USER'S GUIDE FOR ESTIMATING CARBON DIOXIDE, NITROUS OXIDE, HFC, PFC, NF_3, AND SF_6 EMISSIONS FROM INDUSTRIAL PROCESSES USING THE STATE INVENTORY TOOL

JANUARY 2022

Prepared by:
ICF

Prepared for:
State Energy and Environment Program,
U.S. Environmental Protection Agency

This section of the User's Guide provides instruction on using the Industrial Processes (IP) module of the State Inventory Tool (SIT), and describes the methodology used for estimating carbon dioxide (CO_2), nitrous oxide (N_2O), HFC, PFC, NF_3, and SF_6 emissions from industrial processes at the state level.

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1.1 Getting Started

The Industrial Processes (IP) module of the State Inventory Tool (SIT) 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 or later, instructions for opening the module will vary as outlined in the instructions below. Some of the Excel basics are outlined in the sections below. Before you use the IP module, make sure your computer meets the system requirements. In order to install and run the IP 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 IP 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 and Later: 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: Because 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 IP 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 IP 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 and Later: If Excel's security settings are set at the default level a Security Warning appears above the formula box in Excel when the IP 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. Because 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 IP module and re-launch Microsoft Excel *before* opening the IP 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 IP module and enable macros in the manner described in the preceding paragraph.

Viewing and Printing Data and Results

The IP 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 IP 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

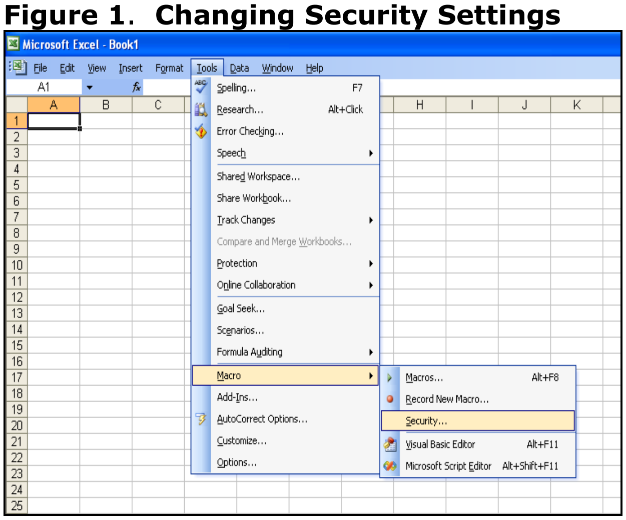
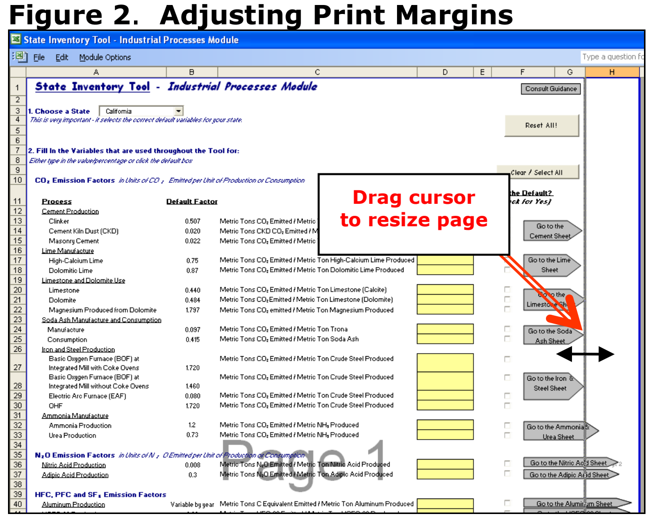


Figure 2. Adjusting Print Margins



1.2 Module Overview

This User's Guide accompanies and explains the Industrial Processes 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 IP module calculates carbon dioxide (CO_2), nitrous oxide (N_2O), hydrofluorocarbon (HFC), perfluorocarbon (PFC), nitrogen trifluoride (NF_3), and sulfur hexafluoride (SF_6) emissions from the IP sectors shown in Table 1. While the module provides default data for each sector (depending on availability), if you have access to a more comprehensive data source, it should be used in place of the default data. 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, N_2O, HFC, PFC, NF_3, and SF_6 emissions from IP, general activity data on various IP sectors are required. A complete list of the activity data and emission factors necessary to run the IP module is provided in Table 1.

