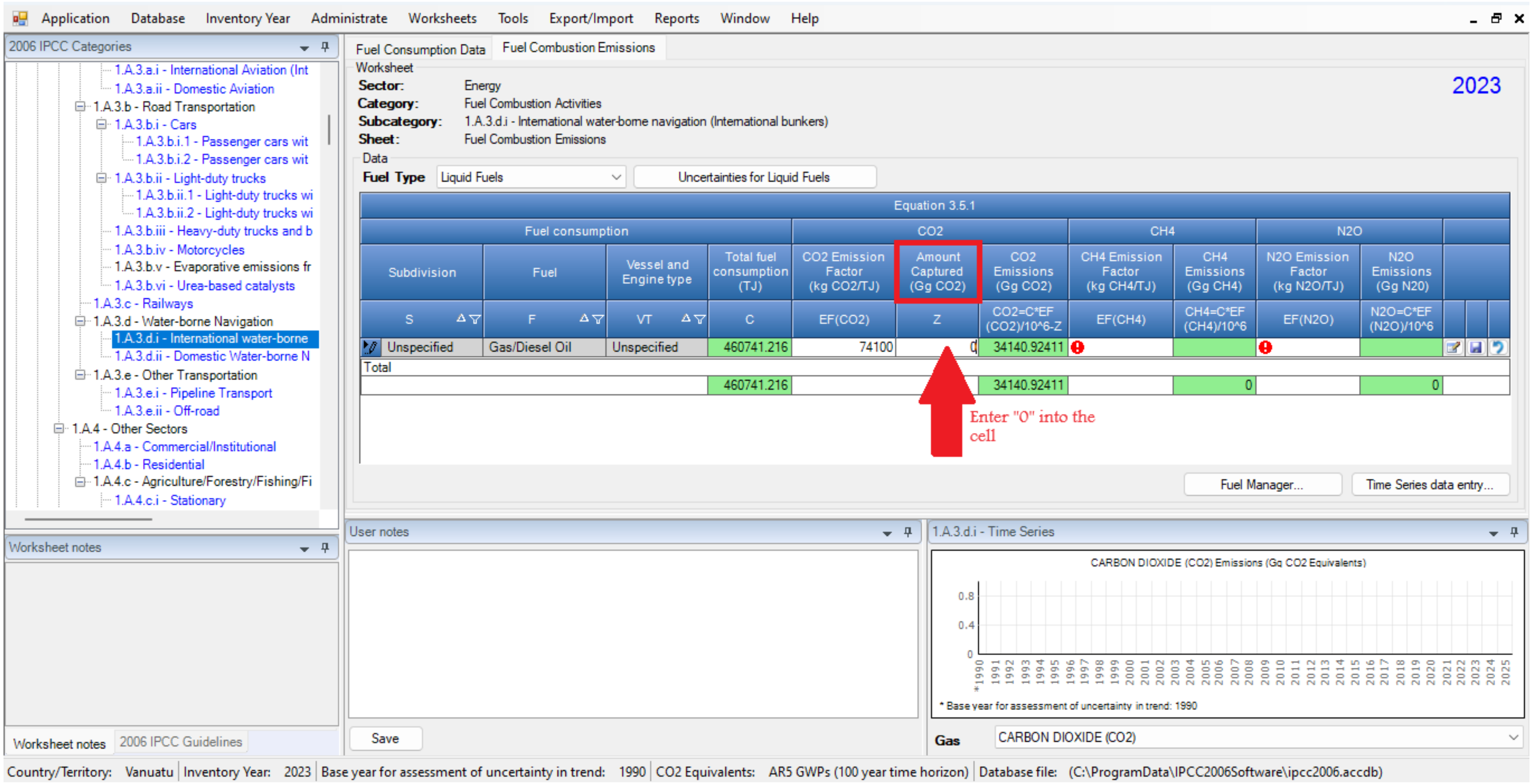
2.2 Click on the “Fuel Combustion Emissions” tab (See illustration below).



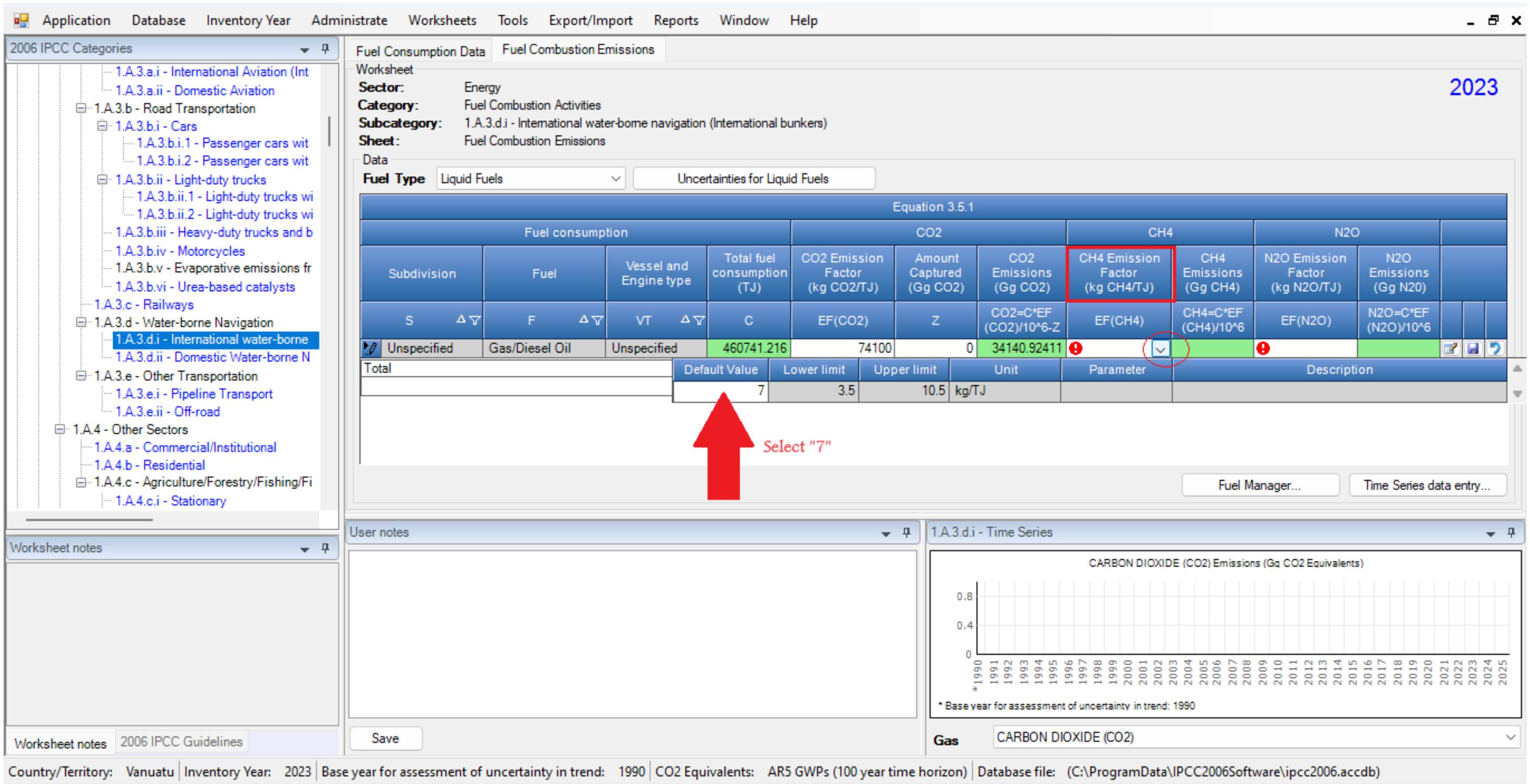
2.3 Click on the drop-down menu under the tab "CO_2 Emission Factor (kg CO_2/TJ)" and select "74100" (See illustration below).



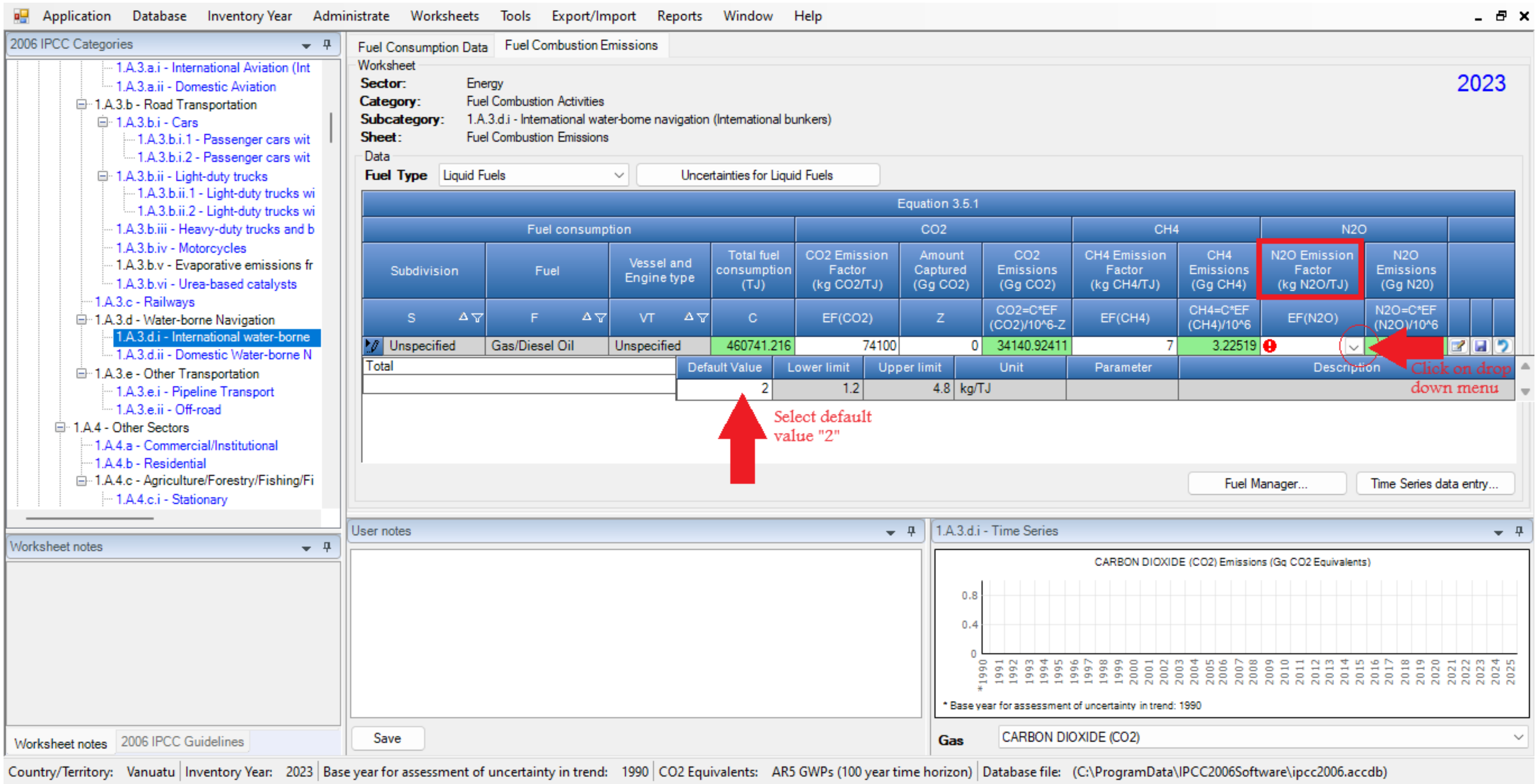
2.4 Under the "Amount Captured (Gg CO_2)" tab, Enter the value "0" (See illustration below).



2.5 select the drop-down menu under the "CH_4 Emission Factor (kg CH_4/TJ)" tab and select the default value "7" (See illustration below).

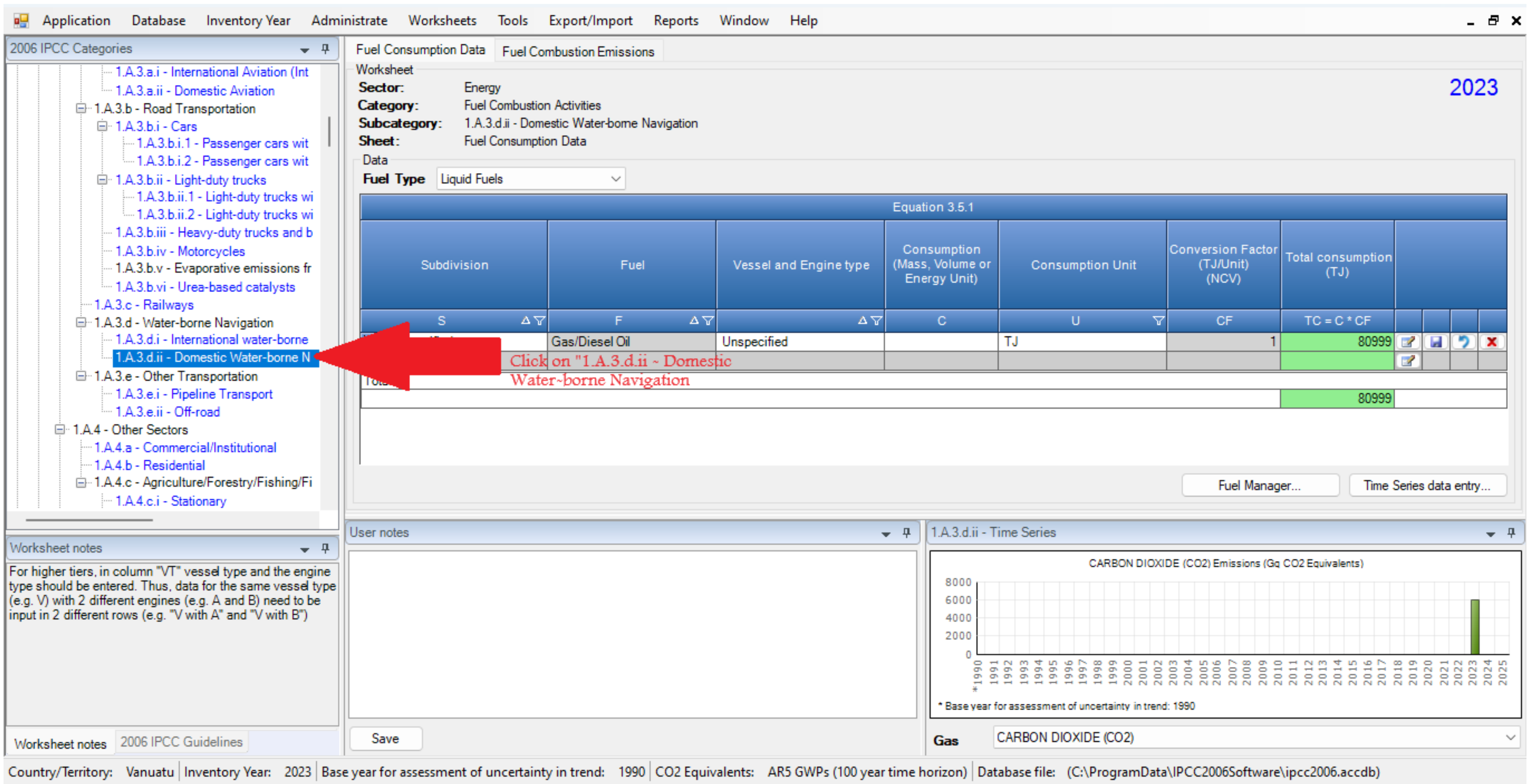


2.6 Under the tab "N_2O Emissions Factor (kg N_2O/TJ) click on the drop-down menu and select the default value "2" (See illustration below).



