User's Guide for Estimating Indirect Carbon Dioxide Equivalent Emissions from Electricity Consumption Using the State Inventory Tool

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This section of the User's Guide provides instruction on using the Indirect CO_2 from Electricity Consumption (Electricity Consumption) module of the State Inventory Tool (SIT), and describes the methodology used for estimating greenhouse gas emissions from electricity consumption at the state level.

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1.1 GETTING STARTED

The Indirect Carbon Dioxide Equivalent (CO$_2$ Eq.) from Electricity Consumption (Electricity Consumption) module was developed using Microsoft® Excel 2000. While the module will operate with older versions of Excel, it functions best with Excel 2000 or later. If you are using Excel 2007, instructions for opening the module will vary as outlined in the Excel basics below. Before you use the Electricity Consumption module, make sure your computer meets the system requirements. In order to install and run the Electricity Consumption module, you must have:

- IBM-PC compatible computer with the Windows 95 operating system or later;

- Microsoft® Excel 1997 or later, with calculation set to automatic and macros enabled;

- Hard drive with at least 20MB free; and

- Monitor display setting of 800 x 600 or greater.

Microsoft Excel Settings

Excel 2003 and Earlier: For the SIT modules to function properly, Excel must be set to automatic calculation. To check this setting, launch Microsoft Excel before opening the Electricity Consumption module. Go to the Tools menu and select "Options..." Click on the "Calculations" tab and make sure that the radio button next to "Automatic" is selected, and then click on "OK" to close the window. The security settings (discussed next) can also be adjusted at this time.

Excel 2007: For the SIT modules to function properly, Excel must be set to automatic calculation. Go to the Formulas ribbon and select "Calculation Options." Make sure that the box next to the "Automatic" option is checked from the pop-up menu.

Microsoft Excel Security

Excel 2003 and Earlier: Since the SIT employs macros, you must have Excel security set to medium (recommended) or low (not recommended). To change this setting, launch Microsoft Excel before opening the Electricity Consumption module. Once in Excel, go to the Tools menu, click on the Macro sub-menu, and then select "Security" (see Figure 1). The Security pop-up box will appear. Click on the "Security Level" tab and select medium. When set to high, macros are automatically disabled; when set to medium, Excel will give you the choice to enable macros; when set to low, macros are always enabled.

When Excel security is set to medium, users are asked upon opening the module whether to enable macros. Macros must be enabled in order for the Electricity Consumption module to work. Once they are enabled, the module will open to the control worksheet. A message box will appear welcoming the user to the module. Clicking on the "x" in the upper-right-hand corner of the message box will close it.

Excel 2007: If Excel's security settings are set at the default level a Security Warning appears above the formula box in Excel when the Electricity Consumption module is initially opened. The Security Warning lets the user know that some active content from the spreadsheet has been disabled, meaning that Excel has prevented the macros in the spreadsheet from functioning. Since SIT needs macros in order to function properly, the user must click the "Options" button in the security message and then select, "Enable this

content" in the pop-up box. Enabling the macro content for the SIT in this way only enables macros temporarily in Excel but does not change the macro security settings. Once macros are enabled, a message box will appear welcoming the user to module. Click on the "x" in the upper right-hand corner to close the message box.

If the Security Warning does not appear when the module is first opened, it may be necessary to change the security settings for macros. To change the setting, first exit out of the Electricity Consumption module and re-launch Microsoft Excel before opening the Electricity Consumption module. Next, click on the Microsoft Excel icon in the top left of the screen. Scroll to the bottom of the menu and select the "Excel Options" button to the right of the main menu. When the Excel Options box appears, select "Trust Center" in left hand menu of the box. Next, click the gray "Trust Center Settings" button. When the Trust Center options box appears, click "Macro Settings" in the left hand menu and select "Disable all macros with notification." Once the security level has been adjusted, open the Stationary Combustion module and enable macros in the manner described in the preceding paragraph.

Viewing and Printing Data and Results

The Electricity Consumption module contains some features to allow users to adjust the screen view and the appearance of the worksheets when they are printed. Once a module has been opened, you can adjust the zoom by going to the Module Options Menu, and either typing in a zoom percentage or selecting one from the drop down menu. In addition, data may not all appear on a single screen within each worksheet; if not, you may need to scroll up or down to view additional information.