Table 1. IP Sectors, Data Requirements, and Gases Emitted

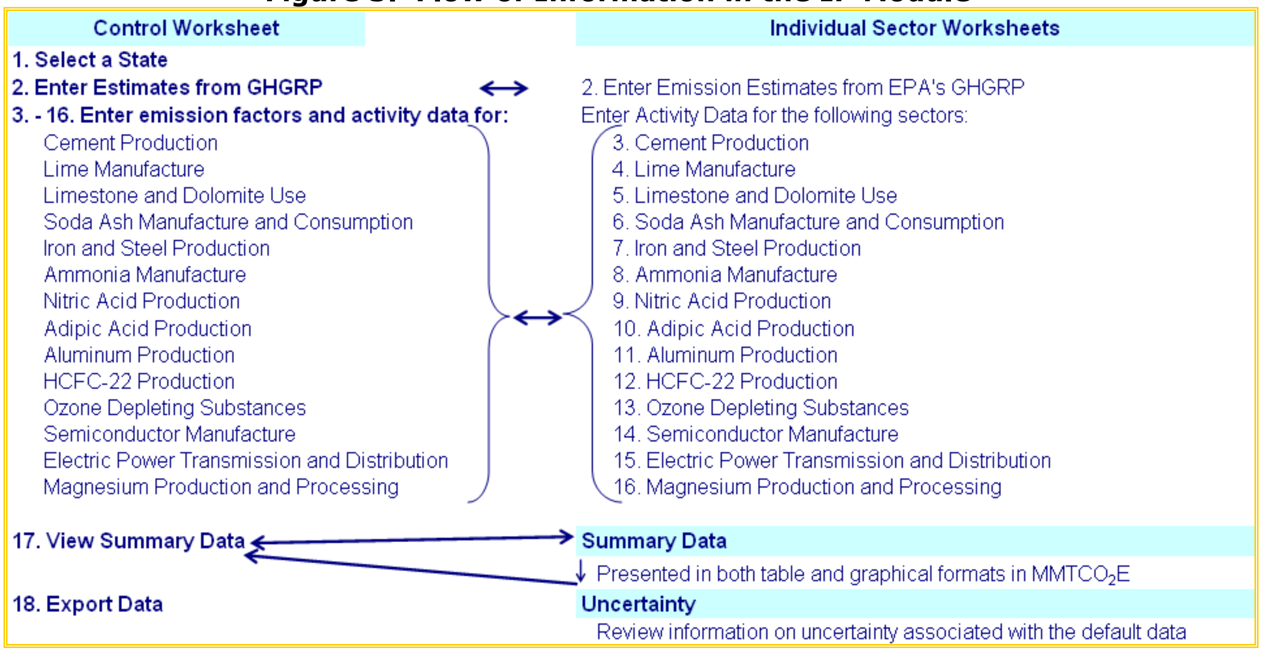
Module Worksheet	Data Required	Gas(es)
Cement Production	Emission factors and production data for clinker and cement kiln dust (CKD)	CO_2
Lime Manufacture	Emission factors and production data for high-calcium lime, and dolomitic lime	
Limestone and Dolomite Use	Emission factors and consumption data for limestone, dolomite, and magnesium produced from dolomite	
Soda Ash Manufacture and Consumption	Emission factors and consumption data for manufacture and consumption of soda ash	
Iron and Steel Production	Emission factors and production data for Basic Oxygen Furnace (BOF) at Integrated Mill with Coke Ovens, Basic Oxygen Furnace (BOF) at Integrated Mill without Coke Ovens, Electric Arc Furnace (EAF), and Open Hearth Furnace (OHF)	
Ammonia Manufacture	Emission factors and production and consumption data for ammonia production, and urea consumption	
Nitric Acid Production	Emission factor, production data, and Percent N_2O Released after Pollution Control for nitric acid production	N_2O
Adipic Acid Production	Emission factor, production data, and Percent N_2O Released after Pollution Control for adipic acid production	
Aluminum Production	Emission factors for Prebake and Søderberg technologies and aluminum production data by technology	CO_2 and PFC
HCFC-22 Production	Emission factor and production data for HCFC-22 production	HFC, PFC, NF_3, and SF_6
Consumption of Substitutes for Ozone-Depleting Substances (ODS)	No input data required*	
Semiconductor Manufacture	No input data required*	
Electric Power Transmission and Distribution	Emission factor and SF_6 consumption data for electric power transmission and distribution	
Magnesium Production and Processing	Emission factor and consumption data for primary production, secondary production, and casting	

*According to inventory guidance, emissions of HFCs, PFCs, NF_3, and SF_6 from ODS substitutes and semiconductor manufacture can be estimated by apportioning national or regional emissions to each state based on population. Because this tool apportions national or regional emissions based on state population, the emission factors and activity data for these sources are not required.

1.2.2 Tool Layout

Because there are multiple steps to complete within the IP module, it is important to understand the module's overall design. The layout of the IP module is presented in Figure 3.

Figure 3. Flow of Information in the IP Module*



* According to inventory guidance, emissions of HFCs, PFCs, NF_3, and SF_6 from ODS substitutes and semiconductor production can be estimated by apportioning national emissions to each state based on population. Because this tool apportions national emissions based on state population, no emission factors need to be entered for these sources.

1.3 METHODOLOGY

This section provides a guide to using the IP module of the SIT to estimate CO_2, N_2O, NF_3, HFC, PFC, and SF_6 emissions from IP. The sectors included in the IP module are cement production, lime manufacture, limestone and dolomite use, soda ash manufacture and consumption, iron and steel production, ammonia manufacture, nitric and adipic acid production, aluminum production, HCFC-22 production, consumption of substitutes for ozone depleting substances, semiconductor manufacture, electric power transmission and distribution, and magnesium production and processing. Because the methodology varies by sector, they are discussed separately and specific examples for each sector are provided.

The IP module follows the general methodology outlined in Chapter 6 of the Emissions Inventory Improvement Program (EIIP) guidance, however because of the automation of the calculations within the tool, the order of steps discussed in this guide do not always follow the order of steps discussed within the EIIP guidance document.

This User's Guide provides an overview of the estimation methodology used in the IP module by walking through the following steps: (1) select a state; (2) enter available data aggregated for EPA's Greenhouse Gas Reporting Program; (3) enter emission factors and activity data for cement production; (4) enter emission factors and activity data for lime manufacture; (5) enter emission factors and activity data for limestone and dolomite use;

(6) enter emission factors and activity data for soda ash manufacture and consumption; (7) enter emission factors and activity data for iron and steel production; (8) enter emission factors and activity data for ammonia manufacture; (9) enter emission factors and activity data for nitric acid production; (10) enter emission factors and activity data for adipic acid production; (11) enter emission factors and activity data for aluminum production; (12) enter emission factors and activity data for HCFC-22 production; (13) review sector worksheet for consumption of substitutes for ozone depleting substances; (14) review sector worksheet for semiconductor manufacture; (15) enter emission factors and activity data for electric power transmission and distribution; (16) complete control and sector worksheets for magnesium production and processing; (17) review summary information; and (18) export data. The general equations used to calculate CO_2, N_2O, and HFC, PFC, NF_3, and SF_6 emissions from IP are shown in the discussion of each specific sector.

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) Enter Emission Estimates for Facilities Reporting to EPA's Greenhouse Gas Reporting Program (OPTIONAL)

Additional data, such as emissions and activity data, are also available through EPA's Greenhouse Gas Reporting Program (GHGRP) for 2010 and on. You have the option to rely on this data to estimate emissions for select source categories.

The GHGRP requires reporting of greenhouse gas (GHG) data and other relevant information from large sources and suppliers in the United States. EPA's reporting threshold for the GHGRP is generally facilities that emit a total of 25,000 $MTCO_2E$ per year. However, in some instances, EPA has identified source categories that are "all in" or do not have a reporting threshold (i.e., all facilities in operation for that source category need to report GHG emissions to EPA). This simplifies the determination process for GHGRP reporting applicability.

Cement production, lime manufacturing, soda ash manufacturing, ammonia manufacturing, nitric acid production, adipic acid production, aluminum production, and HCFC-22 production/HFC-23 destruction are the industrial process source categories that are "all in". Information about the GHGRP can be accessed at: https://www.epa.gov/ghgreporting.

If you would like to incorporate GHGRP data into your state's GHG inventory for the source categories identified above, follow the steps outlined below.