<u>DOMESTIC WATER-BORNE NAVIGATIONN</u>

2.8 Under the “2006 IPCC categories” tab select the subcategory “1.A.3.d.ii – Domestic Water – borne Navigation (International Bunkers) (See illustration below).



2.9 Repeat steps 1.6 to 2.6.

AVIATION

Civil Aviation Calculation for Emissions of Fuel Consumption (TJ).

1.0 calculate the Fuel consumption for Aviation using the stepwise example below

STEPWISE EXAMPLE

i. Convert Litres to Kilograms using the equation:
Fuel Consumed (kilo tonnes (kg) = Fuel Consumed (litres) X Fuel Denisty (Kg/L)

Convert Kg/L to Kg/m^3

Kg / L = (Kg / m^3)/ 1000

Table 6: showing an example of the conversion litres to Kilograms.

Fuel Type	Fuel Consumption (liter)	Fuel Density (kg/L)	Fuel Consumption (Kg)
Aviation Gasoline	10000000	725kg/m3 (= 0.725 kg/L)	7250000

(The consumption figures utilized don't correspond to any published data.)

ii. Convert Fuel Consumption (kg) to Fuel Consumption (kt) using the equation:
Fuel Consumption (kt) = Fuel Consumption (Kg) / 1000000

Table 7: showing an example of the conversion of kilograms to kt.

Fuel Type	Fuel Consumption (liter)	Fuel Density (kg/L)	Fuel Consumption (Kg)	Fuel Consumption (kt)
Aviation Gasoline	10000000	725kg/m3 (= 0.725 kg/L)	7250000	7.25

iii. Convert Fuel consumption (kt) to Fuel Consumption (TJ) using the equation:

Fuel Consumption (TJ) = Fuel Consumption (kt) X NCV (TJ/Gg)

Table 8: showing an example of the conversion from Fuel consumption (kt) to Fuel Consumption (TJ).

Fuel Type	Fuel Consumption (liter)	Fuel Density (kg/L)	Fuel Consumption (Kg)	Fuel Consumption (kt)	NCV (TJ/Gg)	Fuel Consumption (TJ)
Aviation Gasoline	10000000	725kg/m3 (= 0.725 kg/L)	7250000	7.25	44.3	321.175

USING THE IPCC SOFTWARE VER. 2.901 IPCC INVENTORY SOFTWARE - 64BIT

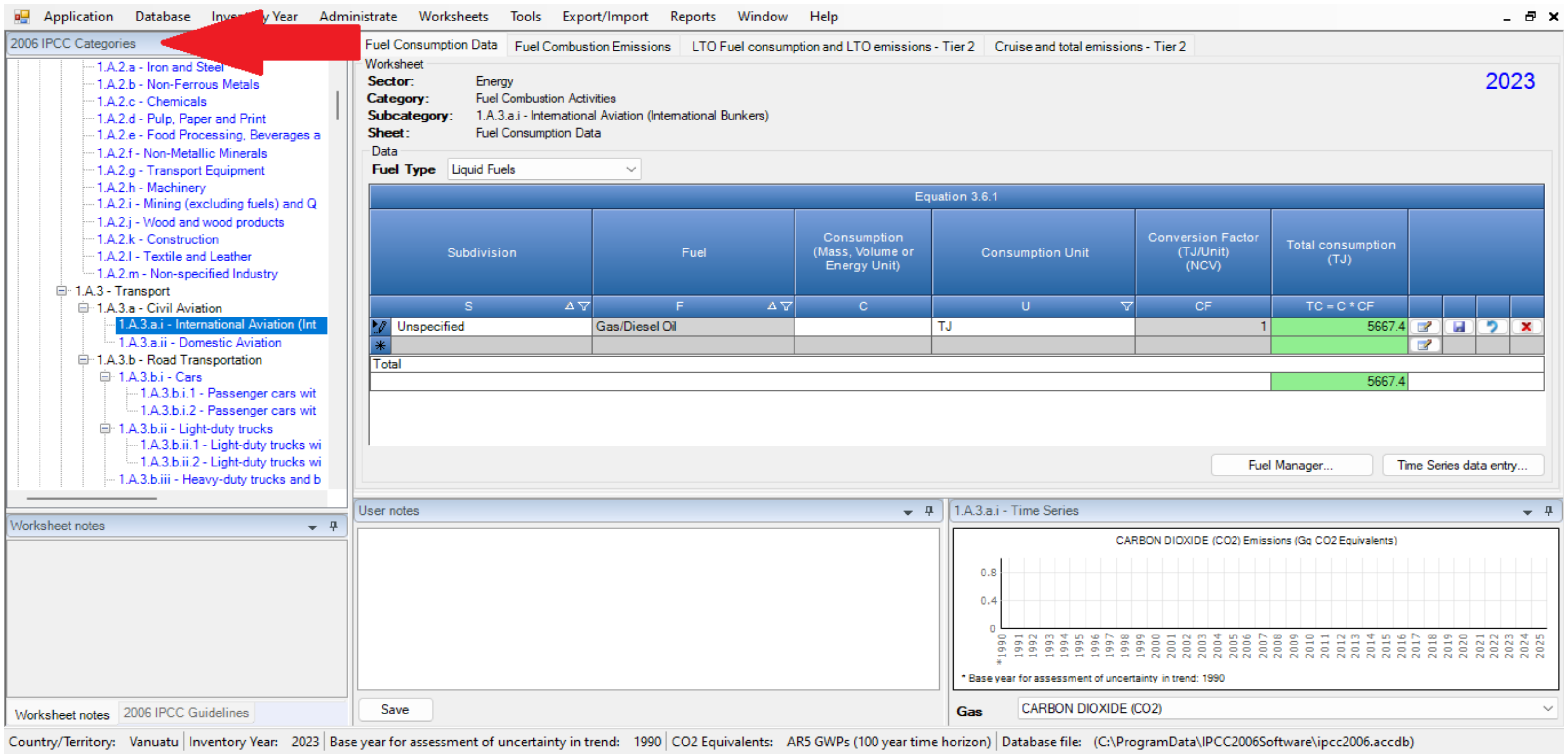
INTERNATIONAL WATER-BORNE NAVIGATION

1.1 Launch the IPCC software ver. 2.901 IPCC Inventory software - 64bit for national GHG inventories.

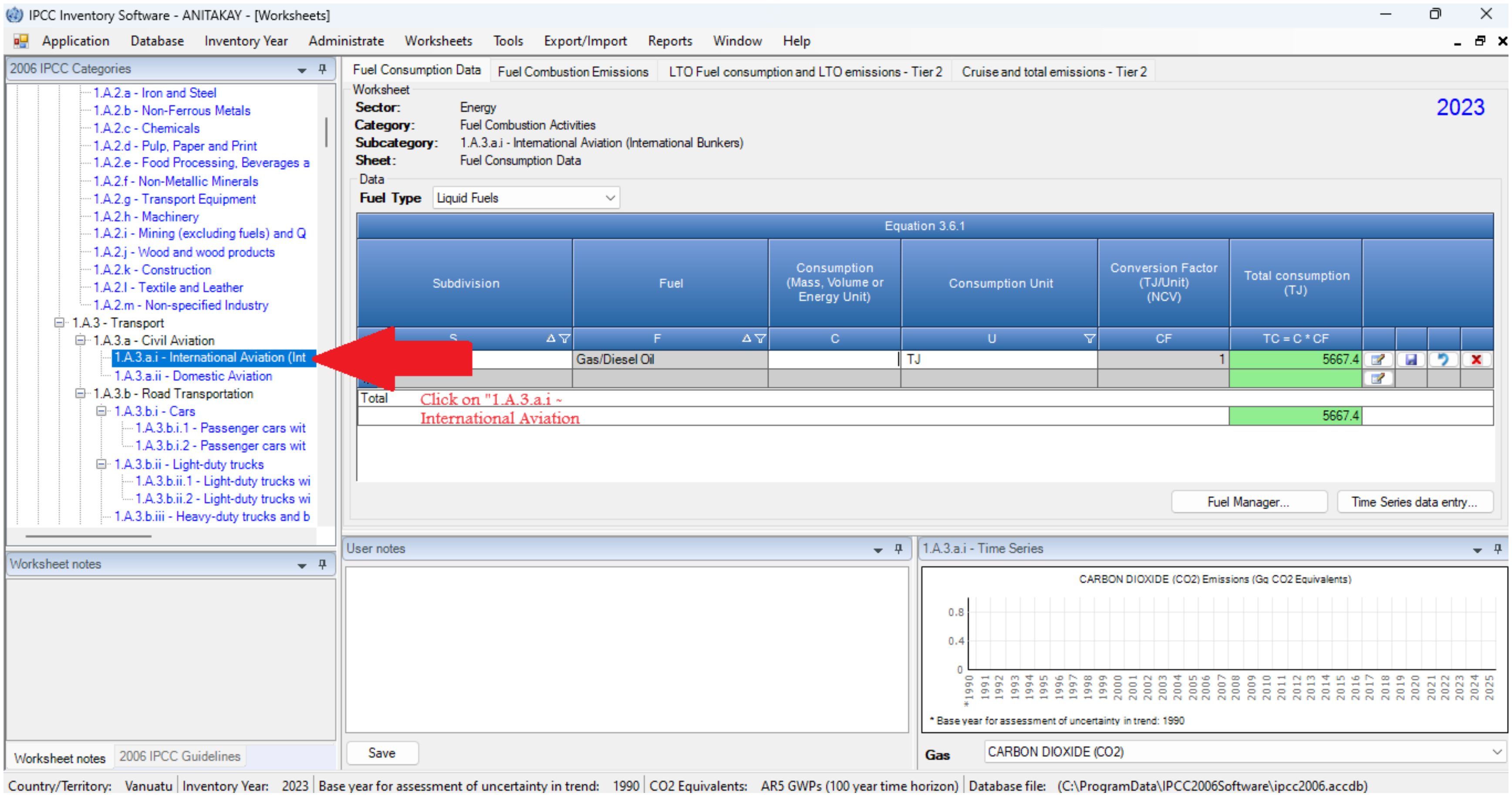
1.2 Type in your password and username.