You may also adjust the print margins of the worksheets to ensure that desired portions of the Electricity Consumption module are printed. To do so, go to the File menu, and then select "Print Preview." Click on "Page Break Preview" and drag the blue lines to the desired positions (see Figure 2). To print this view, go to the File menu, and click "Print." To return to the normal view, go to the File menu, click "Print Preview," and then click "Normal View."

Figure 1. Changing Security Settings
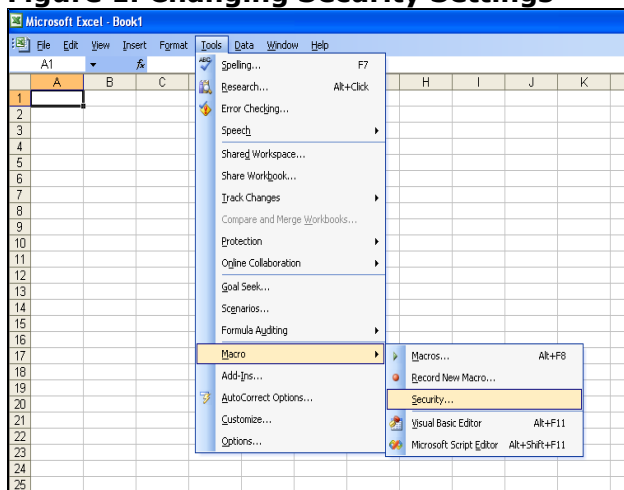
Figure 2. Adjusting Print Margins
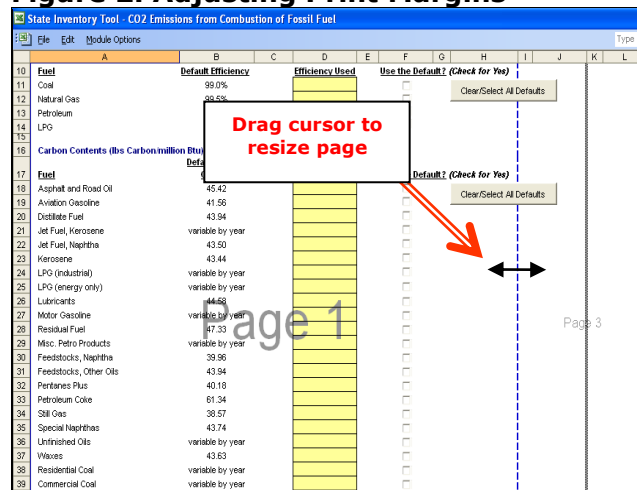
1.2 MODULE OVERVIEW

This User's Guide accompanies and explains the Electricity Consumption module of the SIT. Many of the SIT modules were 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. Ten of the SIT modules 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.

The Electricity Consumption module is the eleventh, and newest, module developed as part of the SIT suite of modules. EPA recognized a need for a module and guidance to estimate indirect greenhouse gas emissions from electricity consumption at the state level. In using this module, an important distinction between direct and indirect emissions must be made. Direct emissions (estimated in the CO$_2$ from Fossil Fuel Combustion module) result from the combustion of fossil fuels at the electricity generating station, whereas indirect emissions occur at the point of use (e.g., residential space heating electricity consumption). State inventories can include direct emissions associated with electricity generation occurring in the state and/or indirect emissions associated with electricity consumed within the boundaries of the state. Because electricity consumption within a state does not correspond to electricity generated in that state, emissions from consumption (indirect emissions) are not likely to be the same as emissions from generation (direct emissions). States are encouraged to include direct emissions in their inventory estimates, and estimate and include indirect emissions as an informational line item. Including both direct and indirect estimates may lead to double counting. If the goal of the inventory is to encourage action and reduce emissions within the state, it would be beneficial to include emissions at the point of consumption (i.e., indirect emissions from electricity consumption).

Since 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 (U.S. EPA 2016). In addition, the emission factors developed for the Electricity Consumption module are consistent with emission factors from Emissions & Generation Resource Integrated Database (eGRID) (U.S. EPA 2007, U.S. EPA 2010, U.S. EPA 2012, U.S. EPA 2014, U.S. EPA 2015, and U.S. EPA 2017).