1. Use EPA's Facility-Level Information on GreenHouse Gases Tool (FLIGHT) to determine if your state has applicable emissions from the GHGRP to incorporate in your GHG inventory.
    a. Go to https://ghgdata.epa.gov/ghgp/main.do.
    b. Select your state on the initial screen pop up or on the top left-hand portion of the webpage.

c. At the bottom of the webpage (under the map), remove checks from all sectors except “Chemicals”, “Minerals”, or “Metals”.[1]
d. Hover over the gear icon to the top right of the selected sector, and only check the source category of interest to determine if applicable emissions are available. (Note: Only select one source category at a time to view emissions from that source.)
e. Select the button on the left side of the webpage labeled "APPLY SEARCH".
f. View if you have emissions for the selected source category in your state.
g. Repeat steps 1a-1f for each source category listed above to determine if your state has applicable emissions from the GHGRP to incorporate in your GHG inventory.

Note: *Do not pull emissions directly from FLIGHT to incorporate into the IP Module, as they include both process and stationary combustion emissions, and this will result in double counting in your GHG inventory between the IP and Stationary Combustion Modules.*

2. Once applicability is determined, use EPA’s Envirofacts Customized Search to access and view process emissions for most source categories. (For adipic acid, HCFC-22 production/HFC-23 destruction, lime manufacturing [CEMS reporters only], and soda ash manufacturing see Step 3.)

    a. Go to https://www.epa.gov/enviro/greenhouse-gas-customized-search.
    b. Scroll down and select the relevant source category.
    c. At the bottom of the next page, select “Step 2: Retrieve Tables for Selected Subjects”.
    d. On the next page, select the table you would like to view by clicking the radio button to the left of the table title, and then select “Step 3: Select Columns”. (Key words to look for when selecting the table to view include “subpart-level”, and/or “emissions”. A common table name you may select is “Subpart_Level_Information”.)
    e. On the next page, select the Columns you would like to view by checking the box to the left, and then select “Step 4: Enter Search Criteria”. (Key words to look for when selecting columns include “emissions”, “specified GHG”, or “facility-wide”. A common column name you may select is “Greenhouse Gas Quantity”.)
    f. On the next page, enter your state’s abbreviation in the State Abbreviation form, and the relevant reporting year, then select “Search Database” or “Output to CSV File” at the bottom of the page. “Search Database” will display your results in a web format first, and then present the option to download the CSV file. “Output to CSV File” will download your results immediately in a CSV file.
    g. Sum the relevant emissions data in the CSV file and then transfer the CSV results to the “GHGRP Data Input” tab in the relevant worksheet cells.

[1] “Chemicals" include ammonia manufacturing, nitric acid production, adipic acid production, and HCFC-22 production/HFC-23 destruction. “Minerals” include cement production, lime manufacturing, and soda ash manufacturing. “Metals” include aluminum production.

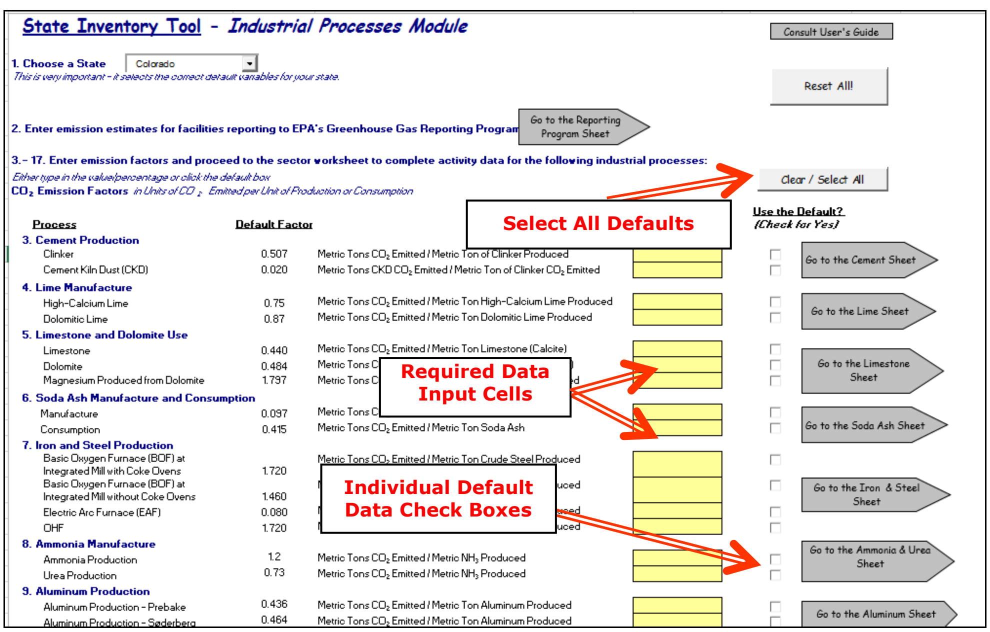
3. For select source categories (adipic acid, HCFC-22 production/HFC-23 destruction, lime manufacturing [CEMS reporters only], and soda ash manufacturing), detailed process emissions data must be accessed through an EPA-published spreadsheet available here: https://www.epa.gov/ghgreporting/ghg-reporting-program-data-sets, in the file titled "Subpart E, O, S-CEMS, BB, CC, LL, RR Data Set". Transfer the relevant emissions data to the "GHGRP Data Input" tab in the relevant worksheet cells.

Step (3) Enter Emission Factors and Activity Data for Cement Production

Control Worksheet

The second step for the control worksheet is to either select the default data provided or to enter user-specified data that will be used throughout the tool. To proceed with the default data, select the "Clear/Select All" button for each sector on the control worksheet or check the individual default box directly to the right of specific yellow input cells. See Figure 4 for locations of the "Clear/Select All" buttons, individual default check boxes, and yellow input cells. Note that this number can be overwritten if you later discover that the data for your state differ from the default data provided by the tool. To enter user-specified inputs, enter data 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. Information requirements on the control worksheet for each sector are discussed separately below.

Figure 4. Control Worksheet for the IP Module



The first type of required data in the control worksheet is emission factors for clinker, and cement kiln dust used in cement production. CO_2 emissions from cement production consist of emissions produced during the cement clinker production processes and are in units of metric tons of CO_2 released per metric ton of clinker or cement kiln dust produced. Emissions from the production of masonry cement are accounted for in Lime emissions estimates.

