1.2 MODULE OVERVIEW

This User's Guide accompanies and explains the CO_2FFC module of the SIT. The SIT was developed in conjunction with EPA's Emissions Inventory Improvement Program (EIIP). Prior to the development of the SIT, EPA developed the States Workbook for estimating greenhouse gas emissions. In 1998, EPA revisited the States Workbook and expanded it to follow the format of EIIP guidance documents for criteria air pollutants. The result was a comprehensive, stepwise approach to estimating greenhouse gas emissions at the state level. This detailed methodology was appreciated by states with the capacity to devote considerable time and resources to the development of emission inventories. For other states, the EIIP guidance was overwhelming and impractical for them to follow from scratch. EPA recognized the resource constraints facing the states and developed the SIT. The ten modules of the SIT corresponded to the EIIP chapters and attempted to automate the steps states would need to take in developing their own emission estimates in a manner that was consistent with prevailing national and state guidelines.

Because most state inventories developed today rely heavily on the tools, User's Guides have been developed for each of the SIT modules. These User's Guides contain the most up-to-date methodologies that are, for the most part, consistent with the Inventory of U.S. Greenhouse Gas Emissions and Sinks. Volume VIII of the EIIP guidance is a historical document that was last updated in August 2004, and while these documents can be a valuable reference, they contain outdated emissions factors and in some cases outdated methodologies. States can refer to Volume VIII of the EIIP guidance documents if they are interested in obtaining additional information not found in the SIT or the companion User's Guide.

The CO_2FFC module calculates carbon dioxide (CO_2) emissions from the fuel types shown in Table 1 by end-use sector. While the module provides default data for fuel types (depending on availability), users are encouraged to use state-specific data, where available. If using outside data sources, or for a more thorough understanding of the tool, please refer to the following discussion for data requirements and methodology.

1.2.1 Data Requirements

To calculate CO_2 emissions from fossil fuel combustion,[1] the following data are required:

- Fossil fuel energy and non-energy consumption by fuel type and sector (non-energy consumption applies only to the industrial sector);
- Carbon content coefficients;
- Carbon stored in products; and
- Percentage of carbon oxidized during combustion.

[1] For this discussion, CO_2 emissions from fossil fuel combustion include all of the carbon in fuels that is either immediately oxidized or oxidized within a short time period (i.e., less than 20 years). It thus includes carbon in the form of gases, like carbon monoxide. It also includes short-lived products that will be burned after use or decompose quickly.

Because the carbon content of fossil fuels varies by fuel type, it is necessary to compile consumption data for each type of fuel (the recommended list of fuels is provided in Table 1).

Energy consumption statistics should be collected on an energy basis—preferably in British thermal units (Btu). Statistics providing energy consumption data in other units, such as barrels or tons, may be used, but require conversion to Btu by using the heat content of the specific fuel. If the conversion to energy units is necessary, the heat contents that were used should be documented (default heat contents are provided in the CO_2FFC module). Please note that even data given in Btu may be preceded by a prefix indicating order of magnitude (i.e. thousand, million, billion). For a better understanding of the quantity prefixes used with Btu, refer to Box 1.

Box 1: Energy Units

A British thermal unit (Btu) is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at or near 39.2° Fahrenheit.

Btu	British thermal unit	1 Btu
MBtu	Thousand Btu	$1x10^3$ Btu
MMBtu	Million Btu	$1x10^6$ Btu
BBtu	Billion Btu	$1x10^9$ Btu
TBtu	Trillion Btu	$1x10^{12}$ Btu
QBtu	Quadrillion Btu	$1x10^{15}$ Btu

Box 2: Caution When Using Non-Default Fuel Consumption Data

If you decide to use fuel consumption data that is different from the default, please be aware of the following possible data problems:

In some cases (e.g., the default EIA's State Energy Consumption, Price, and Expenditure Estimates (EIA/SEDS) data) fuel consumption statistics can include data that is at odds with the methodology used in the CO_2FFC module. For example, SEDS motor gasoline consumption includes ethanol that is blended into gasoline. Ethanol is not a fossil fuel, and thus the default data in the CO_2FFC module has been adjusted to remove the portion of blended gasoline known to be ethanol. If you use external data sources, be sure to determine whether ethanol or other biofuels (e.g., biodiesel) are included in total consumption for any particular fuel type. If so, you must subtract the biofuel portion before entering the data into the CO_2FFC module. State ethanol data can be obtained from FHWA (2019) the Federal Highway Administration's annual Highway Statistics report and are taken into account with default data provided in the CO_2FFC module.

Users should also be aware of double counting. For example, EIA's SEDS data for industrial coal consumption includes coal used to make synthetic natural gas, which is accounted for in both industrial coal and natural gas consumption data. This double-counting issue has been corrected for in the default dataset contained in the CO_2FFC module; similar adjustments may need to be made to outside data sources. State-specific natural gas data can be obtained from Table 12 of EIA's Historical Natural Gas Annual EIA (EIA 2001) and Table 8 of EIA's Natural Gas Annual EIA (EIA 2019) (and is also provided in the CO_2FFC module).