The Electricity Consumption module calculates carbon dioxide equivalent (CO$_2$ Eq.) emissions from the electricity consumption by the end-use equipment types shown in Table 1, by end-use sector. While the module provides default data for electricity consumption by end-use 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$_2$ Eq. emissions from electricity consumption, the following data are required:

- Electricity consumption by sector;

- Percent electricity consumption by end-use equipment;

- Electricity emission factors; and

- Transmission loss factors.

Electricity consumption statistics should be collected on a kilowatt-hour[1] (kWh) basis. Statistics providing energy consumption data in other units, British Thermal Units (Btu), may be used, but require conversion to kWh. One kWh is equivalent to 3,412 Btu. 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

The Electricity Consumption module calculates carbon dioxide equivalent (CO$_2$ Eq.) emissions from the electricity consumption by the end-use equipment types, by end-use sector shown in Table 1. The following sections provide a discussion of the available data for each sector.

Table 1. End-Use Equipment by Sector

| **Residential[1]**	**Commercial[2]**	**Industrial[3]**	**Transportation[4]**

Space Heating
Air-conditioning
Water Heating
Refrigeration
Other
    Appliances
    and Lighting
	Space Heating
	Cooling
	Ventilation
	Water Heating
	Lighting
	Cooking
	Refrigeration
	Office
	    Equipment
	Computers
	Other
		Indirect Uses- Boiler Fuel
		Conventional Boiler Use
		CHP and/or Cogeneration
		    Process
		Direct Uses- Total Process
		Process Heating
		Process Cooling and
		    Refrigeration
		Machine Drive
		Electro-Chemical Processes
		Other Process Use
		Direct Uses- Total
		    Nonprocess
		Facility HVAC
		Facility Lighting
		Other Facility Support
		Onsite Transportation
		Other Nonprocess Use
			Automated
			    Guideway
			Bus (charged
			    batteries)
			Cable Car
			Commuter Rail
			Heavy Rail
			Inclined Plane
			Light Rail
			Trolleybus
			Other

Source: [1]EIA 2008, [2]EIA 2016, [3]EIA 2014, and [4]FTA 2016

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[1] A measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour. One kWh is equivalent to 3,412 Btu.

1.2.2 Tool Layout

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

Figure 3. Flow of Information in the Electricity Consumption Module*
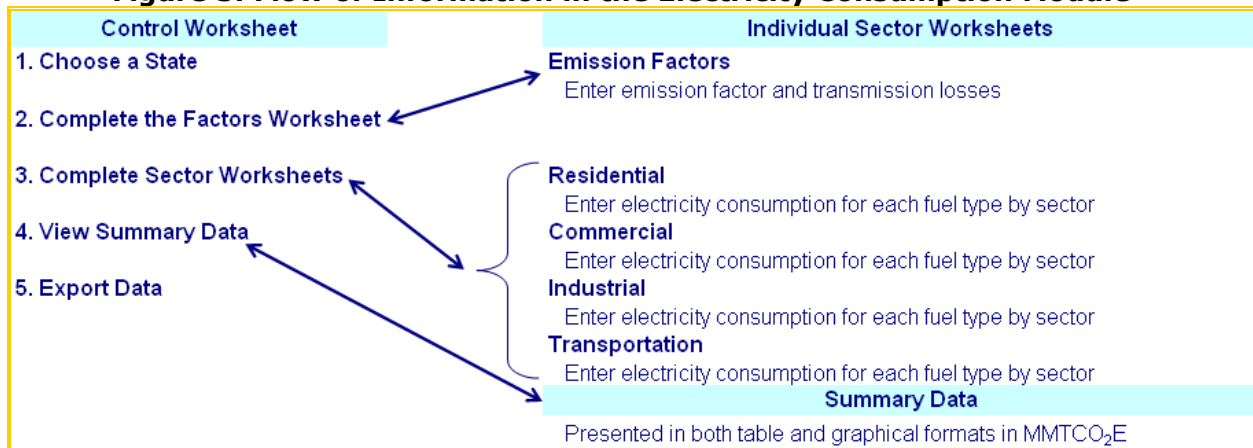
* These worksheets are the primary worksheets used in the Electricity Consumption module; subsequent worksheets are used to populate the default data and are provided for informational purposes only.