Cement Production Sector Worksheet

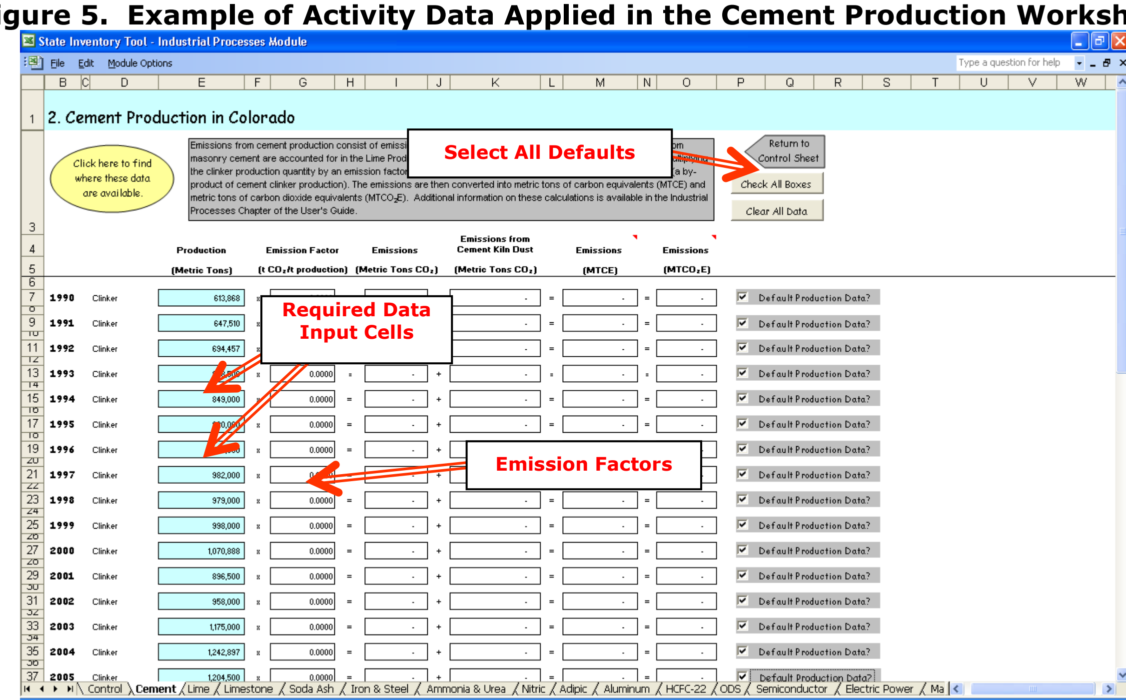
The activity data required to populate the blue cells in the cement production worksheet are metric tons of clinker produced annually, as shown in Figure 5. Select "Check All Boxes" if you would like to use default data provided in the IP module. Activity data for cement production by state is available from USGS (2021e). CO_2 is created when calcium carbonate ($CaCO_3$) is heated in a cement kiln to form lime (calcium oxide or CaO) and CO_2. This process is known as calcination or calcining.

Cement clinker emissions are calculated by multiplying the clinker production quantity by the emission factor entered on the control worksheet and adding the product to the emissions from cement kiln dust (a by-product of cement clinker production). The emissions are then converted from metric tons of carbon equivalents (MTCE) to metric tons of carbon dioxide equivalents ($MTCO_2E$). Equation 1 shows this calculation for CO_2 emissions from cement production.

Equation 1. Emission Equation for Cement Production

$$\text{Emissions } (MTCO_2E) = \text{Production (metric tons)} \times \text{Emission Factor } (t\ CO_2/t\ \text{production}) + \text{Emissions from Cement Kiln Dust (Metric tons } CO_2)$$

Figure 5. Example of Activity Data Applied in the Cement Production Worksheet



Step (4) Enter Emission Factors and Activity Data for Lime Manufacture

Control Worksheet

The emission factors for high-calcium lime and dolomitic lime manufacture are the next required inputs on the control worksheet. Lime is manufactured by heating limestone (mostly CaCO3) in a kiln, creating CaO and CO_2. The IP module estimates these CO_2 emissions from two types of lime: high-calcium lime and dolomitic lime production.

Lime Manufacture Sector Worksheet

Production data for high-calcium dolomite and dolomitic lime, and the amount of these used in sugar refining and precipitated calcium carbonate are required inputs in the blue cells of the lime manufacture worksheet as shown in Figure 6. Activity data for lime manufacture by state is available from USGS (2021c).

Before entering the production of high-calcium and dolomitic lime, you must correct for the water content of hydrated lime. The water content can be assumed to be 24.3 percent for high-calcium hydrated lime and 27.3 percent for dolomitic lime. To correct for the water content of hydrated lime, multiply the production data for high-calcium hydrated lime and dolomitic hydrated lime by their respective percentages of *dry* lime to find the corrected production numbers for both varieties of hydrated lime. An example of this correction for high-calcium lime is shown in Equation 2.

Equation 2. Example Calculation for Hydrated Lime Correction

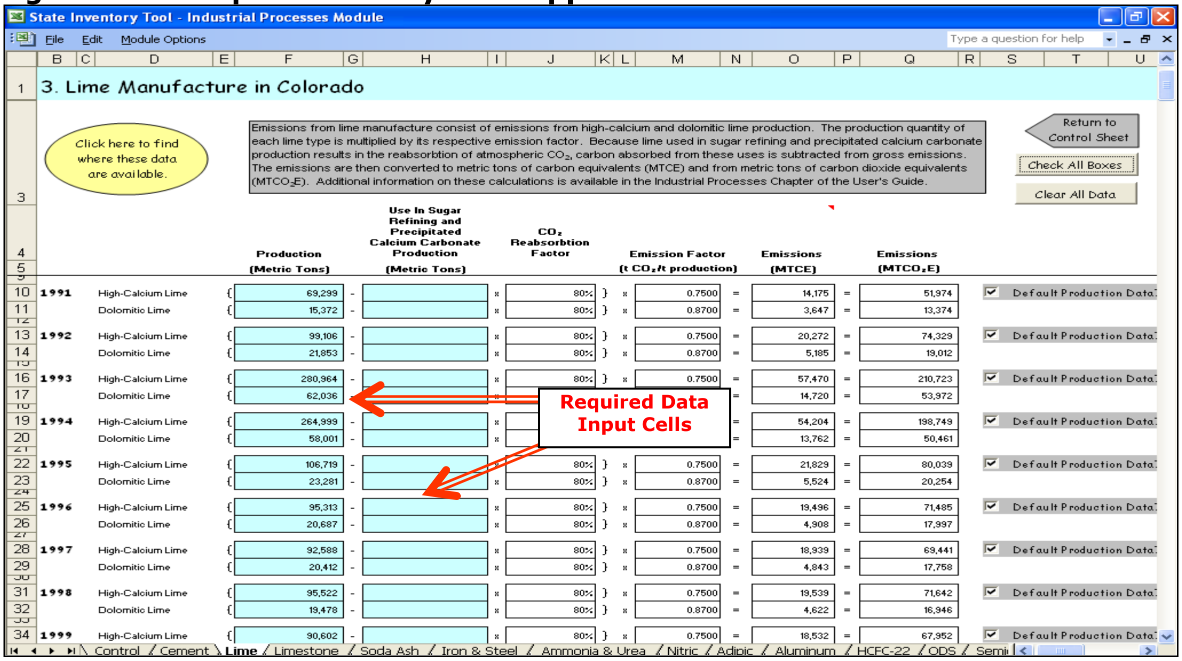
Corrected Lime Content of High-Calcium Hydrated Lime (metric tons) = High-Calcium Hydrated Lime Production (metric tons) x (1 – 0.24 metric tons water/metric ton high-calcium hydrated lime)