1.3 Type in the year of your choosing or the current inventory year.

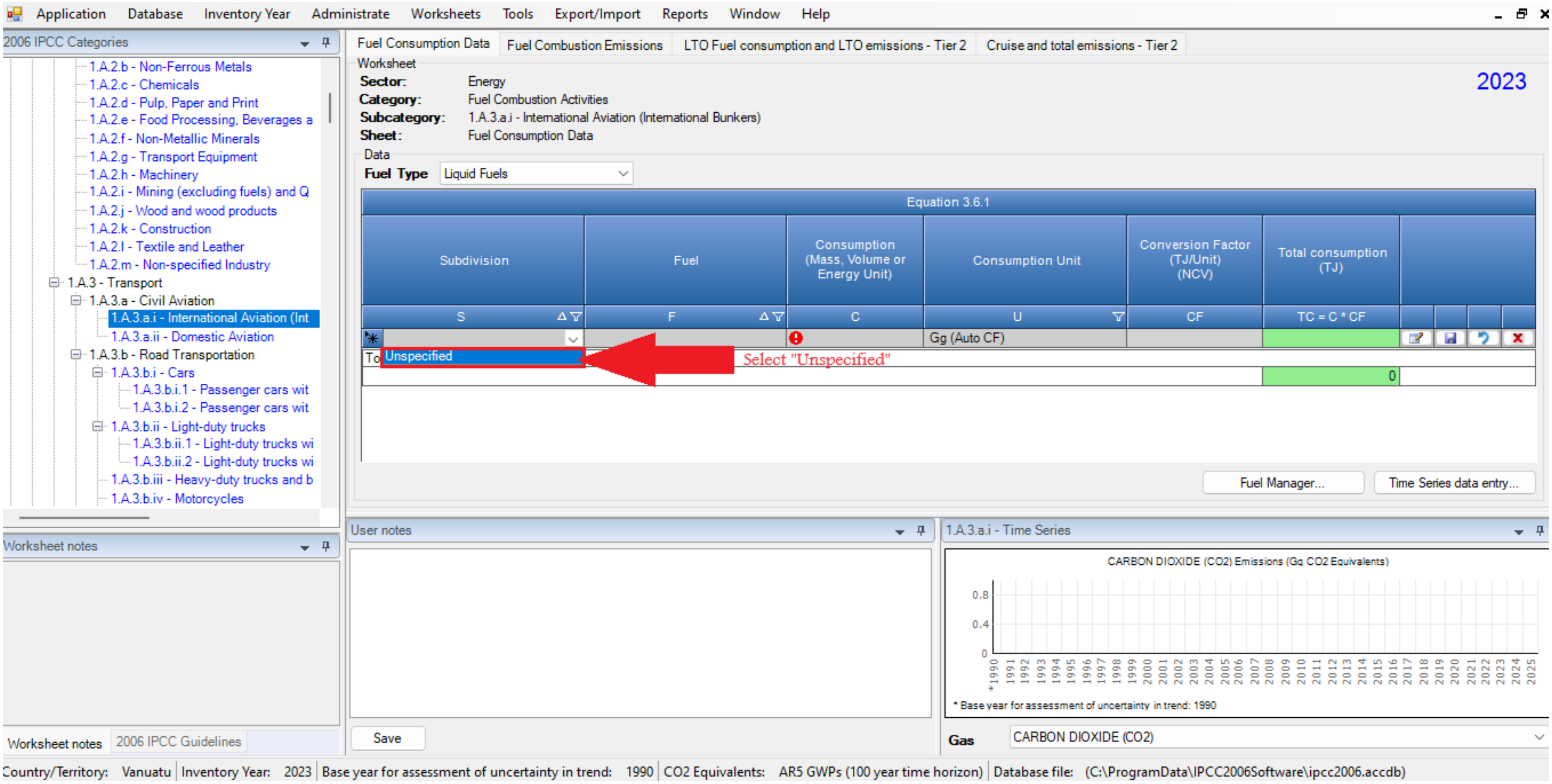
1.4 Locate the bar on the left-hand corner of the page labeled "2006 IPCC categories" (See illustration below).



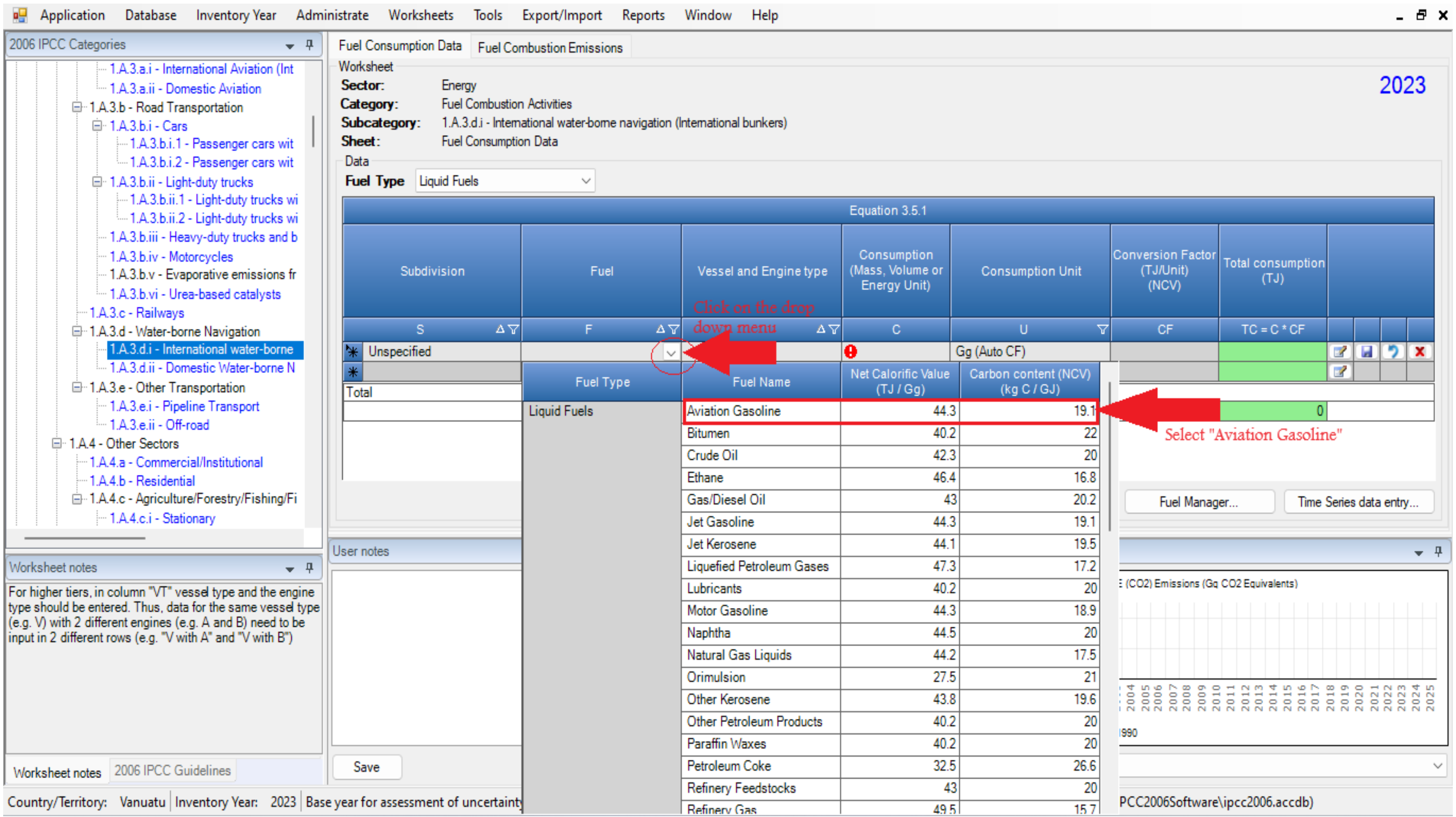
1.5 Click on the subcategory "1.A.3.a.i – international Aviation" (See illustration below)



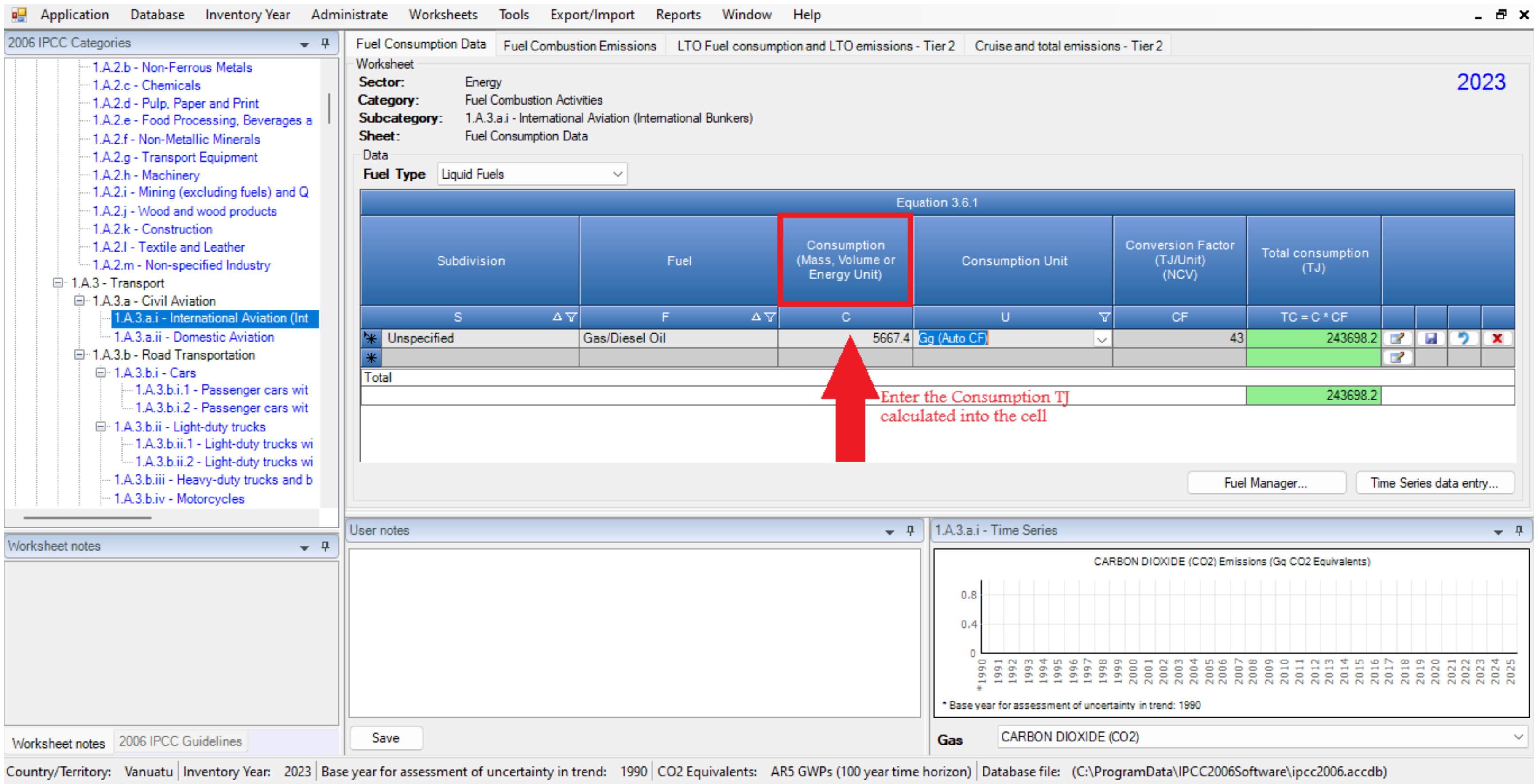
1.6 Click on the drop-down menu from the "subdivision" tab and select "Unspecified" (See illustration below)



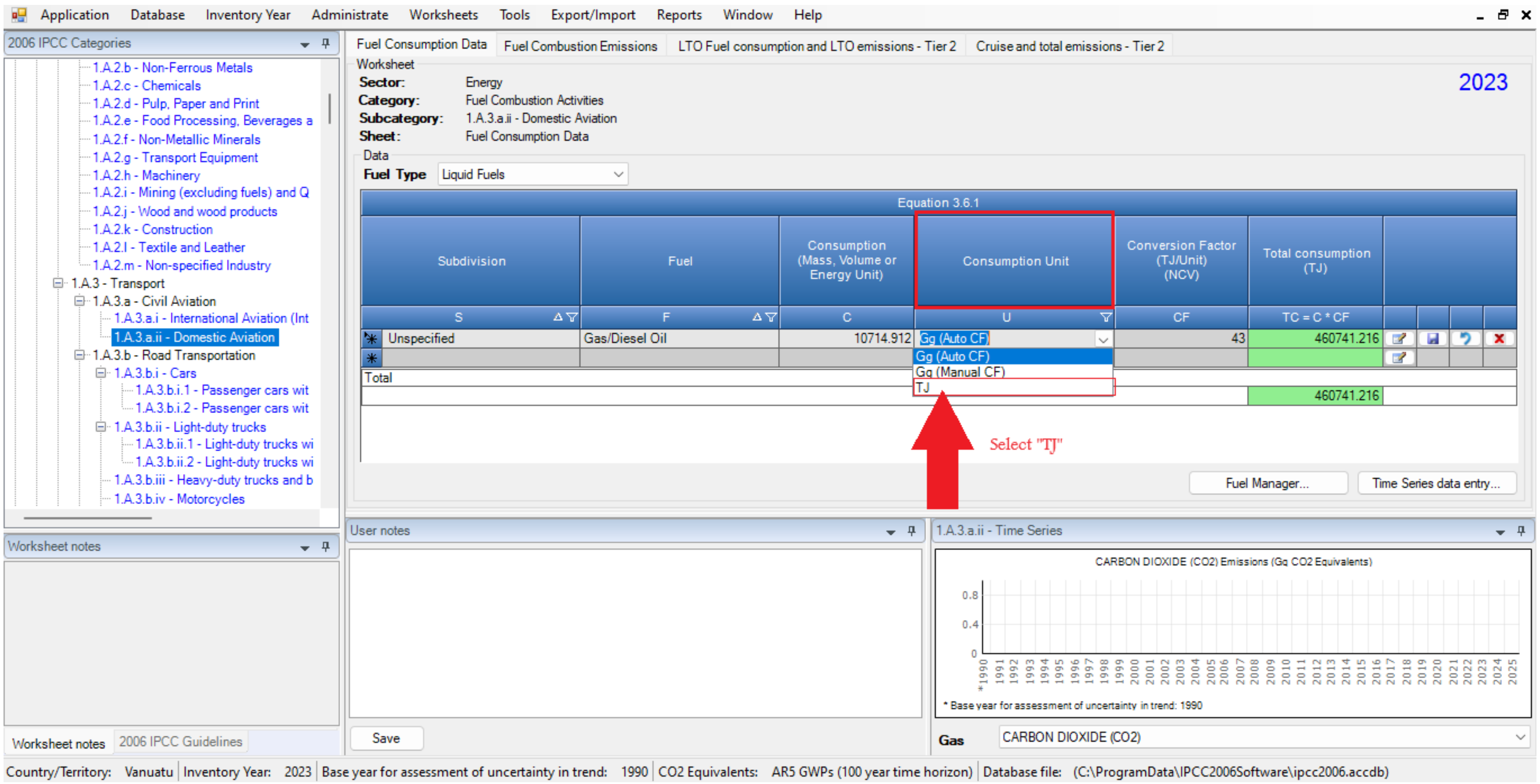
1.7 Under the “Fuel” tab in the table, click on the drop-down menu and select Aviation Gasoline “(See illustration below).