Table 1. Fuel Types Consumed by Sector

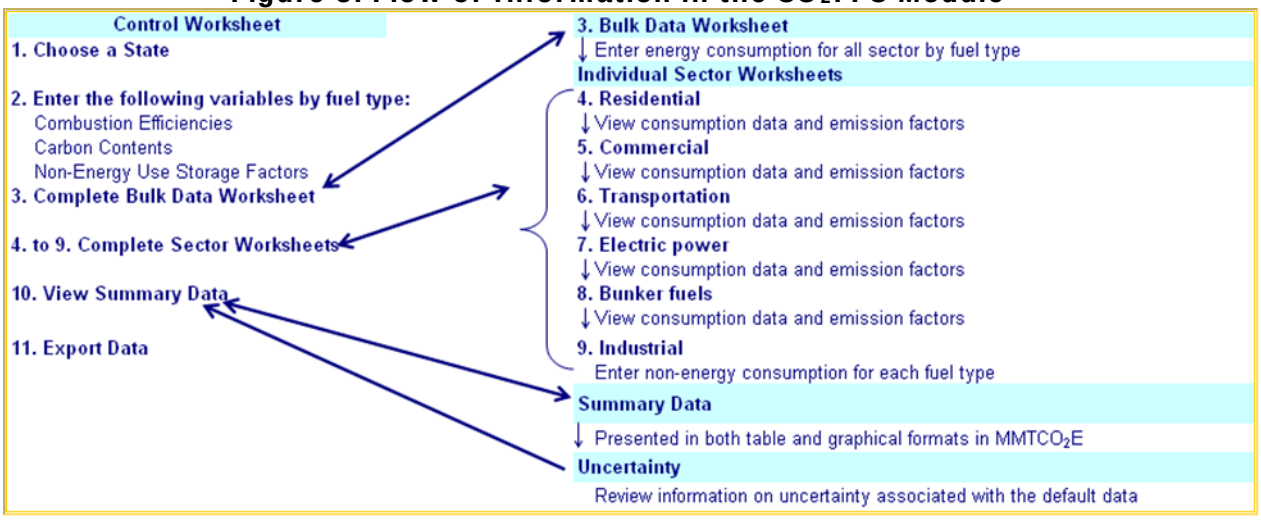
Residential	Commercial	Industrial	Transportation	Electric Utilities	International Bunker Fuels
Coal	**Coal**	**Coking Coal** **Other Coal**	**Coal**	**Coal**	
Natural Gas	**Natural Gas**	**Natural Gas**	**Natural Gas**	**Natural Gas**	
Petroleum: Distillate Fuel Kerosene Hydrocarbon Gas Liquids Motor Gasoline Residual Fuel	**Petroleum:** Distillate Fuel Kerosene Hydrocarbon Gas Liquids Motor Gasoline Residual Fuel	**Petroleum:** Distillate Fuel Kerosene LPG Motor Gasoline Residual Fuel Lubricants Asphalt/Road Oil Crude Oil Feedstocks Misc. Petroleum Products Petroleum Coke Pentanes Plus Still Gas Special Naphthas Unfinished Oils Waxes Aviation Gasoline Blending Components Motor Gasoline Blending Components	**Petroleum:** Distillate Fuel Hydrocarbon Gas Liquids Motor Gasoline Residual Fuel Lubricants Aviation Gasoline Jet Fuel, Kerosene Jet Fuel, Naphtha	**Petroleum:** Distillate Fuel Residual Fuel Petroleum Coke	**Petroleum:** Jet Fuel, Kerosene Distillate Fuel Residual Fuel
Other (e.g. geothermal)	**Other (e.g. geothermal)**	**Other (e.g. geothermal)**	**Other (e.g. geothermal)**	**Other (e.g. geothermal)**	

Source: U.S. EPA 2020.

1.2.2 Tool Layout

Because there are multiple steps to complete within the CO_2FFC module, it is important to have an understanding of the module's overall design. The layout of the CO_2FFC module and the purpose of its worksheets are presented in Figure 3.

Figure 3. Flow of Information in the CO_2FFC Module*



* These worksheets are the primary worksheets used in the CO_2FFC module; subsequent worksheets are used to populate the default data and are provided for informational purposes only.

1.3 METHODOLOGY

This section provides a guide to using the CO_2FFC module of the SIT to estimate CO_2 emissions from sectors that consume fossil fuels. Within the CO_2FFC module, these sectors are residential, commercial, industrial, transportation, electric power, and bunker fuels. Because the methodology is similar in all sectors, a general methodology is discussed and specific examples for each sector are provided.

Box 3: State Energy Data Sources

In-state sources, such as state energy commissions or public utility commissions, should be consulted first. Otherwise, default data provided by the CO_2FFC module may be used. Fossil fuel statistics should be provided on an energy basis (e.g., in Btu).

The CO_2FFC module automatically calculates emissions after you enter energy consumption data (and the factors on the control worksheet). The tool provides default energy consumption data, which comes from the EIA's State Energy Consumption, Price, and Expenditure Estimates (SEDS) EIA (2020).[2] However, other state-specific data may be used if available (see Box 3 for suggestions on where to find data).