To calculate emissions from this source, the production quantity of each lime type is multiplied by its respective emission factor from the control worksheet. Because lime used in sugar refining and precipitated calcium carbonate production results in the reabsorption of atmospheric CO_2, carbon absorbed from these uses is subtracted from gross emissions. The emissions are then converted from metric tons of carbon equivalents (MTCE) to metric tons of carbon dioxide equivalents ($MTCO_2E$). Equation 3 shows this calculation for CO_2 emissions from cement production.

Equation 3. Emission Equation for Lime Manufacture

Emissions ($MTCO_2E$) = [Production (metric tons) - Sugar Refining and Precipitated Calcium Carbonate Production (metric tons) × CO_2 Reabsorbtion Factor (80%)] × Emission Factor (MT CO_2/MT production)

Figure 6. Example of Activity Data Applied in the Lime Manufacture Worksheet



Step (5) Enter Emission Factors and Activity Data for Limestone and Dolomite Use

Control Worksheet

The next inputs on the control worksheet are emission factors for limestone and dolomite use, and magnesium produced from dolomite. Limestone ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$) are basic raw materials used by a wide variety of industries, including the construction, agriculture, chemical, glass manufacturing, environmental pollution control, and metallurgical industries such as magnesium (Mg) production.

Limestone and Dolomite Use Sector Worksheet

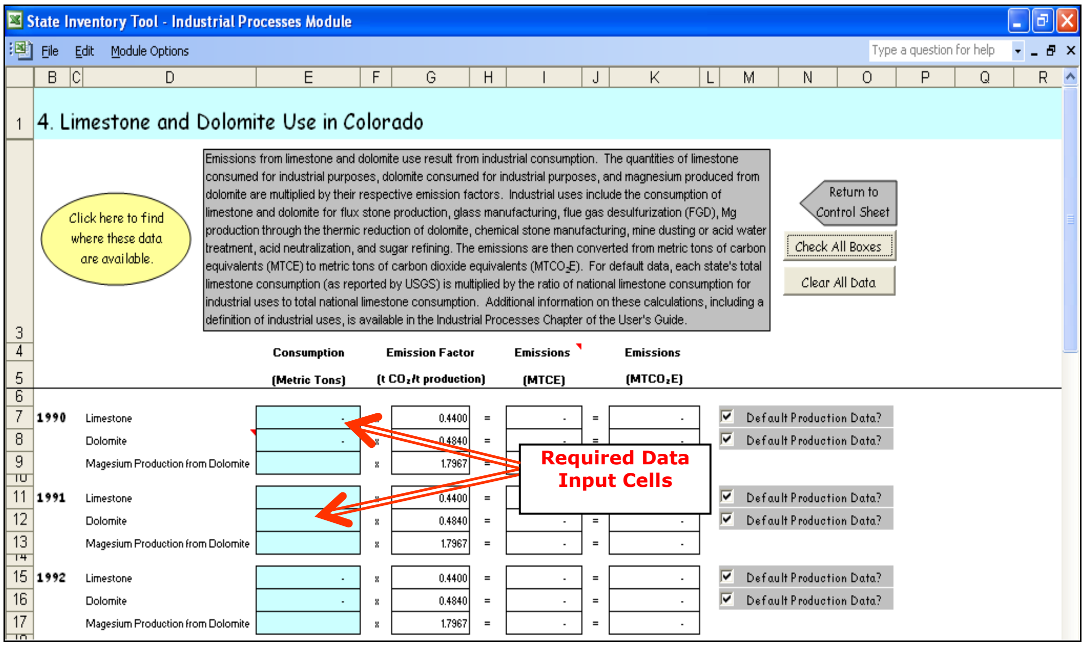
Production data for limestone and dolomite use, and magnesium production from dolomite are required as inputs in the blue cells of the limestone and dolomite worksheet as displayed in Figure 7. As an example, CO_2 is emitted as a by-product from the reaction of limestone or dolomite with impurities in the iron ore and fuels heated in a blast furnace. Activity data for limestone and dolomite use by state is available from USGS (2021f).

The quantities of limestone consumed for industrial purposes, dolomite consumed for industrial purposes, and magnesium produced from dolomite are multiplied by their respective emission factors. The emissions are then converted from metric tons of carbon equivalents (MTCE) to metric tons of carbon dioxide equivalents ($MTCO_2E$). For default data, each state's total limestone consumption (as reported by USGS) is multiplied by the ratio of national limestone consumption for industrial uses to total National limestone consumption. Equation 4 shows this calculation for CO_2 emissions from limestone and dolomite use.

Equation 4. Emission Equation for Limestone and Dolomite Use

$$\text{Emissions } (MTCO_2E) = \text{Consumption (metric tons)} \times \text{Emission Factor } (MT\ CO_2/MT \text{ production})$$

Figure 7. Example of Activity Data Applied in the Limestone and Dolomite Use Worksheet



Step (6) Enter Emission Factors and Activity Data for Soda Ash Manufacture and Consumption

Control Worksheet

Soda ash manufacture and consumption emission factors are required inputs on the control worksheet in order to calculate emissions from this source. Although only three states produced soda ash at the time of publication (Wyoming, California, and Colorado), all states consumed it. Thus, all states should estimate CO_2 emissions from soda ash consumption.