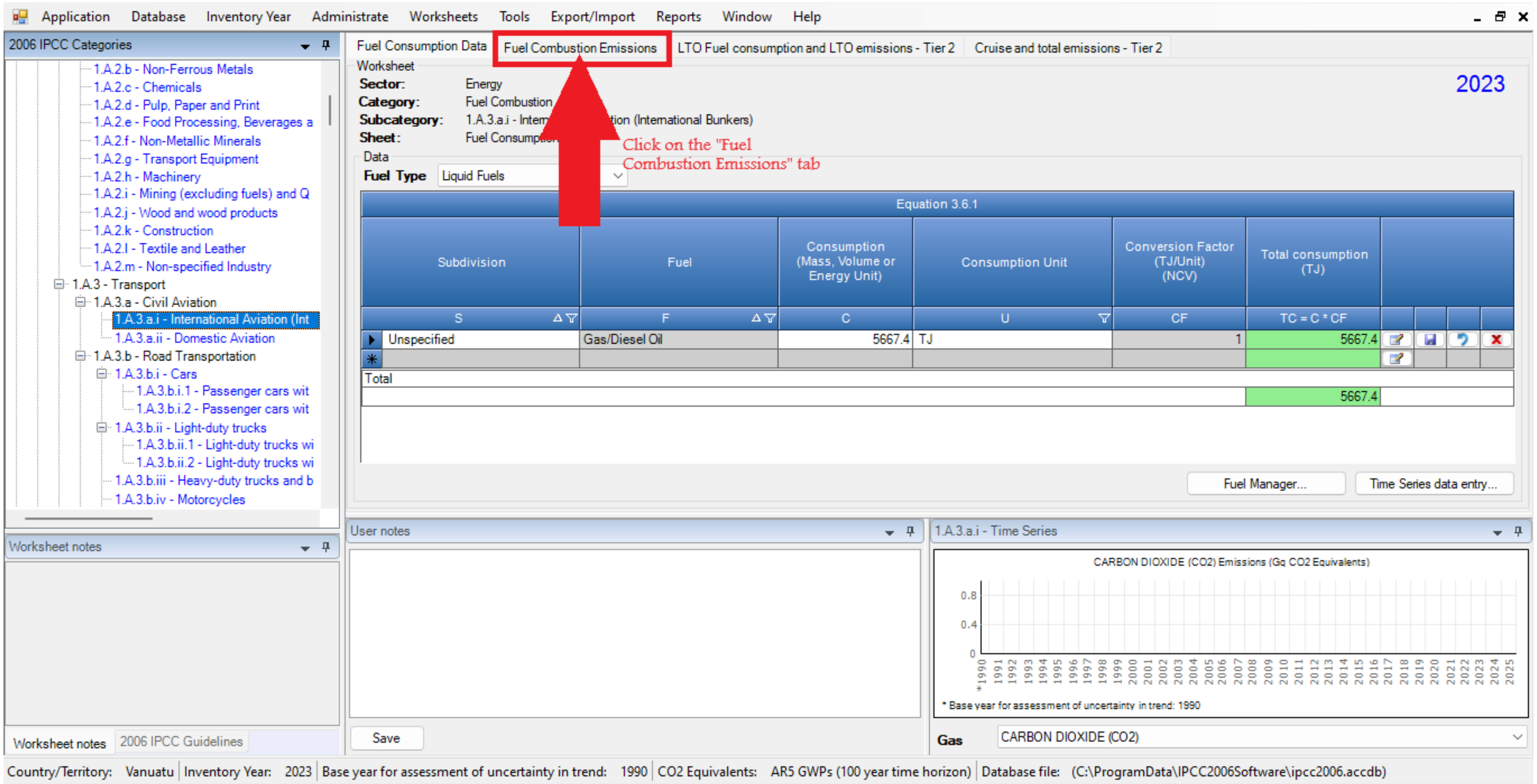
1.8 Enter the Consumption (TJ) value into the cell under the "Consumption (Mass, Volume or Energy Unit)" tab in the table (See illustration below)



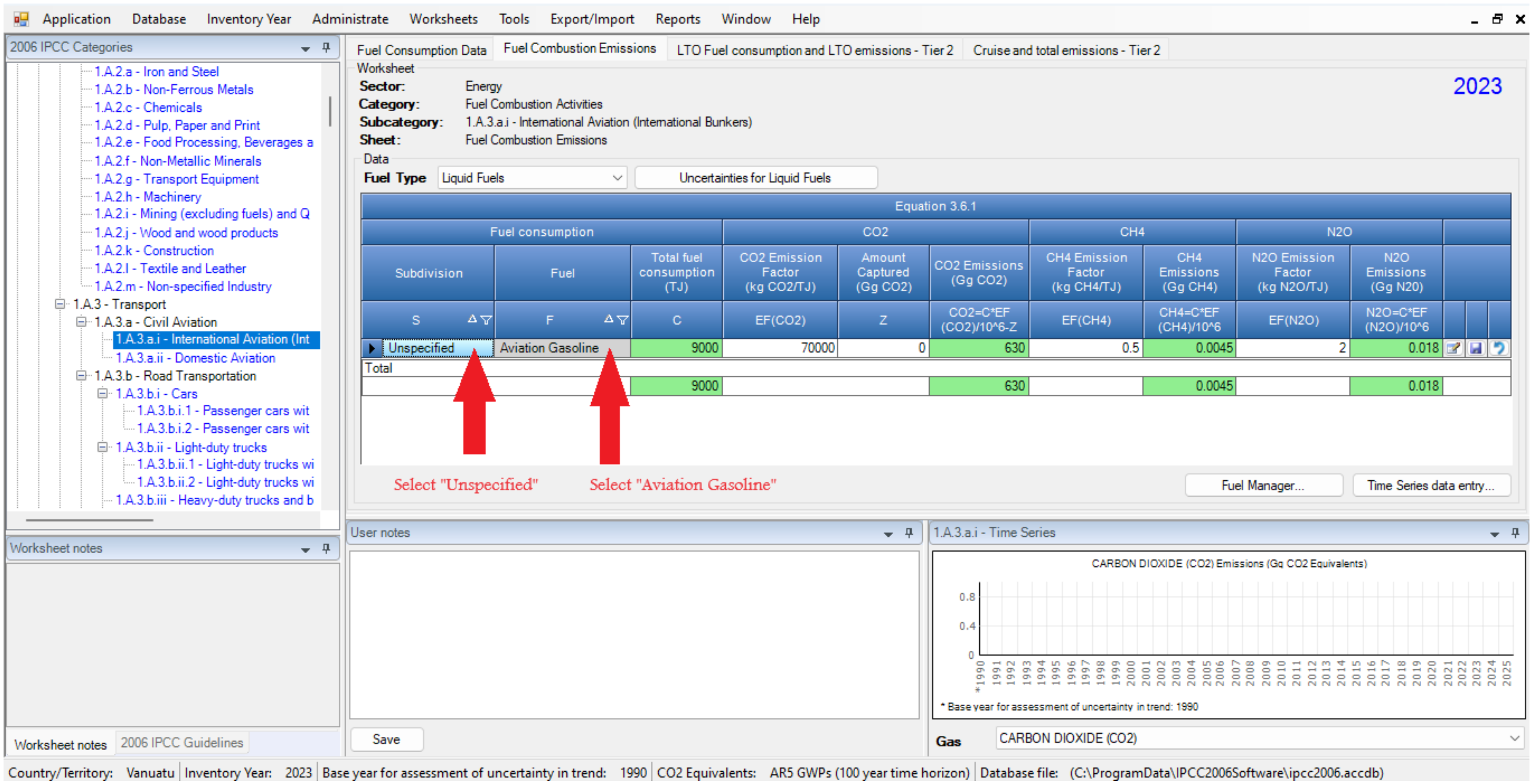
1.9 under the “Consumption Unit” click on the drop-down menu and select “TJ” (See illustration below).



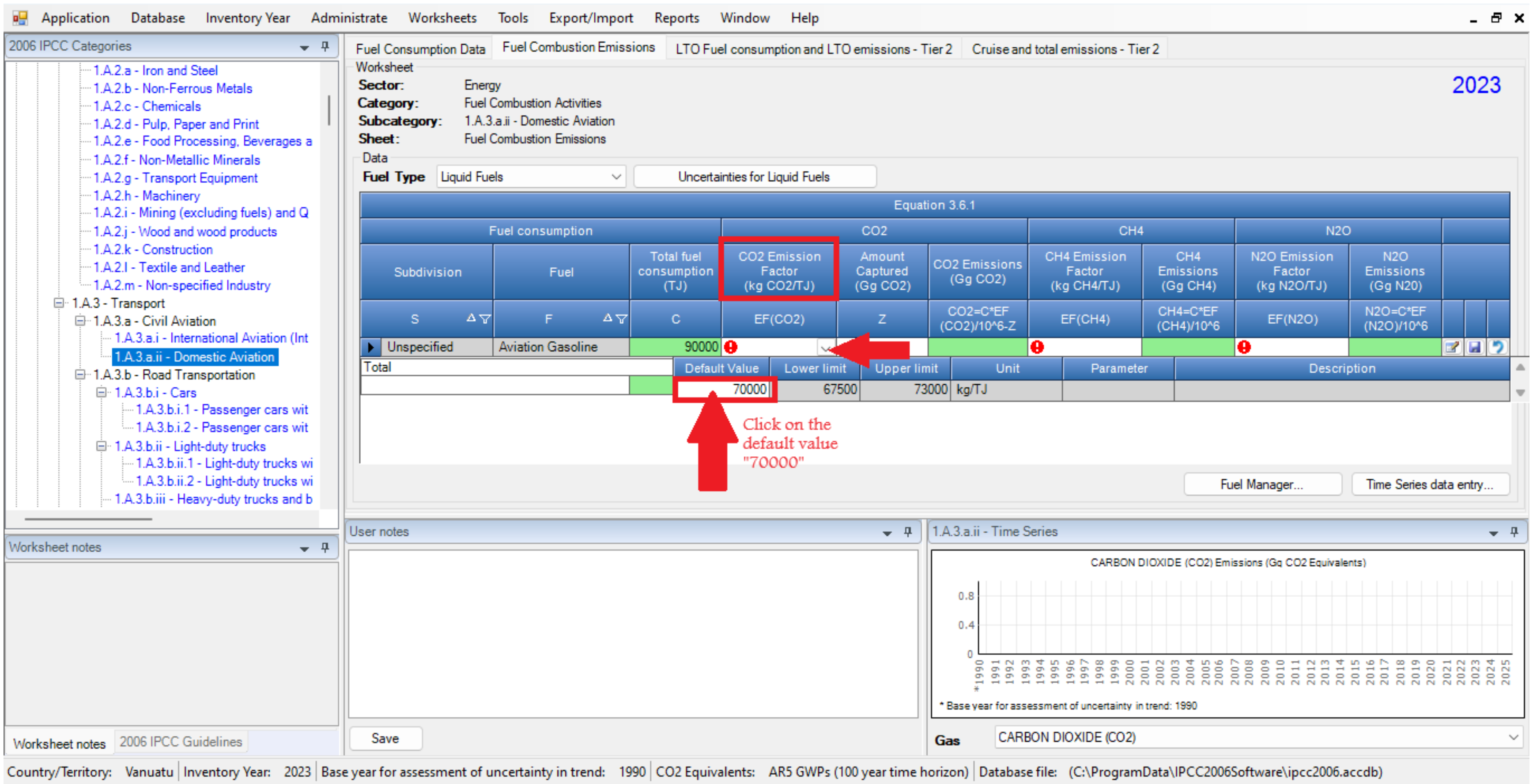
2.0 click on the “Fuel Combustion Emissions “tab (See illustration below).



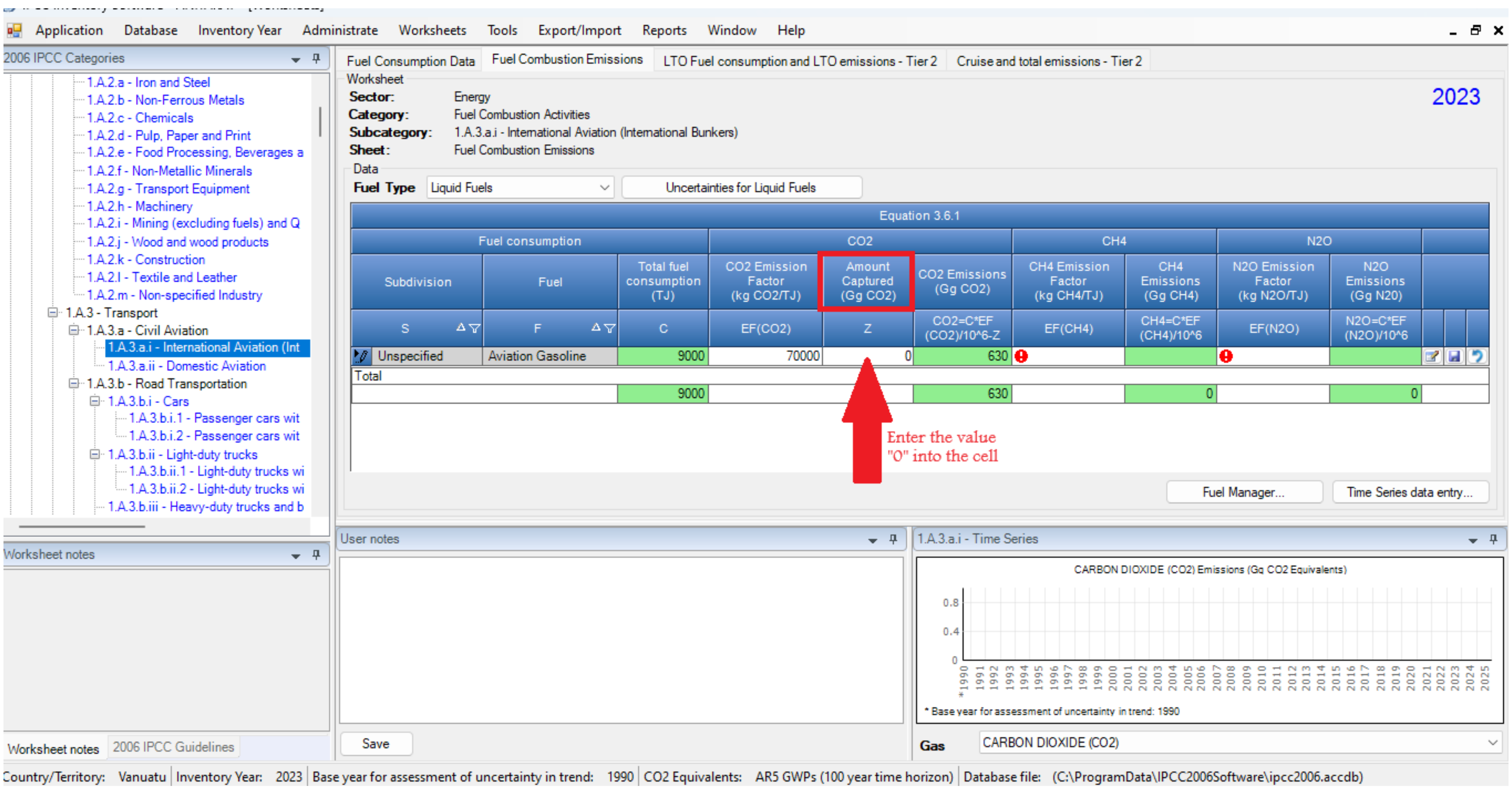
2.1 Under the Subdivision tab in the table click on the drop-down menu and select "Unspecified", then under the "Fuel" tab, click on the drop-down menu and select "Aviation Gasoline" (See illustration below).