The CO_2FFC module follows the general methodology outlined in the EIIP guidance, however because of the automation of the calculations within the tool, the order of steps discussed in this User's Guide do not follow the order of steps discussed within the EIIP guidance document. This User's Guide provides an overview of the estimation methodology used in

[2] These data are available at https://www.eia.gov/state/seds/.

the CO_2FFC module by walking through the following eleven steps: (1) select a state; (2) fill in the variables used throughout the module; (3) complete the bulk data energy consumption worksheet; (4) complete the residential sector worksheet; (5) complete the commercial sector worksheet; (6) complete the transportation sector worksheet; (7) complete the electric power sector worksheet; (8) complete the bunker fuels sector worksheet; (9) complete the industrial sector worksheet; (10) review summary information; and (11) export data.

The general equation used to calculate CO_2 emissions from fossil fuel combustion is shown in Equation 1. The equation used for fuels in the industrial end-use sector is similar, but includes the non-energy use of fuels, as shown in Equation 2.

Equation 1. General Emission Equation

Emissions ($MMTCO_2E$) =
Consumption (BBtu) × Emission Factor (lbs C/BBtu) × 0.0005 short ton/lbs × Combustion Efficiency (% as a decimal) × 0.9072 (Ratio of Short Tons to Metric Tons) ÷ 1,000,000 × (44/12) (to yield $MMTCO_2E$)

Equation 2. Emission Equation for the Industrial Sector*

Emissions ($MMTCO_2E$) =
(Total Consumption (BBtu) – [Non-Energy Consumption (BBtu) × Storage Factor (%)] × Emission Factor (lbs C/BBtu) × Combustion Efficiency (% as a decimal)) × 0.9072 (Ratio of Short Tons to Metric Tons) ÷ 1,000,000 × (44/12) (to yield $MMTCO_2E$)

* This equation also applies to lubricants consumed in the transportation end-use sector.

Box 4: Treatment of Biofuels in the SIT

The CO_2 from Fossil Fuel Combustion (CO_2FFC) module relies on EIA's SEDS database for state-level energy consumption data. The SEDS data provides consumption estimates at the state level for ethanol blended into gasoline. Ethanol is not a fossil fuel, and thus the default data in the CO_2FFC module has been adjusted to remove the portion of blended gasoline known to be ethanol.

Ideally, biodiesel blended into diesel fuel and other biofuels blended into heating fuels, etc. should be treated in the same way to avoid counting emissions from non-fossil fuels. However, due to the lack of state-level data on biofuel consumption, it is not feasible to adjust the default consumption data in the CO_2FFC module to account for these biofuels at this time. The user should note that this may lead to some overestimation of emissions from fuel consumption by not considering all blended biofuels. EPA is continuously monitoring data availability and methodologies that will allow for biofuel adjustments in future versions of the CO_2FFC module.

Users are encouraged to adjust the default data and/or enter their own data for diesel and heating oil consumption if available, especially if the user has access to biodiesel and/or biofuel consumption within their state. Users should refer to the CO_2FFC User's Guide for more guidance on entering non-default fuel consumption data.

Users are also encouraged to refer to EIA's documentation for SEDS energy consumption data for more information regarding the fuels included in the CO_2FFC module.

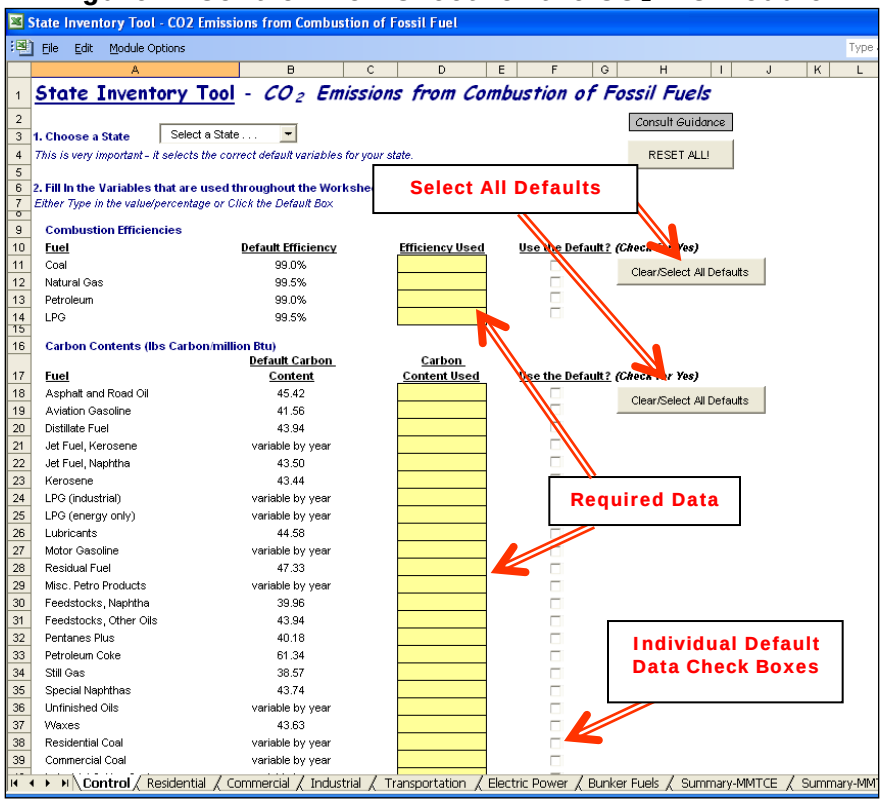
Step (1) Select a State

To begin, select the state you are interested in evaluating. By selecting a state, the rest of the tool will automatically reset to reflect the appropriate state default data and assumptions for use in subsequent steps of the tool.