Soda Ash Manufacture and Consumption Sector Worksheet

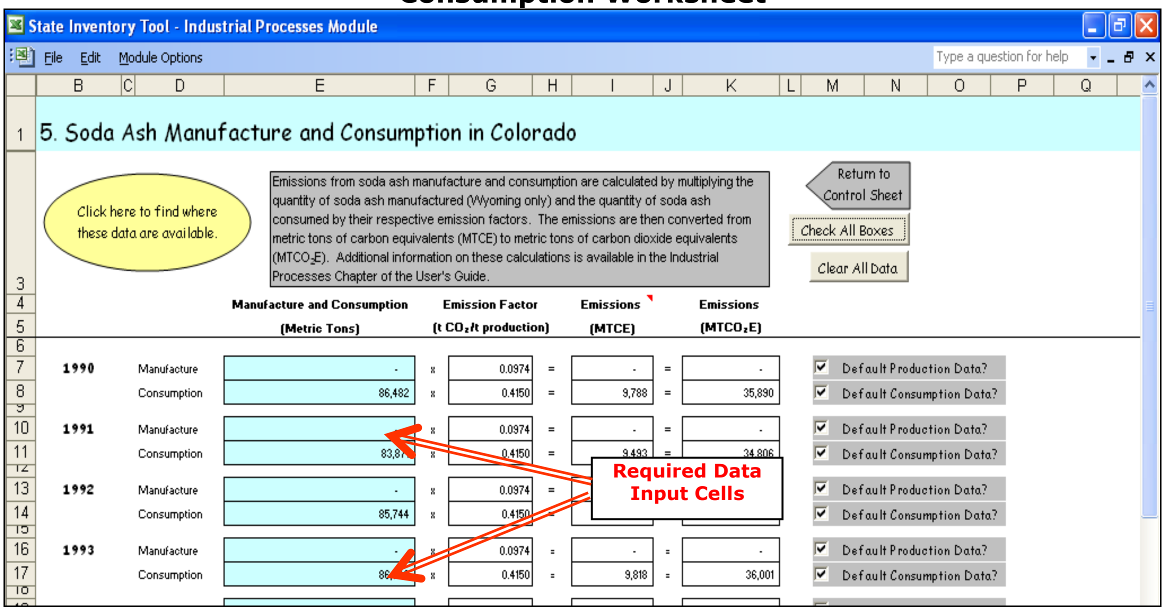
Production data for the manufacture and consumption of soda ash are required as inputs in the blue cells of the soda ash manufacture worksheet as shown in Figure 8. Under the soda ash production method used in some states, trona (an ore from which natural soda ash is made) is calcined in a rotary kiln and chemically transformed into a crude soda ash that requires further processing. CO_2 and water are generated as a by-product of the calcination process. CO_2 is also released when soda ash is consumed in products such as glass, soap, and detergents. Activity data for soda ash manufacture and consumption is available from USGS (2020).

Emissions from soda ash manufacture and consumption are calculated by multiplying the quantity of soda ash manufactured (Wyoming only) and the quantity of soda ash consumed by their respective emission factors. The emissions are then converted from metric tons of carbon equivalents (MTCE) to metric tons of carbon dioxide equivalents ($MTCO_2E$) as shown in Equation 5.

Equation 5. Emission Equation for Soda Ash Manufacture and Consumption

$$\text{Emissions } (MTCO_2E) = \text{Manufacture/Consumption (metric tons)} \times \text{Emission Factor } (MT\ CO_2/MT\ \text{production})$$

Figure 8. Example of Activity Data Applied in the Soda Ash Manufacture and Consumption Worksheet



Step (7) Enter Emission Factors and Activity Data for Iron and Steel Production

Control Worksheet

Emission factors for the following iron and steel production processes are required as inputs on the control worksheet: Basic Oxygen Furnace (BOF) at Integrated Mill with Coke Ovens, Basic Oxygen Furnace (BOF) at Integrated Mill without Coke Ovens, Electric Arc Furnace (EAF), and open hearth furnace (OHF). In addition to being an energy intensive process, the production of iron and steel also generates process-related emissions of CO_2. It is strongly advised that users enter state-specific information, as default data are based on national averages and are not available for all years.

Iron and Steel Production Sector Worksheet

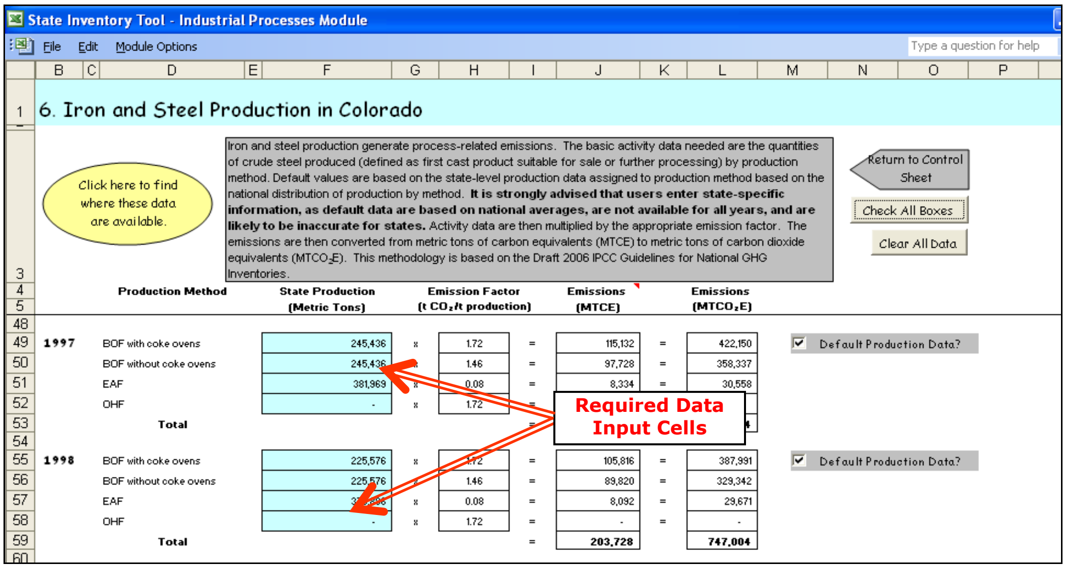
Activity data for the production of iron and steel are required as inputs in the blue cells of the iron and steel worksheet displayed in Figure 9. The basic activity data needed are the quantities of crude steel produced (defined as first cast product suitable for sale or further processing) by production method. It is strongly advised that users enter state-specific information, as default data are based on national averages, are not available for all years, and are likely to be inaccurate for states. The national data are provided by the American Iron and Steel (AISI) Annual Statistics Report 2010 (AISI 2011).

Emissions from iron and steel production are based on the state-level production data assigned to production method based on the national distribution of production by method. The emissions are then converted from metric tons of carbon equivalents (MTCE) to metric tons of carbon dioxide equivalents ($MTCO_2E$) as shown in Equation 6.