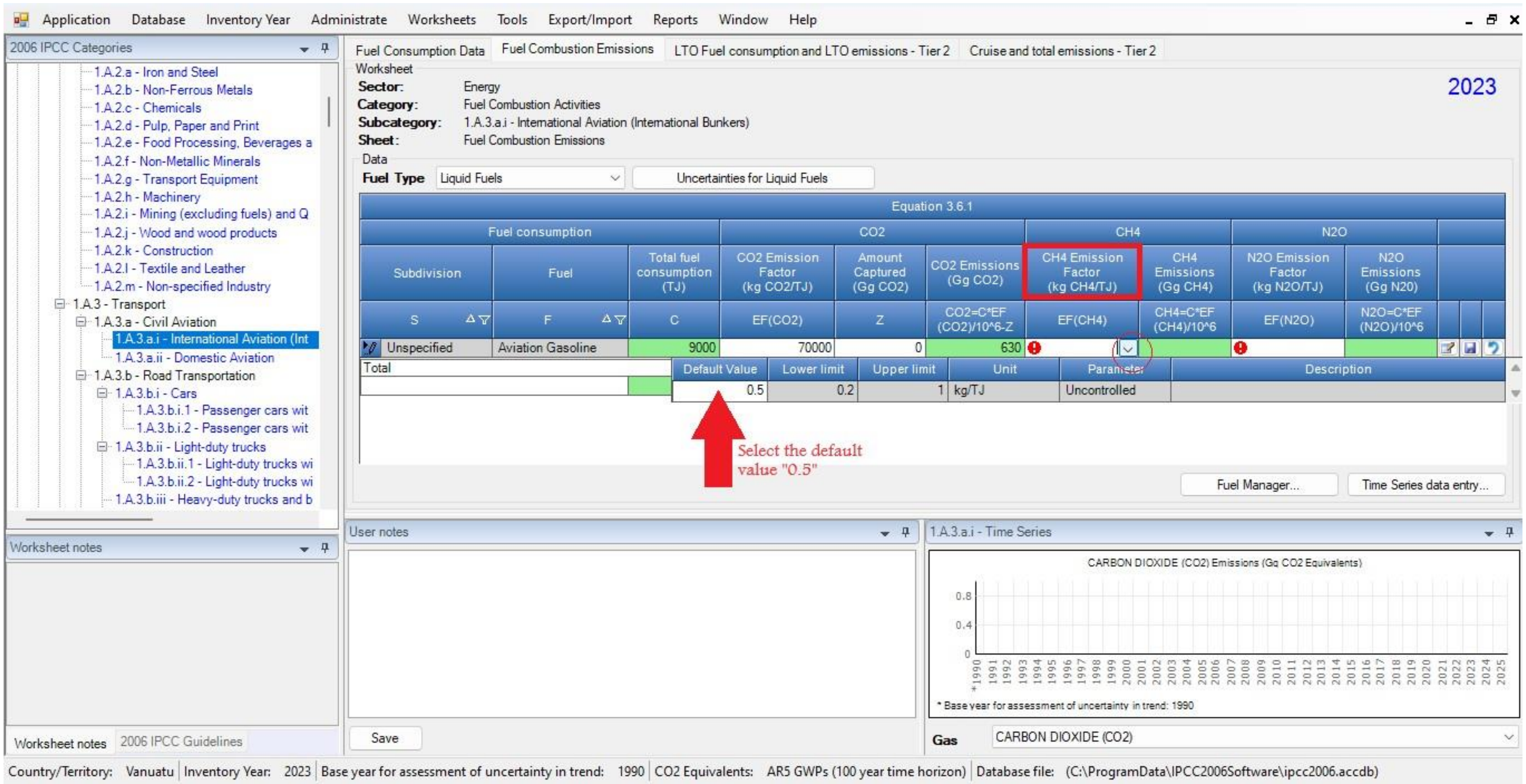
2.2 Click on the drop-down menu under the "CO_2 Emission Factor (kg CO_2/TJ)" tab and select the default value "70000" (See illustration below).



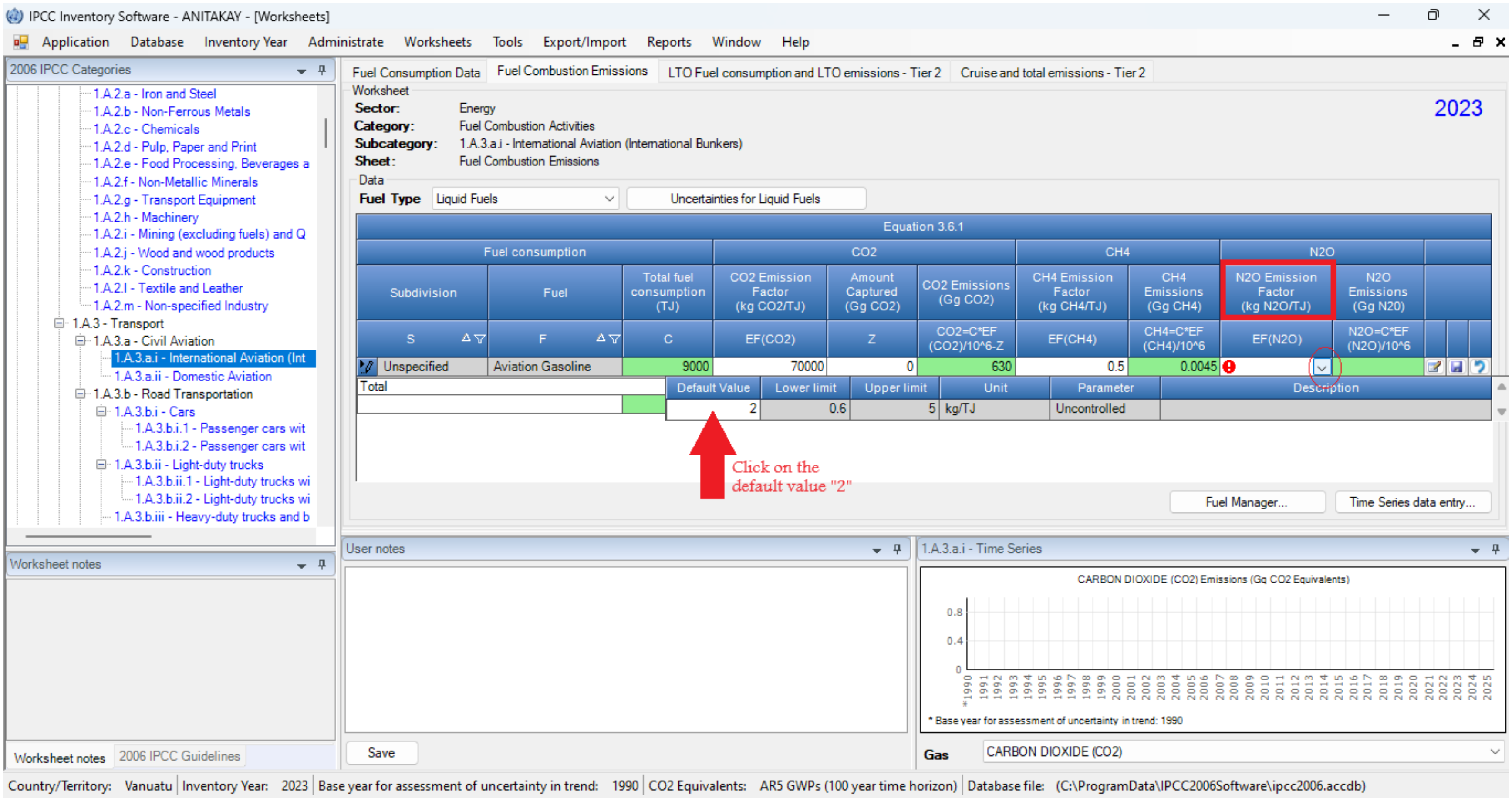
2.3 Under the tab "Amount Captured (Gg CO_2)" enter the value "0" (See illustration below).



2.4 Under the tab "CH_4 Emission Factor (kg CH_4/TJ)" click on the drop-down menu and select the default value "0.5" (See illustration below).

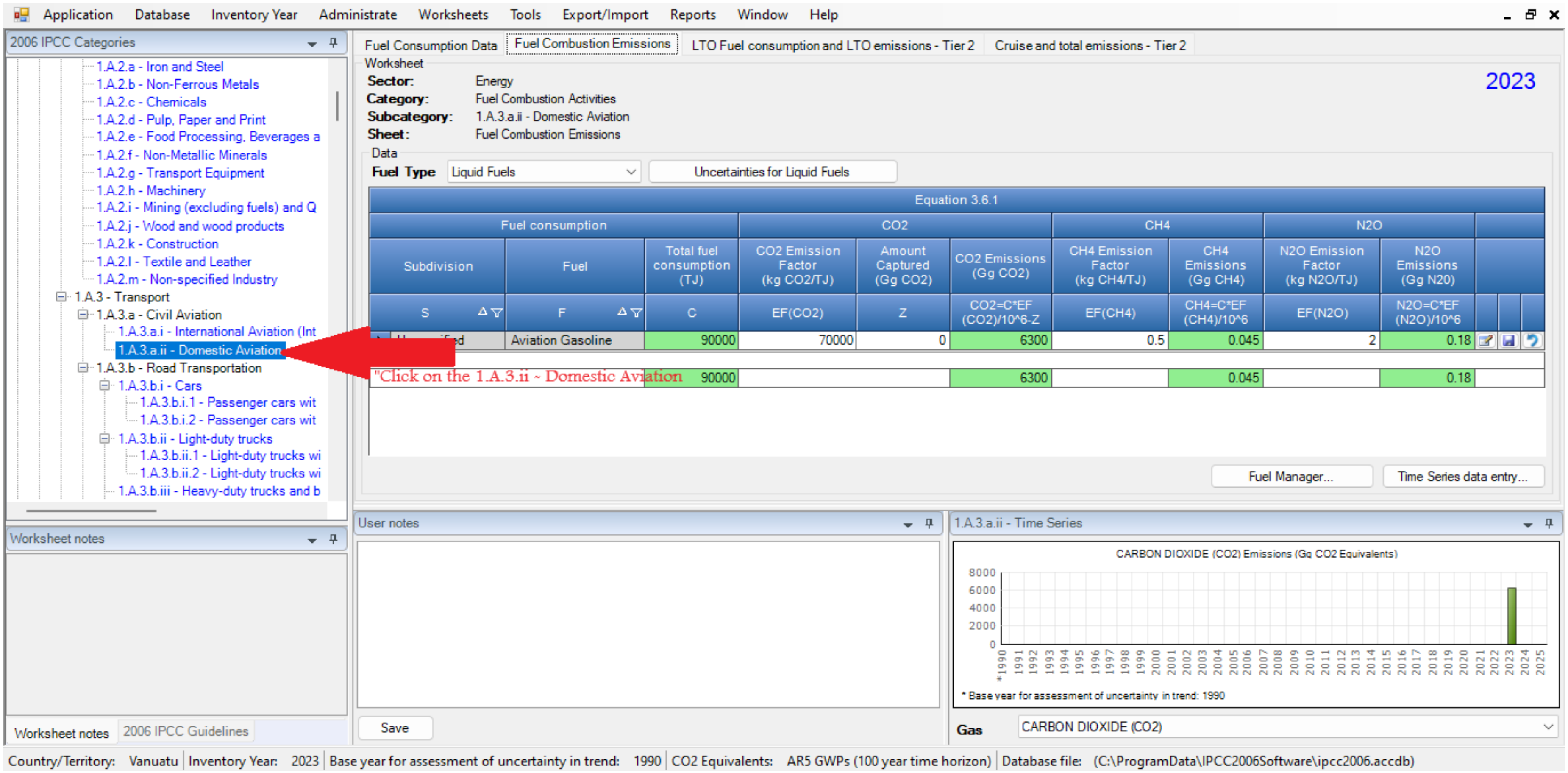


2.6 Click on the drop-down menu under the tab "N_2O Emission Factor (kg N_2O/TJ)" and select the default value "2" (See illustration below).