1.3 METHODOLOGY

This section provides a guide to using the Electricity Consumption module of the SIT to estimate indirect CO$_2$ Eq. emissions from sectors and end-use equipment that consume electricity. Within the Electricity Consumption module, these sectors are residential, commercial, transportation, and industrial. Since the methodology is similar in all sectors, a general methodology is discussed and specific examples for each sector are provided.

> **Box 2: 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 Electricity Consumption module may be used. Electricity consumption statistics should be provided on a kWh basis.

The Electricity Consumption module automatically calculates emissions after you enter factors on the emission factor worksheet, electricity consumption data, and the percent consumption by end-use sector equipment. The tool provides default electricity consumption data, which comes from the EIA's State Energy Consumption, Price, and Expenditure Estimates (SEDS) EIA (2017).[2] However, other more state-specific data may be used if available (see Box 2 for suggestions on where to find data).

This User's Guide provides an overview of the estimation methodology used in the Electricity Consumption module by walking through the following steps: (1) select a state; (2) complete the emission factor worksheet; (3) complete the residential sector worksheet; (4) complete the commercial sector worksheet; (5) complete the transportation sector

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[2] These data are available on the Internet at http://www.eia.doe.gov/emeu/states/_seds.html.

worksheet (6) complete the industrial sector worksheet; (7) review summary information; and (8) export data.

The general equation use to calculate indirect CO$_2$ Eq. emissions from electricity consumption is shown in Equation 1.

Equation 1. General Emission Equation

> **Emissions (MMTCO$_2$E) =**
> **{(Total State Consumption (kWh) × End-Use Equipment Consumption (%)) ÷ (1-Transmission Loss Factor (%))} × Emission Factor (lbs CO$_2$E/kWh) × 0.0005 short ton/lbs × 0.90718 (Ratio of Short Tons to Metric Tons) ÷ 1,000,000**

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)   Complete the Factors Worksheet

Step 2 requires users to select appropriate factors for several key variables necessary for estimating indirect CO$_2$ emissions from electricity consumption. On the Factors worksheet, default electricity emission factors and transmission loss factors are provided and will be used to estimate emissions throughout the tool. To select all of the default data, select the "Check All Boxes" button on the Factors worksheet or check the default box directly above the yellow input cells for each year in the time series. Note that users may select a default factor and later override the factor if better data becomes available. An example of the Factors worksheet is provided in Figure 4 below.

Default emission factors for electricity consumption (lbs CO$_2$E/kWh) are provided in the Factors worksheet. Values are derived from Year 2005, 2007, 2009, 2010, 2012, and 2014 Emissions & Generation Resource Integrated Database (eGRID) subregion values, weighted by the number of households based on distribution utilities within in each eGRID subregion in each state (U.S. EPA 2007, U.S. EPA 2010, U.S. EPA 2012, U.S. EPA 2014, U.S. EPA 2015, and U.S. EPA 2017). This weighted emission factor is intended to better reflect emissions related to electricity consumption within a state, and take into account the flow of electricity across state boundaries. Since these emission factors do not account for any transmission and distribution losses between the points of generation and the points of consumption, a transmission loss factor must be applied. The transmission loss factor takes into account electric energy lost due to the transmission and distribution of electricity. Additional information on eGRID emission factors is provided in Box 3.


Box 3: eGRID Emission Factors

The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive inventory of environmental attributes of electric power systems. The preeminent source of air emissions data for the electric power sector, eGRID is based on available plant-specific data for all U.S. electricity generating plants that provide power to the electric grid and report data to the U.S. government. eGRID integrates many different federal data sources on power plants and power companies, from three different federal agencies: EPA, the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). eGRID also provides aggregated data by state, U.S. total, company, and by three different sets of electric grid boundaries.

Plant level emissions in eGRID are built by summing its component parts – which could simply be unit level boilers and/or turbines or a combination of boilers and prime movers representing an aggregation of like generating units. In general, eGRID plant level emissions reflect a combination of monitored and estimated data. Emissions and emission rates in eGRID represent emissions and rates at the point(s) of generation. They do account for losses within the generating plants (net generation).

Note that default emission factors are identical throughout the time series. While these emission and transmission loss factors were developed for 2005, 2007, 2009, 2010, 2012, and 2014, emission factor and household data were not available for the remaining years in the time series. To facilitate emission calculations for other years, the tool utilizes the 2005, 2007, 2009, 2010, 2012, and 2014 emission factors as proxies (2005 emission factors used from 1990 through 2006, 2007 emission factors from 2007 through 2008, 2009 emission factors used for 2009, 2010 emission factors for 2010 and 2011, 2012 emissions factors for 2012 and 2013, and 2014 emissions factors from 2014 through 2020). Emission factors within the module will be updated as soon as new data become available.