Step (2) Fill in the Variables Used Throughout the Module

Step 2 requires users to select appropriate factors for several key variables necessary for estimating CO_2 emissions from fossil fuel combustion. This can be done by selecting the default data provided or entering user-specified, fuel-specific data for combustion efficiencies, carbon contents, and non-energy use storage factors that will be used throughout the tool. To select the default data, select the "Clear/Select All Defaults" button for each group of variables (combustion efficiency, carbon content, and non-energy use storage factors) or check the default box directly to the right of individual yellow input cells. Note that users may select a default value and later override it if better data becomes available. To enter state-specific data from other sources, enter values directly into the yellow input cells. If the user-specific inputs do not match the default data in the control worksheet (i.e., the default value is overwritten), the text will appear red. See Figure 4 for locations of the "Clear/Select All Defaults" buttons, individual default check boxes, and yellow input cells. Information for combustion efficiencies, carbon contents, and non-energy use storage factors are discussed individually below.

Figure 4. Control Worksheet for the CO_2FFC Module



compared to coal, and natural gas has about 57 percent. However, carbon contents also vary within the major fuel types, as noted below:

- Carbon emissions per ton of coal vary considerably depending on the coal's composition of carbon, hydrogen, sulfur, ash, oxygen, and nitrogen. While variability of carbon emissions on a mass basis can be considerable, carbon emissions per unit of energy (e.g., per Btu) vary less.

- The carbon/energy ratio of different petroleum fractions generally correlates with API (American Petroleum Institute) gravity (Marland and Rotty 1984).[3] Lighter fractions (e.g., gasoline) usually have less carbon per unit energy than heavier fractions (e.g., residual fuel oil).

- Natural gas is a mixture of several gases, and the carbon content depends on the relative proportions of methane, ethane, propane, other hydrocarbons, CO_2, and other gases, which vary from one gas production site to another.

Non-Energy Use Storage Factors

The third and final type of data requested in the control worksheet is the percent of carbon in each fuel that is stored from non-energy uses. Many fossil fuels have potential non-energy uses. For example, LPG is used for production of solvents and synthetic rubber; oil is used to produce asphalt, naphthas, and lubricants; and coal is used to produce coke, yielding crude light oil and crude tar as by-products that are used in the chemical industry.

However, not all non-energy uses of fossil fuels result in carbon storage. For example, the carbon from natural gas used in ammonia production is oxidized quickly; many products from the chemical and refining industries are burned or decompose within a few years; and the carbon in coke is oxidized when the coke is used. The CO_2FFC module provides national default values for storage factors, but state-level fractions may differ depending on the type of non-energy uses. Where state-specific estimates are available, their use is preferred, if adequate supporting documentation is available. If the user-specific inputs do not match the default data in the control worksheet (i.e., the default value is overwritten), the text will appear red. Data on the non-energy use storage factor is used in the industrial sector worksheet (Step 9).

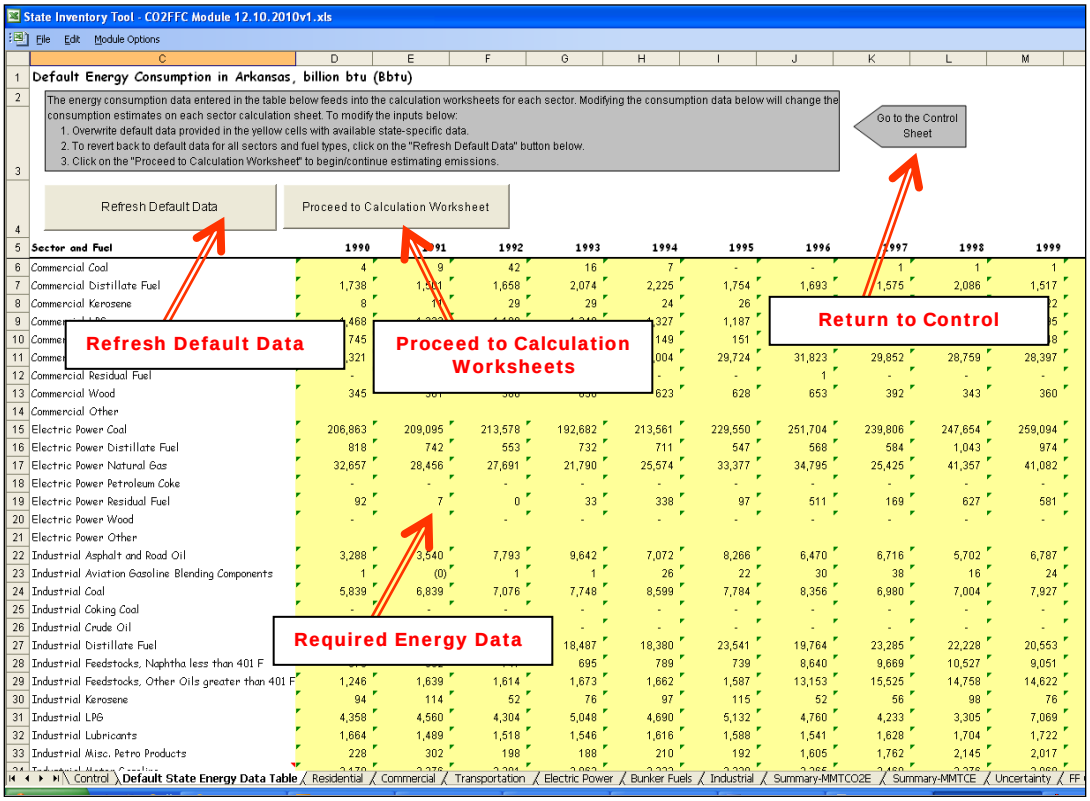
Step (3) Complete the Bulk Energy Consumption Data Worksheet