DOMESTIC AVIATION

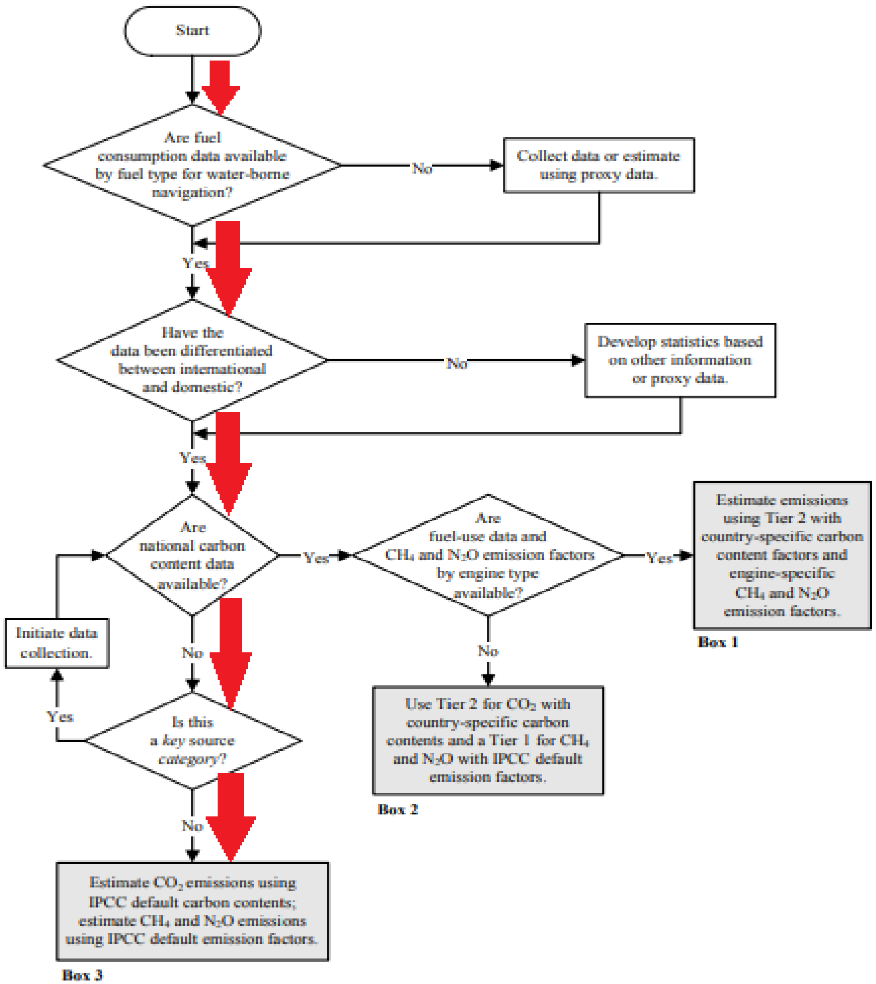
2.7 Under the “20006 IPCC Categories” tab select 1.A.3.a.ii – Domestic Aviation



2.7 Repeat steps 1.6 to 2.6

Figure 1: Displays the decision tree employed for selecting the method approach for actual CO2 from fuel combustion in Water-borne navigation emissions. The Decision implemented during this operation are indicated by the red arrows.

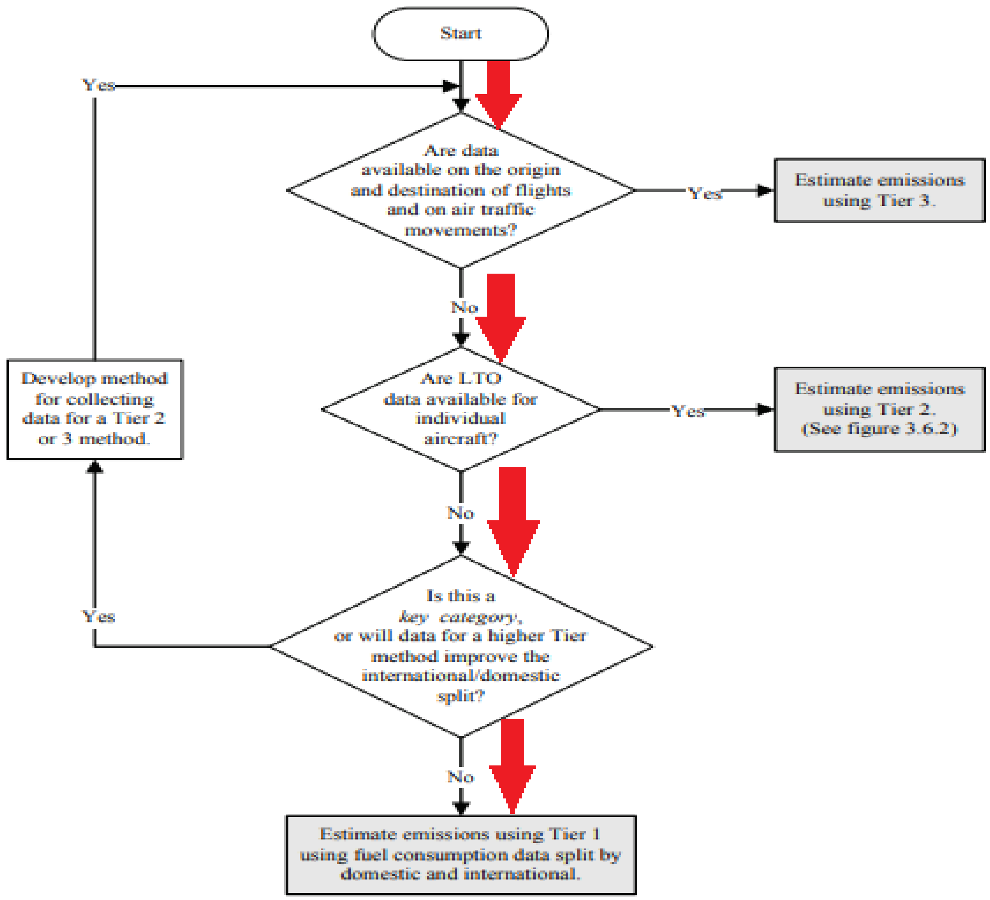
Figure 3.5.1 Decision tree for emissions from water-borne navigation



NOTE: Due to national Circumstances (Lack of resources) Vanuatu does not have yet reliable country-specific emission factors and parameters and therefore, is applying the default parameters and Tier 1 method to estimate Emissions.

Figure 2: Displays the decision tree employed for selecting the method approach for actual emissions (Applied to each greenhouse gas) from fuel combustion in aircraft emissions. The Decision implemented during this operation are indicated by the red arrows.

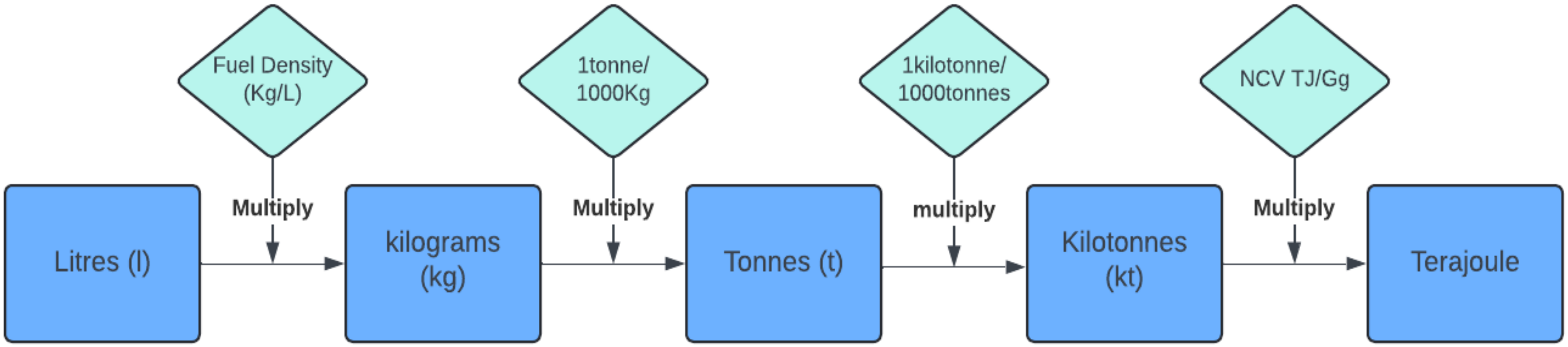
Figure 3.6.1 Decision tree for estimating aircraft emissions (applied to each greenhouse gas)



NOTE: Due to national Circumstances (Lack of resources) Vanuatu does not have yet reliable country-specific emission factors and parameters and therefore, is applying the default parameters and Tier 1 method to estimate Emissions.

STEPS FOR ESTIMATING TOTAL FUEL CONSUMED IN TERAJOULES

Figure 3.: The step-by-step conversion of liters to terajoules is shown below



Step 1 Convert Liters to Kilograms

TOTAL FUEL CONSUMED (Kg)
Total Fuel Consumed (L) X Fuel Density (Kg/L)

Step 2: Convert Kilograms to Tonnes

TOTAL FUEL CONSUMPTION (Tonnes)

Total Fuel Consumed (kg) X $\frac{1\ tonne}{1000\ Kg}$

Step 3: Convert Tonnes to Kilotonnes(kt)

TOTAL FUEL CONSUMED (KILOTONNES)

Total Fuel Consumed (tonnes) X $\frac{1\ Kilotonne}{1000\ tonnes}$

Step 4: Convert Kilotonnes (kt) to Terajoules

TOTAL FUEL CONSUMED (TERAJOULES)

Total Fuel Consumed (terajoules) X NCV (TJ/Gg)

WATER-BORNE NAVIGATION EQUATION

EQUATION 3.5.1

WATER-BORNE NAVIGATION EQUATION

$$\text{Emissions Fuel} = \sum(\text{Consumed}_{ab}\ \text{Emission Factor}_{ab})$$

Where:

Where: a = fuel type (diesel, gasoline, LPG, bunker, etc.) (See 2006 IPCC Guidelines, Vol. 2, Ch. 3, Pg. 47, Equation 3.5.1).

b = water-borne navigation type (i.e., ship or boat, and possibly engine type.) (Only at Tier 2 is the fuel used differentiated by type of vessel so b can be ignored at Tier 1) (See 2006 IPCC Guidelines, Vol. 2, Ch. 3, Pg. 47, Equation 3.5.1).

1.3.3 ROAD TRASNPORT TIMESERIES

Where:

NA = Not Applicable
NU= Needs Updating

Vanuatu's base year is 1994, even though introduction of the first vehicles was in the late 1950s. The most recent national inventory states that only ghg emissions from 2007 to 2017 were computed using the Tier 1 IPCC methodology, default IPCC assumptions, and default EF taken from reports. The Emission values require updating from 1994 – 2006 and 2018-2023[6].

[6] *Sources: See 2006 IPCC Guideline Vol 2 Chapter 3, Table 3.2.1 and Table 3.2.2 (Waldron, et al., 2006) and, The Republic of Vanuatu First Biennial Update Report, UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (MOCC, 2021).*

Table 9: Total CO2 emissions (gg) and emission factor for each fuel type from 1994 to 2023.

Item	Units	Fuel Type	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EF	(kg/TJ)	Motor Gasoline	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300	69300
		Gas/ Diesel Oil	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100	74100
		Liquefied Petroleum Gas	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100	63100
		Lubricants	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300	73300
Emission	Kg	NA	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	18.93	29.28	33.08	52.09	62.04	63.95	66.72	69.56	72.14	77.96	86.1	NU	NU	NU	NU	NU	NU
Method	NA	NA	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1

Table 10: Total CH4 emission (gg) and emission factor for each fuel type from 1994 to 2023.

Item	Units	Fuel Type	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EF	(kg/TJ)	Motor Gasoline -Unc	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
		Motor Gasoline –Oxid	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
		Motor Gasoline –Low	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
		Gas / Diesel Oil	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
		Liquified petroleum g	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Emissio	Kg	NA	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	0.001	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.004	NU	NU	NU	NU	NU	NU
Method	NA	NA	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1

Table 11: Total N2O emission (gg) and emission factor for each fuel type from 1994 to 2023.

Item	Units	Fuel Type	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
EF	(kg/TJ)	Motor Gasoline -Uncor	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33
		Motor Gasoline –Oxida	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
		Motor Gasoline –Low I	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
		Gas / Diesel Oil	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9
		Liquified petroleum gas	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
Emission	Kg	NA	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	NU	0.001	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.005	NU	NU	NU	NU	NU	NU
Method	NA	NA	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1	Tier 1

UNCERTAINTIES

Road Transportation

In the 2006 IPCC Guideline Volume 2, Chapter 3 states that CO_2, CH_4 and N_2O contribute to approximately 97, where 2-3 and 1% of CO_2-equivalent emissions from the road transportation sector. N_2O and CH_4 have a much higher uncertainty compared to CO_2, however, CO_2 dominates the emissions from road transportation. With the use of local data, uncertainty will be reduced with the bottom-up approach (Waldron, et al., Chapter 3 Mobile Combustion , 2006).

Emission Factor Uncertainty

The CO_2 uncertainty from the emission factor is less than 2% when national values are used. In Table 3.2.1, Vol 2 Chapter 3, the default CO_2 emission factor for road transportation have an uncertainty of 2%-5% due to uncertainty within the fuel composition. The use of fuel blends (involving adulterated or biofuels) can increase the uncertainty in the emission factors considering the uncertain in the composition of the blend.