Figure 4. Factors Worksheet for the Electricity Consumption Module
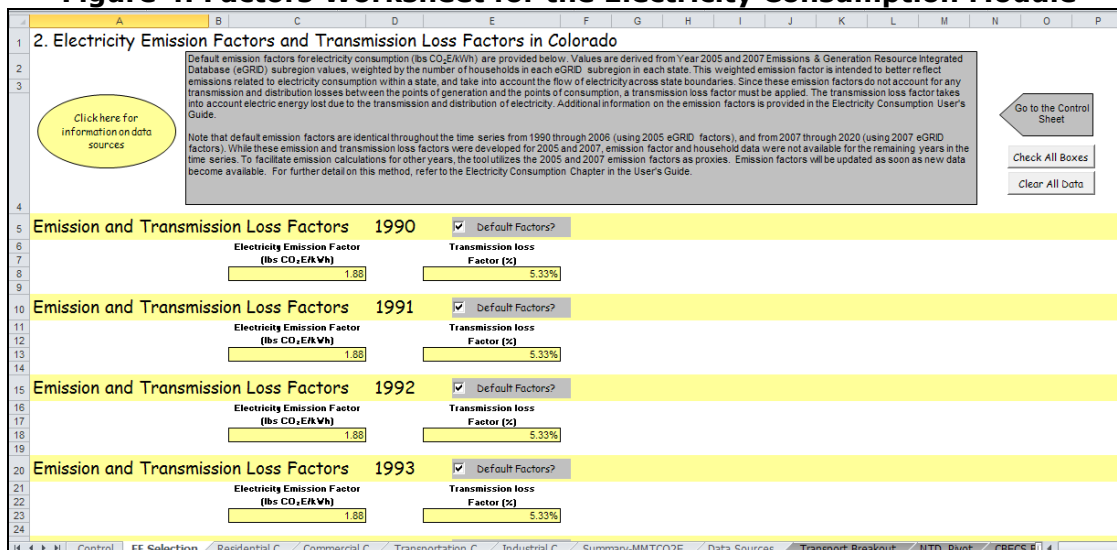
Step (3) through Step (6) Complete Individual Sector Worksheets

The worksheets for each sector have the same basic set-up, with variations in the color of the data input cells, and the end-use equipment for each end-use sector. On the residential sector worksheet, presented as an example in Figure 5, the orange cells indicate where the

required energy activity data are entered either manually or automatically from default data. This activity data are converted into CO$_2$ emissions using the factors entered on the Factors worksheet and the formula presented in Equation 1.

There are two types of activity data required to populate the orange cells in the residential sector worksheet. First, activity data used to populate the orange cells is annual electricity consumption by *sector* (e.g.*,* residential, commercial, transportation, and industrial). Default annual electricity consumption is from EIA's State Energy Data System (EIA 2016).

The second piece of activity data required to estimate emissions is the percent end-use equipment for each sector across the state. A list of end-use equipment that consumes electricity in each sector is provided in Table 1 and is included in the Electricity Consumption module. End-use consumption data used in the module is derived from a variety of publications, discussed further in Box 4.

The Electricity Consumption module calculates emissions for each sector by multiplying total electricity consumption by the percent consumption by end-use equipment and the emission and transmission loss factor to obtain the total carbon emitted. Then, the total amount of carbon emitted are converted into MMTCO$_2$E, 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$_2$E (Equation 1).