The energy consumption data entered in the “Bulk Energy Consumption Data” (bulk data) worksheet feed into the calculation worksheets for each sector. Modifying the consumption data in this worksheet will change the consumption estimates on each sector calculation sheet. The default data will automatically be populated in the yellow cells by sector and fuel type for the selected state. On the bulk data worksheet, presented as an example in Figure 6, the yellow cells indicate where the required energy activity data are entered either manually or automatically from default data. Default data in the yellow cells on this worksheet can be overwritten with state-specific data. To revert to default data for all sectors and fuel types, click on the "Refresh Default Data" button at the top of the

[3] Variations in petroleum are most often expressed in terms of specific gravity at 15 degrees Celsius. The API gravity, where API gravity = 141.5/specific gravity - 131.5, is an indication of the molecular size, carbon/hydrogen ratio, and hence carbon content of a crude oil.

worksheet. Click on the "Proceed to Calculation Worksheet" to begin/continue estimating emissions, or click on the “Return to Control” button to return to the control worksheet.

Figure 6. Example of the Required Energy Consumption Data in the Bulk Data Worksheet



Step (4) through Step (7) View Emission Estimates on Individual Sector Worksheets (Excluding International Bunker Fuels and Industrial Sector)

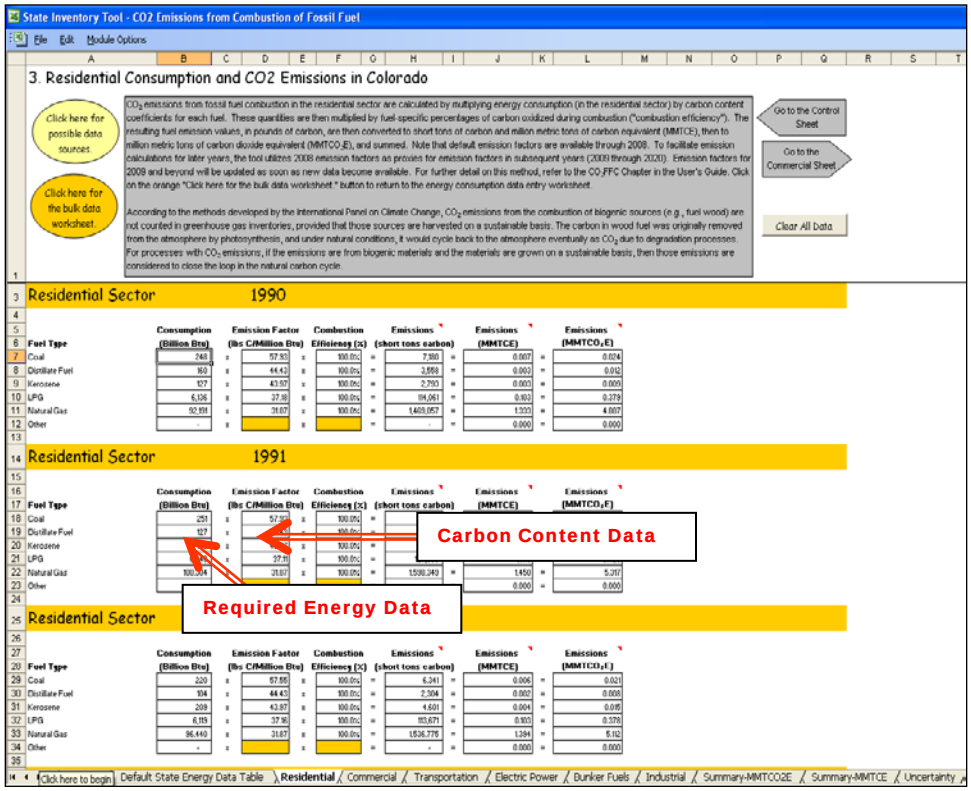
With the exception of the industrial sector, the worksheets for each sector have the same basic set-up. On the residential sector worksheet, presented as an example in Figure 7, the cells in the first column indicate where the required energy activity data were entered from the bulk data worksheet. These activity data are converted into CO_2 emissions using the factors entered on the control worksheet, the energy consumption data entered on the bulk data worksheet, and the formula presented in Equation 1. Click on the orange "Click here for the bulk data worksheet." button to return to the energy consumption data entry worksheet.