The uncertainties for CH_4 and N_2O emission factors are relatively high (especially N_2O) and are expected to be a factor of 2-3. This depends on several factors:

- Uncertainties in fuel composition (including the possibility of fuel adulteration) and Sulphur content.
- Uncertainties in fleet age distribution and other characterization of the vehicle stock, including cross-border effects - the technical characteristics of vehicles from another country that take on fuel may be covered by technology models.
- Uncertainties in maintenance patterns of the vehicle stock.
- Uncertainties in combustion conditions (climate, altitude) and driving practices, such as speed, proportion of running distance to cold starts, or load factors (CH_4 and N_2O).
- Uncertainties in application rates of post-combustion emission control technologies (e.g. three-way catalyst).
- Uncertainties in the use of additives to minimize the aging effect of catalysts.
- Uncertainties in operating temperatures (N_2O); and,
- Uncertainties of test equipment and emission measurement equipment (Waldron, et al., Chapter 3 Mobile Combustion , 2006).

Estimation of uncertainty should be based on published literature from which emission factors are derived. At the very least, some of the types of uncertainties that are discussed in published literature and should be considered when developing national emission factors derived from empirical data are:

- A range in the emission factor of an individual vehicle, represented as a variance of measurements, due to variable emissions in different operating conditions (e.g. speed, temperature); and
- Uncertainty in the mean of emission factors of vehicles within the same vehicle class.

In addition, the sample size of vehicles measured may have been very small, or even a larger sample of measurements may not represent the national fleet. Test driving cycles cannot fully capture real driving behavior. At least in some emission factor studies, cold start emissions are now tested separately from running emissions. Countries may be able to make country-specific adjustments. However, these adjustments will necessitate more data collection with their own uncertainties.

Activity Data Uncertainties

The main source of uncertainty for the emission estimate is activity data. Activity data can be expressed in energy units (such as Tj) or in other units used for other purposes such as P/T-kilometer, Vehicle Stocks, Trip Length Distribution, Fuel Efficiency, etc. Potential sources of uncertainty (generally around +/-5%) include:

- Uncertainties in national energy surveys and data returns
- Misclassification of fuels
- Misclassification in vehicle stock
- Lack of completeness (fuel not recorded in other source categories may be used for transportation purposes)
- and
- Uncertainty in the conversion factor from one set of activity data to another (e.g. from fuel consumption
- data to person-/ton-kilometers, or vice versa, see above).

Reducing uncertainty can be achieved through the stratification of activity data, especially when they can be linked to outcomes obtained from a top-down fuel use approach.

When estimating CH_4 and N_2O emissions, it is necessary to utilize different tiers and corresponding sets of activity data. It is considered good practice to ensure that the top-down and bottom-up approaches align, and any deviations should be thoroughly documented and explained (refer to 2006 IPCC Guideline Vol 2 Chap 3 Section 3.2.1.4 Completeness). In the case of these gases, the uncertainty in emission factors will have a greater impact, while the uncertainty in activity data can be assumed to be like that of CO_2 (Waldron, et al., Chapter 3 Mobile Combustion , 2006).

Water-borne Navigation

Emission factors

CO_2 emission factors for fuels are typically well determined based on the carbon content of the fuel, according to expert judgment. For instance, the default uncertainty value for diesel fuel is approximately ± -1.5 percent, while for residual fuel oil it is ± -3 percent. However, when it comes to non-CO_2 emissions, the uncertainty is much higher. The uncertainty for the CH_4 emission factor can reach as high as 50 percent, and for the N_2O emission factor, it can range from about 40% below to about 140% above the default value.

Activity data

The uncertainty in estimating water-borne navigation emissions largely stems from the challenge of distinguishing between domestic and international fuel consumption. When complete survey data is available, the uncertainty may be low, around ± -5 percent. However, for estimations or incomplete surveys, the uncertainties can be significant, around ± -50 percent. It is important to note that the level of uncertainty will vary greatly from country to country and cannot be easily generalized. The use of global data sets may prove beneficial in this area, and it is anticipated that reporting will improve for this category in the future (Waldron, et al., Chapter 3 Mobile Combustion , 2006).

Civil Aviation

Emission factors

The carbon dioxide (CO_2) emission factors must fall within a range of ±5 percent, as they solely depend on the carbon content of the fuel and the fraction that undergoes oxidation. However, there is a significant level of uncertainty involved in calculating CO_2 emissions due to the uncertainties in the activity data discussed earlier. In Tier 1, the uncertainty in the methane (CH_4) emission factor can range from -57 to +100 percent. Similarly, the uncertainty in the nitrous oxide (N_2O) emission factor can range from -70 to +150 percent. Furthermore, the CH_4 and N_2O emission factors vary depending on the technology used, and using a single emission factor for aviation is a substantial simplification.

Activity Data

The accuracy of the data collected on domestic and international aviation will greatly impact the uncertainty in reporting. When complete survey data is available, the uncertainty can be minimal, less than 5 percent. However, estimates or incomplete surveys may lead to larger uncertainties, possibly doubling for the domestic sector. The uncertainty ranges mentioned are based on input from experts trying to estimate the 95 percent confidence interval around the central estimate. It is important to note that uncertainty levels will differ significantly from one country to another. The utilization of global data sets, along with radar support, could prove beneficial in enhancing reporting accuracy in this field, with expectations for improvements in the future.

Reference Approach

If the Reference Approach is the primary accounting method for the CO_2 from fuel combustion, then it is advisable to conduct an uncertainty analysis.

Activity Data

The total uncertainty in activity data consists of both systematic and random errors. Most developed countries compile balances of fuel supply, which helps in identifying systematic errors. In such cases, systematic errors are expected to be minimal. However, incomplete accounting may occur in areas where individuals and small producers extract fossil fuel (mainly coal) for personal use without it being included in the formal accounting system. Experts suggest that uncertainty due to errors in the activity data of countries with well-established statistical systems is likely around ±5% for a specific fuel. For countries with less developed energy data systems, this uncertainty could be significantly higher, possibly around ±10% for a specific fuel.

Carbon content and net calorific values

The uncertainty related to carbon content and net calorific values arises from the accuracy of measurement and the variability in the fuel supply source and sampling quality. As a result, errors are predominantly random. The uncertainty is primarily influenced by the variability in fuel composition. For traded fuels, the uncertainty is expected to be lower compared to non-traded fuels.

Oxidation factors

There are no standard uncertainty ranges for oxidation factors. Uncertainties related to oxidation factors can be determined by gathering data from major consumers regarding the efficiency of combustion in the specific equipment they utilize (Treanton, et al., CHAPTER 6 REFERENCE APPROACH, 2006).

1.3.4 QAULITY ASSURANCE AND QUALITY CONTROL (QA/QC)

Quality assurance and quality control (QA/QC), a thorough evaluation process, played a crucial role in enhancing transparency, consistency, comparability, completeness, and accuracy of the energy manual.

Comparison of emissions using alternative methods

To evaluate CO_2 emissions, the inventory compiler must compare estimates derived from both fuel statistics and vehicle kilometers traveled data. Any discrepancies in emission estimates should be investigated and clarified. The outcomes of these comparisons should be documented internally. Adjusting the following assumptions could help reconcile any disparities found between the methods:

- Use of off-road/non-transportation fuels
- Annual average vehicle mileage
- Vehicle fuel efficiency
- Breakdown of vehicles by type, technology, age, etc.
- Utilization of oxygenates, biofuels, or other additives
- Fuel consumption statistics
- Fuel sold or used

Review of emission factors

When default emission factors are utilized, the inventory compiler should confirm their applicability and relevance to the respective categories. Whenever feasible, these default factors should be compared against local data to further validate their suitability. For CH_4 and N_2O emissions, the inventory compiler must ensure that the local factors derived from original data sources are appropriate for the specific category. Additionally, accuracy checks on data acquisition and calculations should be conducted. If default factors were used for estimating N_2O emissions, the inventory compiler should ensure that the revised emission factors specified in Table 3.2.3, Chapter 3: Mobile Combustion of the 2006 IPCC Guidelines, were applied in calculations.

Activity data verification

The inventory compiler should scrutinize the sources of activity data to ensure their relevance and applicability to the category. Section 3.2.1.3, Chapter 3: Mobile Combustion of the 2006 IPCC Guidelines, outlines best practices for validating activity data. Where possible, the compiler should compare current data with historical activity data or model outputs to identify potential anomalies. Special attention should be given to ensuring the reliability of activity data pertaining to minor fuel distributions, off-road and on-road traffic, and illegal transportation of fuels into or out of the country. The compiler must also prevent double counting of agricultural and off-road vehicles.

External review

To evaluate the effectiveness of the quality control program, the inventory compiler should conduct an impartial external review of emission inventory calculations, assumptions, and documentation. This peer review should involve expert evaluators familiar with the specific source category and knowledgeable about inventory requirements. Given the significant uncertainties associated with default factors, particularly for CH_4 and N_2O emissions, the development of accurate emission factors is crucial.

1.4 IMPROVEMENT PLAN

1.4.1: VANUATU'S CURRENT INVENTORY PROCESS.

The energy sector is the predominant emitter of GHGs in Vanuatu. The Energy sector GHG emissions includes emissions from the fuel (fossil fuel or petroleum) combustion activity from Energy Industry (electricity generation), Manufacturing Indus tries and Construction, Transportation (Road and Domestic aviation and water borne navigation), and other sectors (Commercial, Institutional and residential); in the nutshell the energy sector emissions are mainly at tributed from the combustion of fossil fuel or petroleum.

Vanuatu is net importer of the petroleum product; hence the GHG emission calculation of overall emissions in this sector was relatively straightforward once the imported quantity of fossil fuel was known (activity data). The difficulty for Vanuatu has been in terms of the sectoral breakdown of emissions, given that there were no energy balances for the country available; further the sectoral fuel sales forthcoming from the fuel suppliers/retailers are not available. An attempt was made using some available data from stakeholders and proxy data to estimate the sectoral emissions.

The sectoral data was entered into IPCC Inventory Software (Version 2.54- June 2017) as per the requirement of standard IPCC sectoral model, the IPCC tool was customized for specific requirement of GHG emissions calculation for Vanuatu i.e. by using the default emission factors for energy conversion and IPCC AR5 GHG emission factors.

The result gives a sectoral breakdown of Vanuatu's energy sector CO2 emissions for the period 2007 to 2015. The IPCC inventory software calculates direct CO2 emissions and nonCO2 emissions (CH4 and N2O) for this sector; further other gases like SOx, NOx and NMVOC were negligible and outside the estimated accuracy of the main CO2, CH4 and N2O emissions[7].

[7] Vanuatu Third National Communication Report.pdf (unfccc.int)

Energy Sector Emissions (in Gg CO_2e): 2007 - 2015

Categories	Net CO2 Emissions, (CO2 Equivalents Gg)								
	2007	2008	2009	2010	2011	2012	2013	2014	2015
1 - Energy	60.42	92.31	95.10	119.66	127.53	114.87	121.54	128.55	129.55
1.A - Fuel Combustion Activities	60.42	92.31	95.10	119.66	127.53	114.87	121.54	128.55	129.55
1.A.1 - Energy In-dustries	27.73	42.05	39.47	38.02	38.81	35.88	31.68	35.74	32.19
1.A.2 - Manufactur-ing Indus-tries and Con-struction	9.85	16.26	16.21	23.67	20.91	8.96	17.40	17.92	19.94
1.A.3 - Transport	18.93	29.28	33.08	52.09	62.04	63.95	66.72	69.56	72.14
1.A.4 - Other Sec-tors	3.92	4.72	6.34	5.88	5.77	6.08	5.74	5.33	5.28
1.B - Fugitive emis-sions from fuels	NO (Not-Occurring)								
1.C - Carbon dioxide Transport and Storage	NO (Not-Occurring)								
Total GHG Emissions, excl. Removals	517.41	556.06	435.65	566.82	587.79	581.13	545.30	604.26	610.20
% Share of Energy Sec-tor in Total GHG emis-sions	12%	17%	22%	21%	22%	20%	22%	21%	21%

1.4.2: AREAS IDENTIFIED FOR IMPROVEMENT AND IDENTIFIED GAPS

The national energy balance of Vanuatu needs to be updated on a regular basis in order for reporting to be precise and consistent when calculating GHG emissions. In Vanuatu, key uncertainties are associated with data availability, missing data, lack of comprehensive in formation, data archiving and lack of country specific emission factors. It is recognized that having country specific emission factors and more detailed activity data will help reduce uncertainty in future inventory. For example, in the energy sector there is good data available on fuel imports into the country but there is lack of information on end usage (Ministry of Climate Change, 2020).

1.4.3: PROPOSED IMPROVEMENT ACTIONS

There are few improvement actions that needs to be done in the energy sector to ensure reporting is accurate.

The following needs to be address:

- create/update National Energy Balance for Vanuatu
- Biomass and Biofuel Consumption: The Biomass and Biofuel (coconut oil) consumption data collection and QA/QC procedure will be implemented to include these fuels in the future inventory reports.
- Well established database.
- Improve archiving of data
- Energy sector needs country specific emission factor.

Addressing these points above will contribute in accurate calculation of GHG emissions and also provide clear reporting relating to the country's inventory.

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ANNEX

Table 2.2.1.1: Tier 1 method default CO_2 emission factor and uncertainty ranges

Fuel Type	Default (kg/TJ)	Lower	Upper
Motor Gasoline	69 300	67 500	73 000
Gas/ Diesel Oil	74 100	72 600	74 800
Liquefied Petroleum Gases	63 100	61 600	65 600
Kerosene	71 900	70 800	73 700
Lubricants [b]	73 300	71 900	75 200
Compressed Natural Gas	56 100	54 300	58 300
Liquefied Natural Gas	56 100	54 300	58 300

Source: Table 1.4 in the Introduction chapter of the Energy Volume.

Notes:
[a] Values represent 100 percent oxidation of fuel carbon content.
[b] See Box 3.2.4 Lubricants in Mobile Combustion for guidance for uses of lubricants.