Equation 6. Emission Equation for Iron and Steel Production

Emissions ($MTCO_2E$) =
Manufacture/Consumption (metric tons) × Emission Factor (MT CO_2/MT production)

Figure 9. Example of Activity Data Applied in the Iron and Steel Production Worksheet



Step (8) Enter Emission Factors and Activity Data for Ammonia Manufacture

Control Worksheet

The emission factors for ammonia and urea production are the next required inputs on the control worksheet. Emissions of CO_2 occur during the production of synthetic ammonia, primarily through the use of natural gas as a feedstock.

Ammonia Manufacture Sector Worksheet

Data for the production of ammonia and consumption of urea are required inputs in the blue cells on the ammonia production worksheet, shown in Figure 10. Activity data for ammonia manufacture by state is available from USGS (2021d). Activity data for urea consumption by state is estimated based on state data from AAPFCO (2017) and TVA (1991 through 1994).

Emissions from ammonia production and urea consumption are calculated by multiplying the quantity of ammonia produced and urea applied by their respective emission factors. Emissions from urea consumption are subtracted from emissions due to ammonia production. The emissions are then converted from metric tons of carbon equivalents

(MTCE) to metric tons of carbon dioxide equivalents ($MTCO_2E$) as shown in Equation 7 and Equation 8.

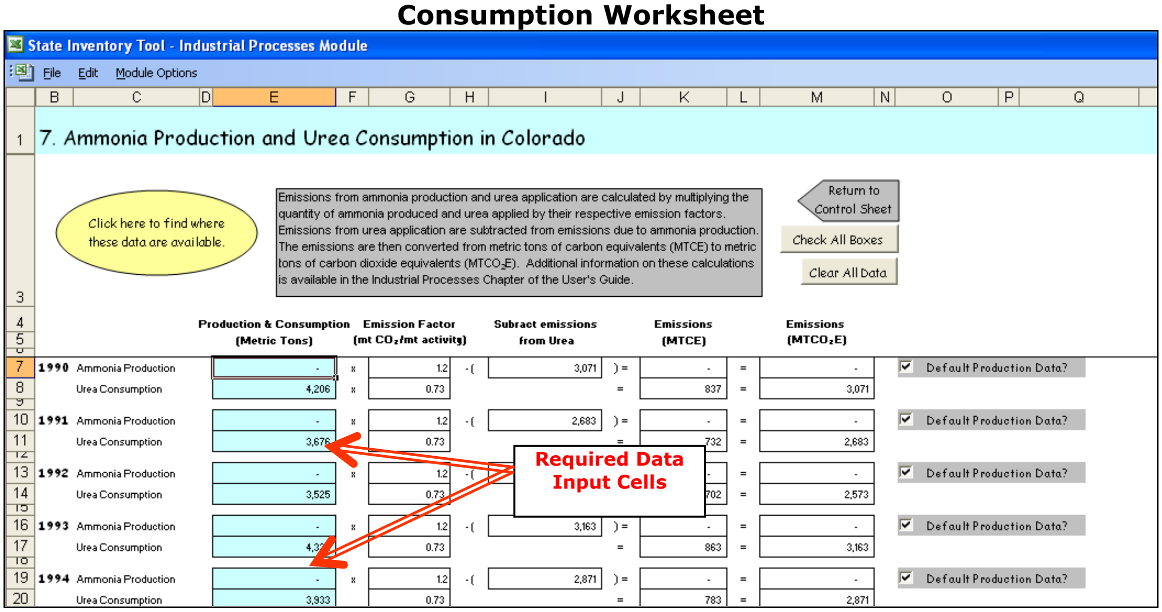
Equation 7. Emission Equation for Ammonia Production

Emissions ($MTCO_2E$) =
Production of Ammonia (metric tons) × Emission Factor (MT CO_2/MT activity) - Emissions from Urea ($MTCO_2E$)

Equation 8. Emission Equation for Urea Consumption

Emissions ($MTCO_2E$) =
Consumption of Urea (metric tons) × Emission Factor (MT CO_2/MT activity)

Figure 10. Example of Activity Data Applied in the Ammonia Production and Urea Consumption Worksheet



Step (9) Enter Emission Factors and Activity Data for Nitric Acid Production

Control Worksheet

The emission factor for nitric acid production is the next required input for the control worksheet. The production of nitric acid (HNO_3) produces N_2O as a by-product, via the oxidation of ammonia. Nitric acid is a raw material used primarily to make synthetic commercial fertilizer and is also a major component in the production of adipic acid (a feedstock for nylon) and explosives.

Nitric Acid Production

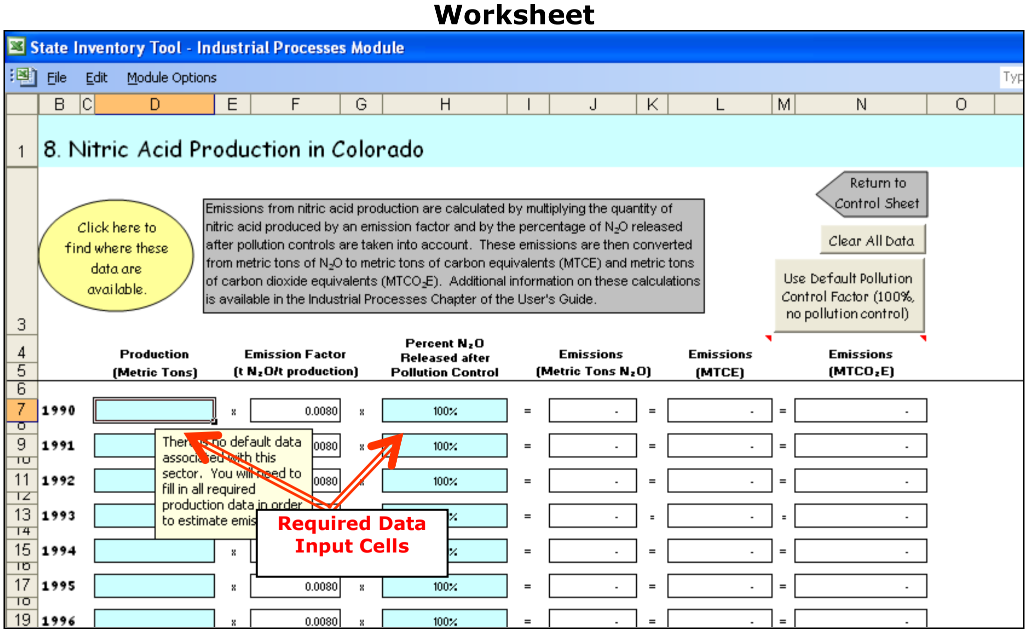
Data for the amount of nitric acid produced, as well as the percent N_2O released after pollution control are inputs for the nitric acid worksheet as seen in Figure 11. Activity data for nitric acid production is available from SRI 2000. The production of nitric acid (HNO_3) produces N_2O as a by-product, via the oxidation of ammonia. During this reaction, N_2O is formed as a by-product and is released from reactor vents into the atmosphere. At present, the nitric industry controls for oxides of nitrogen through two technologies: non-selective catalytic reduction (NSCR) and selective catalytic reduction (SCR). Only one of these technologies, NSCR, is effective at destroying N_2O emissions in the process of destroying NO_x emissions.