The activity data used to populate the energy consumption input cells is annual fuel consumption based on *primary fuel type* (e.g., coal, petroleum, and natural gas) and *secondary fuel type* (e.g., gasoline, residual oil, natural gas, etc.) by *sector* (e.g., residential, commercial, industrial, transportation, and electric utilities). A list of potential fuel types consumed in each sector is provided in Table 1 and is included in the CO_2FFC module.

The CO_2FFC module calculates emissions for each sector by multiplying consumption by the carbon content and the combustion efficiency to obtain the total carbon oxidized. Then, the total tons of carbon oxidized are converted into $MMTCO_2E$, by multiplying by the ratio of

metric tons per short ton (0.9072) to obtain metric tons and dividing by 10^6 and multiplying by 44/12 to express emissions in $MMTCO_2E$ (Equation 1).

Figure 7. Example of the Required Energy Data Applied in the Residential Worksheet



Step (8) View Estimates on Bunker Fuels Worksheet

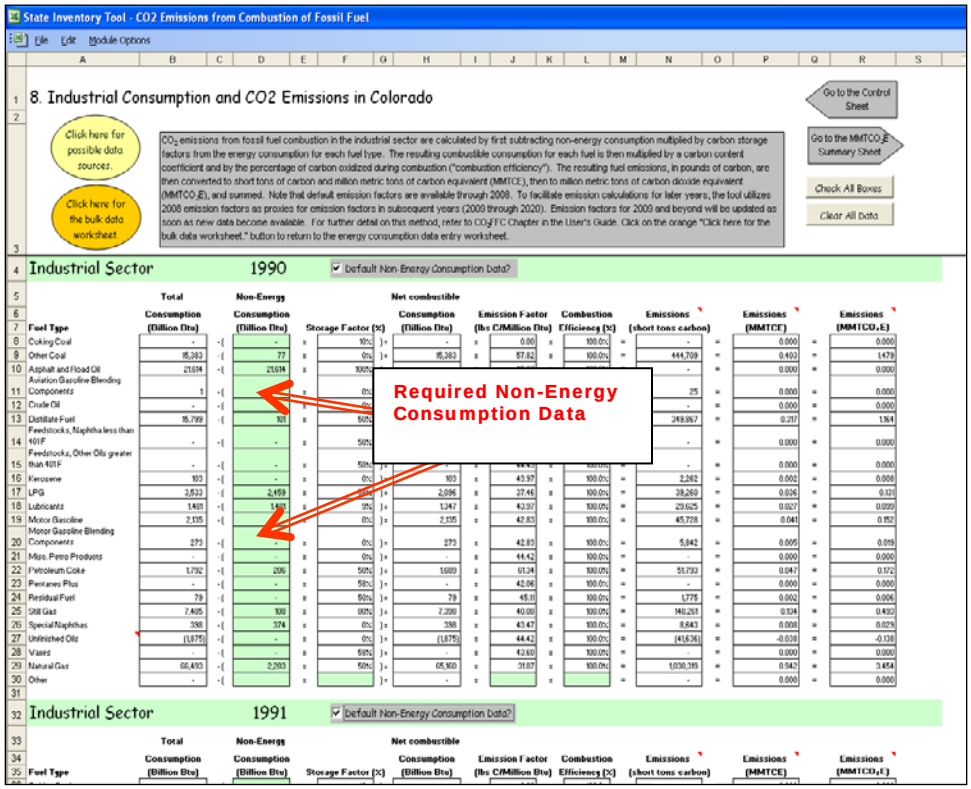
Emissions from international bunker fuels are calculated in step 7. International bunker fuels are fuels used in marine and aviation transport originating in the United States with international destinations. According to the Revised 1996 IPCC Guidelines, emissions from international transport should be reported separately as a memo item, instead of allocating them to a particular country.

Step (9) Complete Non-Energy Use Activity Data on the Industrial Sector Worksheet

The industrial worksheet is unique because both total energy consumption and total non-energy consumption are required as inputs to calculate CO_2 emissions, shown in Figure 8 (input cells are shown in green). Including activity data on non-energy use allows calculation of the amount of carbon from these fuels that is stored in non-energy products for a significant period of time (i.e., more than 20 years). The CO_2FFC module estimates carbon stored in non-energy uses for each state by multiplying the total number of Btu consumed by the default percent of that fuel type that is used for non-energy purposes, and then by a storage factor (i.e., the amount of carbon in non-energy uses that typically remains stored for longer than 20 years, entered in Step 2). This non-energy consumption is then subtracted from the total consumption to yield the net combustible consumption. From this point forward, the industrial worksheet functions in the same manner as the other sector worksheets. The net combustible consumption is multiplied by the carbon content

and the combustion efficiency to obtain the total carbon oxidized. Then, the total tons of carbon oxidized are converted into $MMTCO_2E$, by multiplying by the ratio of metric tons per short ton (0.9072) to obtain metric tons and dividing by 10^6 and multiplying by 44/12 to express emissions in $MMTCO_2E$ (Equation 2). Click on the orange "Click here for the bulk data worksheet." button to return to the energy consumption data entry worksheet.