Figure 5. Example of the Required Electricity Data in the Residential Worksheet
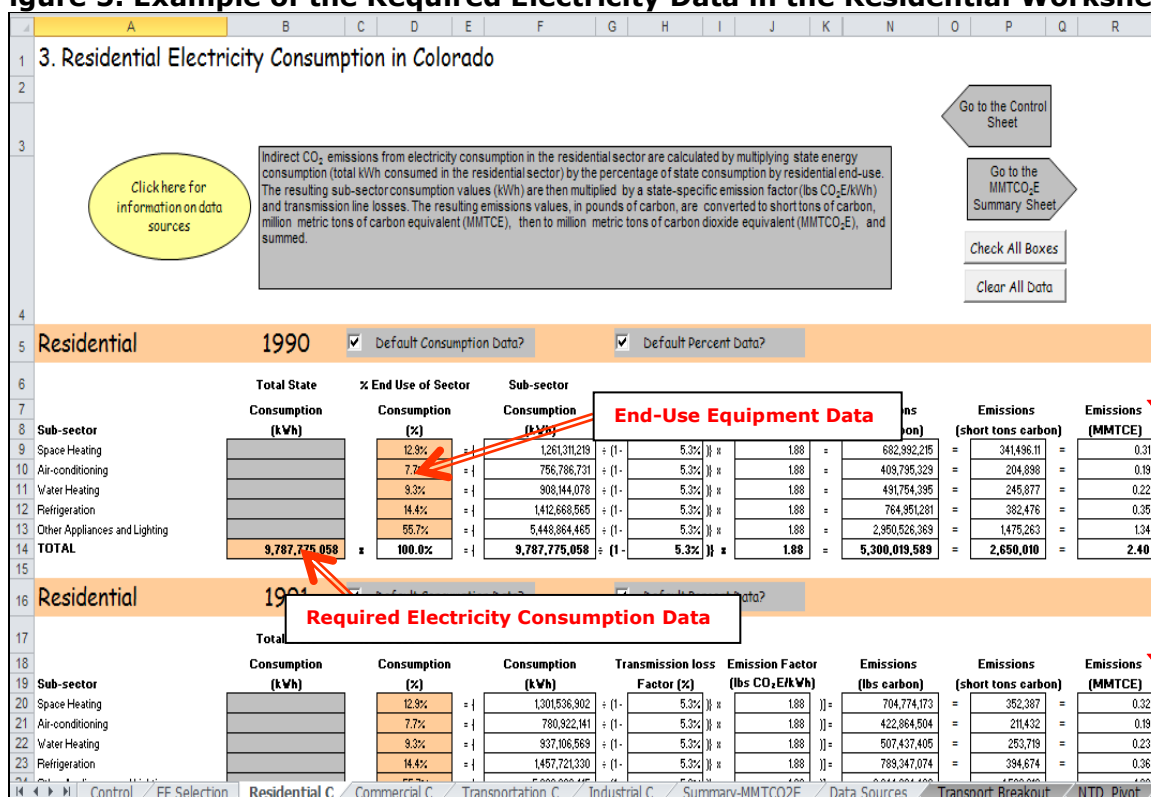
Box 4: End-Use Equipment Data Sources

Residential

Residential end-use equipment activity is from the Residential Energy Consumption Survey (RECS) (EIA 2008). The Residential Energy Consumption Survey (RECS) provides information on the use of energy in residential housing units in the United States. This information includes: the physical characteristics of the housing units; the appliances utilized including space heating and cooling equipment; demographic characteristics of the household; the types of fuels used; and other information that relates to energy use. The RECS also provides energy consumption and expenditures data for: natural gas, electricity, fuel oil, liquefied petroleum gas (LPG), and kerosene. The RECS is published in 4 year intervals. As a result, the Electricity Consumption Module uses 2001, 2005, and 2009 RECS data, and interpolates to estimate intervening years. Activity data beyond 2009 is proxied to the 2009 values. The Electricity Consumption Module utilizes regional-level data available from the RECS.

RECS data are available online at: http://www.eia.doe.gov/emeu/recs/.

Commercial

Commercial end-use equipment activity is from the Commercial Building Energy Consumption Survey (CBECS) (EIA 2016). The Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, their energy-related building characteristics, and their energy consumption and expenditures. Commercial buildings include all buildings in which at least half of the floorspace is used for a purpose that is not residential, industrial, or agricultural, so they include building types that might not traditionally be considered "commercial," such as schools, correctional institutions, and buildings used for religious worship. The CBECS is published in 4 year intervals. As a result, the Electricity Consumption Module uses 2002, 2006, and 2010 data, and proxies other years in the time series to these estimates (1990 through 2005 are proxied to 2002, 2007 through 2009 are proxied to 2006, and 2011 through 2020 are proxied to 2010). The Electricity Consumption Module utilizes regional-level data available from the CBECS.