Table 2.2.1.2: Tier 1 method default CH_4 and N_2O emission factor and uncertainty ranges

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

Sources: USEPA (2004b), EEA (2005a), TNO (2003) and Borsari (2005) CETESB (2004 & 2005) with assumptions given below. Uncertainty ranges were derived from data in Lipman and Delucchi (2002), except for ethanol in cars.

(a) Except for LPG and ethanol cars, default values are derived from the sources indicated using the NCV values reported in the Energy Volume Introduction chapter; density values reported by the U.S. Energy Information Administration; and the following assumed representative fuel consumption values: 10 km/l for motor gasoline vehicles; 5 km/l for diesel vehicles; 9 km/l for natural gas vehicles (assumed equivalent to gasoline vehicles); 9 km/l for ethanol vehicles. If actual representative fuel economy values are available, it is recommended that they be used with total fuel use data to estimate total distance travelled data, which should then be multiplied by Tier 2 emission factors for N_2O and CH_4.

(b) Motor gasoline uncontrolled default value is based on USEPA (2004b) value for a USA light duty gasoline vehicle (car) – uncontrolled, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(c) Motor gasoline – light duty vehicle oxidation catalyst default value is based on the USEPA (2004b) value for a USA Light Duty Gasoline Vehicle (Car) – Oxidation Catalyst, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(d) Motor gasoline – light duty vehicle vintage 1995 or later default value is based on the USEPA (2004b) value for a USA Light Duty Gasoline Vehicle (Car) – Tier 1, converted using values and assumptions described in table note (a). If motorcycles account for a significant share of the national vehicle population, inventory compilers should adjust the given default emission factor downwards.

(e) Diesel default value is based on the EEA (2005a) value for a European heavy duty diesel truck, converted using values and assumptions described in table note (a).

(f) Natural gas default and lower values were based on a study by TNO (2003), conducted using European vehicles and test cycles in the Netherlands. There is a lot of uncertainties for N_2O. The USEPA (2004b) has a default value of 350 kg CH_4/TJ and 28 kg N_2O/TJ for a USA CNG car, converted using values and assumptions described in table note (a). Upper and lower limits are also taken from USEPA (2004b)

(g) The default value for methane emissions from LPG, considering for 50 MJ/kg low heating value and 3.1 g CH_4/kg LPG was obtained from TNO (2003). Uncertainty ranges have not been provided.

(h) Ethanol default value is based on the USEPA (2004b) value for a USA ethanol heavy duty truck, converted using values and assumptions described in table note (a).

(i) Data obtained in Brazilian vehicles by Borsari (2005) and CETESB (2004 & 2005). For new 2003 models, best case: 51.3 kg THC/TJ fuel and 26.0 percent CH_4 in THC. For 5 years old vehicles: 67 kg THC/TJ fuel and 27.2 percent CH_4 in THC. For 10 years old: 308 kg THC/TJ fuel and 27.2 percent CH_4 in THC.

Table 2.2.1.3: Reference Approach default carbon content value for each fuel type

Fuel type English description	Default carbon content [1] (kg/GJ)	Lower	Upper
Crude Oil	20.0	19.4	20.6
Orimulsion	21.0	18.9	23.3
Natural Gas Liquids	17.5	15.9	19.2
Motor Gasoline	18.9	18.4	19.9
Aviation Gasoline	19.1	18.4	19.9
Jet Gasoline	19.1	18.4	19.9
Jet Kerosene	19.5	19	20.3
Other Kerosene	19.6	19.3	20.1
Shale Oil	20.0	18.5	21.6
Gas/Diesel Oil	20.2	19.8	20.4
Residual Fuel Oil	21.1	20.6	21.5
Liquefied Petroleum Gases	17.2	16.8	17.9
Ethane	16.8	15.4	18.7
Naphtha	20.0	18.9	20.8
Bitumen	22.0	19.9	24.5
Lubricants	20.0	19.6	20.5
Petroleum Coke	26.6	22.6	31.3
Refinery Feedstocks	20.0	18.8	20.9
Refinery Gas [2]	15.7	13.3	19.0
Paraffin Waxes	20.0	19.7	20.3
White Spirit & SBP	20.0	19.7	20.3

Other Petroleum Products	20.0	19.7	20.3
Anthracite	26.8	25.8	27.5
Coking Coal	25.8	23.8	27.6
Other Bituminous Coal	25.8	24.4	27.2
Sub-Bituminous Coal	26.2	25.3	27.3
Lignite	27.6	24.8	31.3
Oil Shale and Tar Sands	29.1	24.6	34
Brown Coal Briquettes	26.6	23.8	29.6
Patent Fuel	26.6	23.8	29.6
Coke Oven Coke and Lignite Coke	29.2	26.1	32.4
Gas Coke	29.2	26.1	32.4
Coal Tar [3]	22.0	18.6	26.0
Gas Works Gas [4]	12.1	10.3	15.0
Coke Oven Gas [5]	12.1	10.3	15.0
Blast Furnace Gas [6]	70.8	59.7	84.0
Oxygen Steel Furnace Gas [7]	49.6	39.5	55.0
Natural Gas	15.3	14.8	15.9

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

Notes:

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

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

[3] EFDB; uncertainty range: expert judgement

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

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

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

[8] Solid Biomass; uncertainty range: expert judgement

[9] Lubricants ; uncertainty range: expert judgement

[10] EFDB; uncertainty range: expert judgement

[11] Japanese data; uncertainty range: expert judgement

[12] Solid Biomass; uncertainty range: expert judgement

[13] EFDB; uncertainty range: expert judgement

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

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

[16] Liquid Biomass; uncertainty range: expert judgement

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

[20] Solid Biomass; uncertainty range: expert judgement

Table 2.2.1.4: Reference Approach default calorific value for each fuel type

Fuel type English description		Net calorific value (TJ/Gg)	Lower	Upper
Crude Oil		42.3	40.1	44.8
Orimulsion		27.5	27.5	28.3
Natural Gas Liquids		44.2	40.9	46.9
Gasoline	Motor Gasoline	44.3	42.5	44.8
	Aviation Gasoline	44.3	42.5	44.8
	Jet Gasoline	44.3	42.5	44.8
Jet Kerosene		44.1	42.0	45.0
Other Kerosene		43.8	42.4	45.2
Shale Oil		38.1	32.1	45.2
Gas/Diesel Oil		43.0	41.4	43.3
Residual Fuel Oil		40.4	39.8	41.7
Liquefied Petroleum Gases		47.3	44.8	52.2
Ethane		46.4	44.9	48.8
Naphtha		44.5	41.8	46.5
Bitumen		40.2	33.5	41.2
Lubricants		40.2	33.5	42.3
Petroleum Coke		32.5	29.7	41.9
Refinery Feedstocks		43.0	36.3	46.4
Other Oil	Refinery Gas [2]	49.5	47.5	50.6
	Paraffin Waxes	40.2	33.7	48.2
	White Spirit and SBP	40.2	33.7	48.2
	Other Petroleum Products	40.2	33.7	48.2

Anthracite		26.7	21.6	32.2
Coking Coal		28.2	24.0	31.0
Other Bituminous Coal		25.8	19.9	30.5
Sub-Bituminous Coal		18.9	11.5	26.0
Lignite		11.9	5.50	21.6
Oil Shale and Tar Sands		8.9	7.1	11.1
Brown Coal Briquettes		20.7	15.1	32.0
Patent Fuel		20.7	15.1	32.0
Coke	Coke Oven Coke and Lignite Coke	28.2	25.1	30.2
	Gas Coke	28.2	25.1	30.2
Coal Tar [3]		28.0	14.1	55.0
Derived Gases	Gas Works Gas [4]	38.7	19.6	77.0
	Coke Oven Gas [5]	38.7	19.6	77.0
	Blast Furnace Gas [6]	2.47	1.20	5.00
	Oxygen Steel Furnace Gas [7]	7.06	3.80	15.0
Natural Gas		48.0	46.5	50.4
Municipal Wastes (non-biomass fraction)		10	7	18
Industrial Wastes		NA	NA	NA
Waste Oil [8]		40.2	20.3	80.0
Peat		9.76	7.80	12.5

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

Notes:

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

[2] Japanese data; uncertainty range: expert judgement

[3] EFDB; uncertainty range: expert judgement

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

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

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

[9] EFDB; uncertainty range: expert judgement

[10] Japanese data ; uncertainty range: expert judgement

[11] Solid Biomass; uncertainty range: expert judgement

[12] EFDB; uncertainty range: expert judgement

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

[15] Liquid Biomass; uncertainty range: expert judgement

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

Table 2.2.1.5: Reference Approach default Carbon Oxidation Factor for each fuel type

Fuel type English description		Default carbon content (kg/GJ)	Default carbon oxidation factor	Effective CO_2 emission factor (kg/TJ) [2]		
				Default value [3]	95% confidence interval	
		A	B	C=A*B*44/ 12*1000	Lower	Upper
Crude Oil		20.0	1	73 300	71 100	75 500
Orimulsion		21.0	1	77 000	69 300	85 400
Natural Gas Liquids		17.5	1	64 200	58 300	70 400
Gasoline	Motor Gasoline	18.9	1	69 300	67 500	73 000
	Aviation Gasoline	19.1	1	70 000	67 500	73 000
	Jet Gasoline	19.1	1	70 000	67 500	73 000
Jet Kerosene		19.5	1	71 500	69 700	74 400
Other Kerosene		19.6	1	71 900	70 800	73 700
Shale Oil		20.0	1	73 300	67 800	79 200
Gas/Diesel Oil		20.2	1	74 100	72 600	74 800
Residual Fuel Oil		21.1	1	77 400	75 500	78 800
Liquefied Petroleum Gases		17.2	1	63 100	61 600	65 600
Ethane		16.8	1	61 600	56 500	68 600
Naphtha		20.0	1	73 300	69 300	76 300
Bitumen		22.0	1	80 700	73 000	89 900
Lubricants		20.0	1	73 300	71 900	75 200
Petroleum Coke		26.6	1	97 500	82 900	115 000
Refinery Feedstocks		20.0	1	73 300	68 900	76 600

Other Oil	Refinery Gas	15.7	1	57 600	48 200	69 000
	Paraffin Waxes	20.0	1	73 300	72 200	74 400
	White Spirit & SBP	20.0	1	73 300	72 200	74 400
Other Petroleum Products		20.0	1	73 300	72 200	74 400
Anthracite		26.8	1	98 300	94 600	101 000
Coking Coal		25.8	1	94 600	87 300	101 000
Other Bituminous Coal		25.8	1	94 600	89 500	99 700
Sub-Bituminous Coal		26.2	1	96 100	92 800	100 000
Lignite		27.6	1	101 000	90 900	115 000
Oil Shale and Tar Sands		29.1	1	107 000	90 200	125 000
Brown Coal Briquettes		26.6	1	97 500	87 300	109 000
Patent Fuel		26.6	1	97 500	87 300	109 000
Coke	Coke oven coke and lignite Coke	29.2	1	107 000	95 700	119 000
	Gas Coke	29.2	1	107 000	95 700	119 000
Coal Tar		22.0	1	80 700	68 200	95 300
Derived Gases	Gas Works Gas	12.1	1	44 400	37 300	54 100
	Coke Oven Gas	12.1	1	44 400	37 300	54 100
	Blast Furnace Gas [4]	70.8	1	260 000	219 000	308 000
	Oxygen Steel Furnace Gas [5]	49.6	1	182 000	145 000	202 000

Cont...

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

Notes:

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

[2] TJ = 1000GJ

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

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

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

Table 2.2.1.6a: Default CO_2 emission factor for Domestic Aviation

Fuel	Default (kg/TJ)	Lower	Upper
Aviation Gasoline	70 000	67 500	73 000
Jet Kerosene	71 500	69 800	74 400

Table 2.2.1.6b: Default N_2O and CH_4 emission factor for Domestic Aviation

Fuel	CH_4 Default (Uncontrolled) Factors (in kg/TJ)	N_2O Default (Uncontrolled) Factors (in kg/TJ)	NOx Default (Uncontrolled) Factors (in kg/TJ)
All fuels	0.5[a] (-57%/+100%) [b]	2 (-70%/+150%) [b]	250 +25% [c]

[a] in the cruise mode CH4 emissions is assumed to be negligible (Wiesen et al., 1994). For LTO cycles only

(i.e., below an altitude of 914 meters (3000 ft.)) the emission factor is 5 kg/TJ (10% of total VOC factor)

(Olivier, 1991). Since globally about 10% of the total fuel is consumed in LTO cycles (Olivier, 1995), the

resulting fleet averaged factor is 0.5 kg/TJ.

[b] IPCC, 1999.

[c] Expert
Judgement.

Emission factors for other gases (CO and NMVOC) and sulphur content which were included in the 1996

IPCC Guidelines can be found in the
EFDB.

Table 2.2.1.7a: Default CO_2 emission factor for Domestic Waterborne Navigation

		kg/TJ		
Fuel		**Default**	**Lower**	**Upper**
Gasoline		69 300	67 500	73 000
Other Kerosene		71 900	70 800	73 600
Gas/Diesel Oil		74 100	72 600	74 800
Residual Fuel Oil		77 400	75 500	78 800
Liquefied Petroleum Gases		63 100	61 600	65 600
Other Oil	Refinery Gas	57 600	48 200	69 000
Other Oil	Paraffin Waxes	73 300	72 200	74 400
Other Oil	White Spirit & SBP	73 300	72 200	74 400
Other Oil	Other Petroleum Products	73 300	72 200	74 400
Natural Gas		56 100	54 300	58 300

Table 2.2.1.7a: Default N_2O and CH_4 emission factor for Domestic Waterborne Navigation

	CH_4 (kg/TJ)	N_2O (kg/TJ)
Ocean-going Ships *	7 ± 50%	2 +140% -40%
*Default values derived for diesel engines using heavy fuel oil. Source: Lloyd's Register (1995) and EC (2002)		