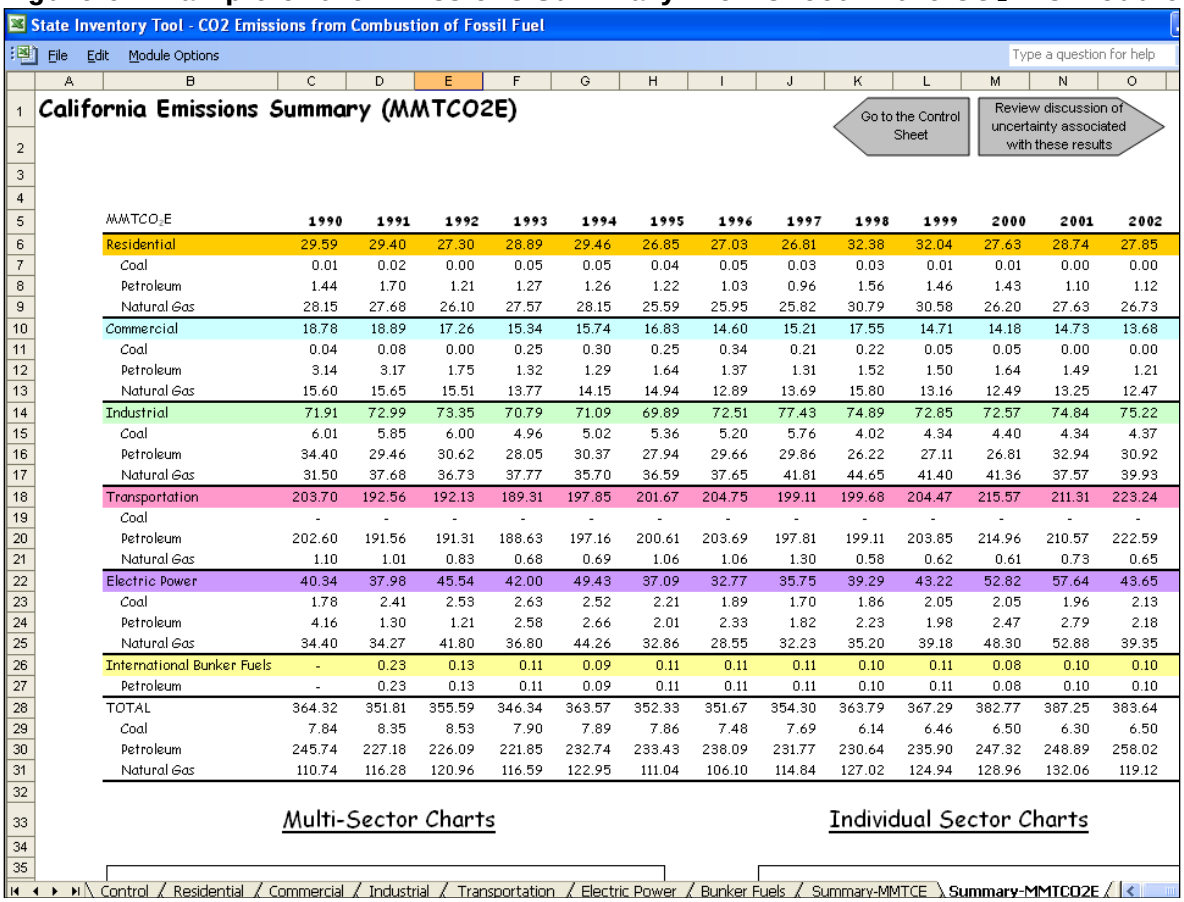
Figure 8. Example of Energy and Non-Energy Consumption Data Applied in the Industrial Worksheet



Step (10) Review Summary Information

The steps above provide estimates of total carbon in fossil fuels consumed, carbon stored in non-energy products, and amount of carbon oxidized to CO_2. Total carbon emissions are equal to the total carbon content in fuel, minus carbon stored in non-energy uses, adjusted for the carbon not oxidized during combustion, and summed over all fuel types and sectors, for each year. The information is collected on the summary worksheet, displaying results in $MMTCO_2E$. Figure 9 shows the summary worksheet that sums the emissions from all sectors in the CO_2FFC module. In addition, the results are displayed in graphical format at the bottom of the summary worksheets.