CBECS data are available online at: http://www.eia.doe.gov/emeu/cbecs/.

Transportation

Transportation end-use equipment activity is from the National Transit Database (NTD) (FTA 2016). The NTD was established by Congress to be the Nation's primary source for information and statistics on the transit systems of the United States. The data contained in the 2007 National Transit Database (NTD) is one of three publications comprising the National Transit Database Program's Annual Report. It provides detailed summaries of financial and operating data submitted to the Federal Transit Administration (FTA) by the nation's mass transit agencies for the report year ending on or between January 1 and December 31, 2014. The Electricity Consumption Module uses 2007 through 2014 data from the NTD, and proxies 1990 through 2006 to 2007, and 2015 through 2020 to 2014. The Electricity Consumption Module utilizes state-level data available from the NTD.

NTD data are available online at: http://www.ntdprogram.gov/ntdprogram/.

Industrial

Industrial end-use equipment activity is from the Manufacturing Energy Consumption Survey (MECS) (EIA 2014). The Manufacturing Energy Consumption Survey (MECS) is the Federal Government's comprehensive source of information on energy use by U.S. manufacturers. The survey collects data on energy consumption and expenditures, fuel-switching capability, onsite generation of electricity, byproduct energy use, and other energy related topics. The Electricity Consumption Module uses 2002, 2006, and 2010 data from the MECS, and 1990 through 2005 are proxied to 2002, while all other years are proxied to 2010. The Electricity Consumption Module utilizes regional-level data available from the MECS.

MECS data are available online at: https://www.eia.gov/consumption/manufacturing/data/2010/.

Step (7)   Review Summary Information

The steps above provide estimates of total CO$_2$ Eq. emissions from electricity consumption. The information for each sector is collected on the summary worksheet, displaying results in MMTCO$_2$E. Figure 6 shows the summary worksheet that sums the emissions from all sectors in the Electricity Consumption module. In addition, the results are displayed in graphical format at the bottom of the summary worksheets. Toggle buttons to the left of each sector either expand ("+") or collapse ("-") rows to show end-use equipment data.

Figure 6. Example of the Emissions Summary Worksheet in the Electricity Consumption Module
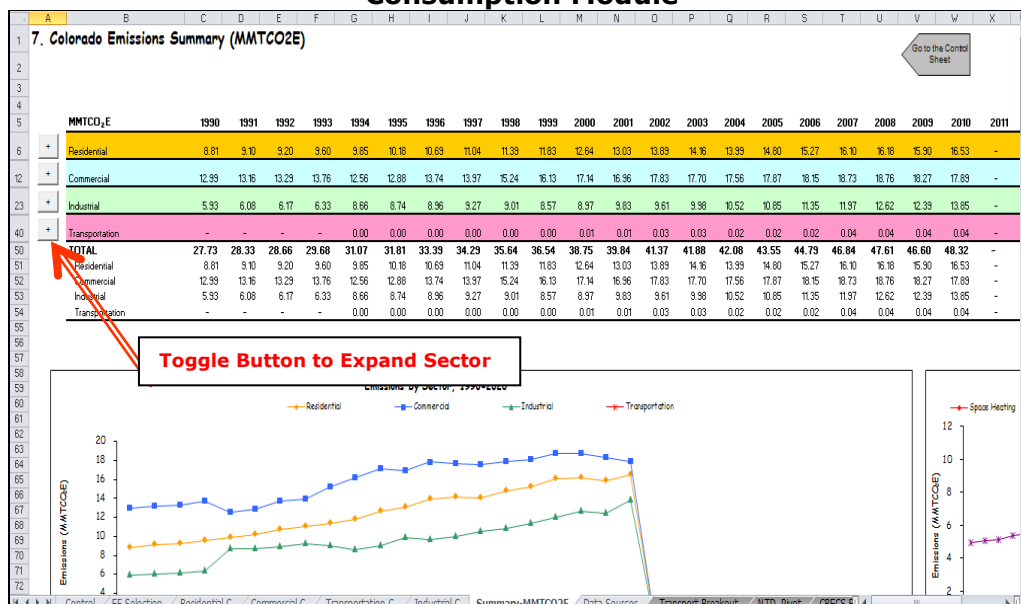
Step (8)   Export Data

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 (8). 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 Electricity Consumption 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 REFERENCES

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