Figure 9. Example of the Emissions Summary Worksheet in the CO_2FFC Module



State Inventory Tool - CO2 Emissions from Combustion of Fossil Fuel

File Edit Module Options — Type a question for help

California Emissions Summary (MMTCO2E)

Go to the Control Sheet | Review discussion of uncertainty associated with these results

MMTCO2E	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Residential	29.59	29.40	27.30	28.89	29.46	26.85	27.03	26.81	32.38	32.04	27.63	28.74	27.85
Coal	0.01	0.02	0.00	0.05	0.05	0.04	0.05	0.03	0.03	0.01	0.01	0.00	0.00
Petroleum	1.44	1.70	1.21	1.27	1.26	1.22	1.03	0.96	1.56	1.46	1.43	1.10	1.12
Natural Gas	28.15	27.68	26.10	27.57	28.15	25.59	25.95	25.82	30.79	30.58	26.20	27.63	26.73
Commercial	18.78	18.89	17.26	15.34	15.74	16.83	14.60	15.21	17.55	14.71	14.18	14.73	13.68
Coal	0.04	0.08	0.00	0.25	0.30	0.25	0.34	0.21	0.22	0.05	0.05	0.00	0.00
Petroleum	3.14	3.17	1.75	1.32	1.29	1.64	1.37	1.31	1.52	1.50	1.64	1.49	1.21
Natural Gas	15.60	15.65	15.51	13.77	14.15	14.94	12.89	13.69	15.80	13.16	12.49	13.25	12.47
Industrial	71.91	72.99	73.35	70.79	71.09	69.89	72.51	77.43	74.89	72.85	72.57	74.84	75.22
Coal	6.01	5.85	6.00	4.96	5.02	5.36	5.20	5.76	4.02	4.34	4.40	4.34	4.37
Petroleum	34.40	29.46	30.62	28.05	30.37	27.94	29.66	29.86	26.22	27.11	26.81	32.94	30.92
Natural Gas	31.50	37.68	36.73	37.77	35.70	36.59	37.65	41.81	44.65	41.40	41.36	37.57	39.93
Transportation	203.70	192.56	192.13	189.31	197.85	201.67	204.75	199.11	199.68	204.47	215.57	211.31	223.24
Coal	-	-	-	-	-	-	-	-	-	-	-	-	-
Petroleum	202.60	191.56	191.31	188.63	197.16	200.61	203.69	197.81	199.11	203.85	214.96	210.57	222.59
Natural Gas	1.10	1.01	0.83	0.68	0.69	1.06	1.06	1.30	0.58	0.62	0.61	0.73	0.65
Electric Power	40.34	37.98	45.54	42.00	49.43	37.09	32.77	35.75	39.29	43.22	52.82	57.64	43.65
Coal	1.78	2.41	2.53	2.63	2.52	2.21	1.89	1.70	1.86	2.05	2.05	1.96	2.13
Petroleum	4.16	1.30	1.21	2.58	2.66	2.01	2.33	1.82	2.23	1.98	2.47	2.79	2.18
Natural Gas	34.40	34.27	41.80	36.80	44.26	32.86	28.55	32.23	35.20	39.18	48.30	52.88	39.35
International Bunker Fuels	-	0.23	0.13	0.11	0.09	0.11	0.11	0.11	0.10	0.11	0.08	0.10	0.10
Petroleum	-	0.23	0.13	0.11	0.09	0.11	0.11	0.11	0.10	0.11	0.08	0.10	0.10
TOTAL	364.32	351.81	355.59	346.34	363.57	352.33	351.67	354.30	363.79	367.29	382.77	387.25	383.64
Coal	7.84	8.35	8.53	7.90	7.89	7.86	7.48	7.69	6.14	6.46	6.50	6.30	6.50
Petroleum	245.74	227.18	226.09	221.85	232.74	233.43	238.09	231.77	230.64	235.90	247.32	248.89	258.02
Natural Gas	110.74	116.28	120.96	116.59	122.95	111.04	106.10	114.84	127.02	124.94	128.96	132.06	119.12

Multi-Sector Charts — Individual Sector Charts

Control / Residential / Commercial / Industrial / Transportation / Electric Power / Bunker Fuels / Summary-MMTCE / Summary-MMTCO2E /

Step (11) Export Data

The final step is to export the summary data. Exporting data allows the estimates from each module to be combined later by the Synthesis Module to produce a comprehensive greenhouse gas inventory for the state.

To access the "Export Data" button, return to the control sheet and scroll down to the bottom (11). Click on the "Export Data" button and a message box will open that reminds the user to make sure all steps of the module have been completed. If you make any changes to the CO_2FFC module later, you will then need to re-export the results.

Note: the resulting export file should not be modified. The export file contains a summary worksheet where users can view the results, as well as a separate data worksheet with an unformatted version of the results; this data worksheet contains the information that is exported to the Synthesis Tool, and it is especially important that users do not modify it. Adding/removing rows, moving data, or making other modifications jeopardize the ability of the Synthesis Module to accurately analyze the data.

Clicking "OK" prompts you to save the file. The file is already named, so you only need to choose a convenient place to save the file. After the file is saved, a message box will appear indicating that the data was successfully exported.

While completing the modules, you are encouraged to save each completed module; doing so will enable you to easily make changes without re-running it entirely.

Following data export, the module may be reset and run for an additional state. Alternatively, you may run the remaining modules of the State Inventory Tool to obtain a comprehensive profile of emissions for your state.

1.4 UNCERTAINTY

In the upper right-hand corner of the summary worksheet is a button: "Review discussion of uncertainty associated with these results." By clicking on this button, you are taken to a worksheet that discusses the uncertainty surrounding the activity data and emission factors, and how the uncertainty estimates for this source category affect the uncertainty of the emission estimates for your state.

1.5 REFERENCES

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