Emissions from nitric acid production are calculated by multiplying the quantity of nitric acid produced by an emission factor and by the percentage of N_2O released after pollution controls are considered. These emissions are then converted from metric tons of carbon equivalents (MTCE) to metric tons of carbon dioxide equivalents ($MTCO_2E$) as seen in Equation 9.

Equation 9. Emission Equation for Nitric Acid Production

Emissions ($MTCO_2E$) =
Production of Nitric Acid (metric tons) × Emission Factor (MT N_2O/MT production) x Percent N_2O Released after Pollution Control x GWP N_2O

Figure 11. Example of Activity Data Applied in the Nitric Acid Production Worksheet



Step (10) Enter Emission Factors and Activity Data for Adipic Acid Production

Control Worksheet

The emission factor for adipic acid production is required next on the control worksheet. About 90 percent of all adipic acid produced in the United States is used in the production of nylon 6,6, as well as production of some low-temperature lubricants. It is also used to provide foods with a "tangy" flavor.

Adipic Acid Production Sector Worksheet

Data for the amount of adipic acid produced, as well as the percent N_2O released after pollution control are inputs for the adipic acid worksheet as seen in Figure 12. A dialogue box will appear if adipic acid is not produced in your state. Note that plants may consider this data confidential and could be reluctant to disclose it, in which case, states should use the adipic acid production capacity data in the Chemical Market Reporter.

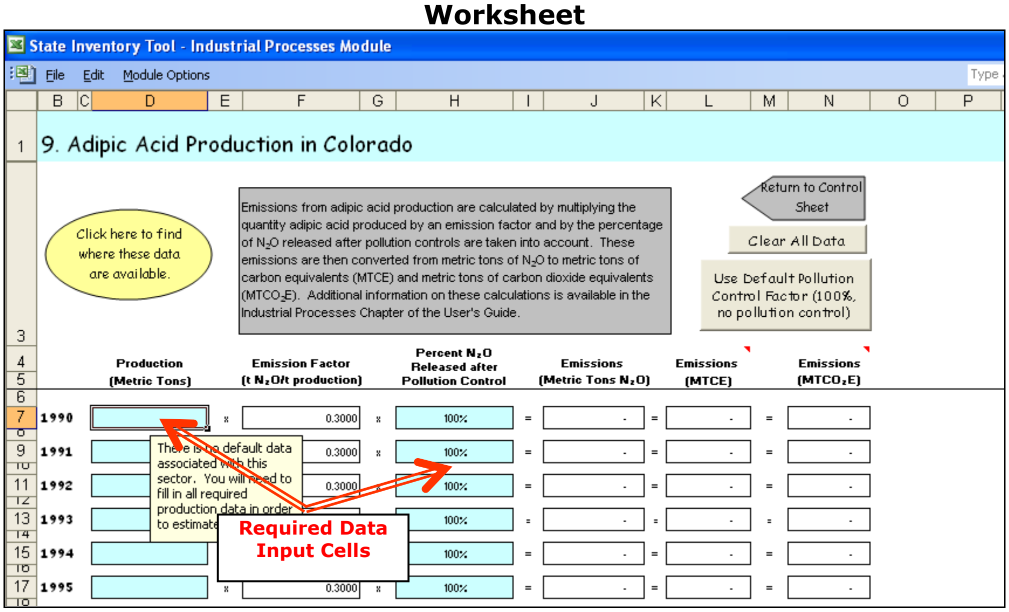
Adipic acid is produced through a two-stage process. The first stage involves the oxidation of cyclohexane to form a cyclohexanone/cyclohexanol mixture. The second stage involves the oxidation of ketone-alcohol with nitric acid. N_2O is generated as a by-product of this reaction and enters the waste gas stream. In the United States, this waste gas is treated to remove NO_x and other regulated pollutants (and, in some cases, N_2O as well) and is then released into the atmosphere.

Emissions from adipic acid production are calculated by multiplying the quantity adipic acid produced by an emission factor and by the percentage of N_2O released after pollution controls are considered. These emissions are then converted from metric tons of N_2O to metric tons of carbon equivalents (MTCE) and then metric tons of carbon dioxide equivalents ($MTCO_2E$), shown in Equation 10.

Equation 10. Emission Equation for Adipic Acid Production

Emissions ($MTCO_2E$) =
Production of Adipic Acid (metric tons) × Emission Factor (MT N_2O/MT production) x Percent N_2O Released after Pollution Control x GWP N_2O

Figure 12. Example of Activity Data Applied in the Adipic Acid Production Worksheet



Step (11) Enter Emission Factors and Activity Data for Aluminum Production Control Worksheet

The emission factors for aluminum production are the next required inputs on the control worksheet. The aluminum production industry is thought to be the largest source of two PFCs – tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6). Emissions of these two potent greenhouse gases (GHGs) and CO_2 occur during the reduction of alumina in the primary smelting process.[2] Emission factors are required as inputs on the control worksheet for PFC emissions, CO_2 emissions from Prebake technology, and CO_2 emissions from Søderberg technology.

Aluminum Production Sector Worksheet

Data for the production of aluminum are required in the blue cells of the aluminum worksheet, shown in Figure 13. Activity data for aluminum production is available from USGS (2021b).

PFC emissions from aluminum production are calculated by multiplying the quantity of aluminum produced during a year by the specific emission factor for that year. CO_2 emissions from aluminum production are calculated by multiplying the quantity of aluminum produced during a year by a weighted CO_2 emission factor. The emission factor is weighted by the percent of aluminum production using either Prebake or Søderberg technology. If the percent of production by technology type is unknown, a default percentage is assumed based on national data from the U.S. Inventory (U.S. EPA 2020). It is strongly advised that users enter state-specific information, as default data are based on national averages.

These emissions are then converted from metric tons of carbon equivalents (MTCE) to metric tons of carbon dioxide equivalents ($MTCO_2E$), shown in Equation 11.

Equation 11. Emission Equation for Aluminum Production

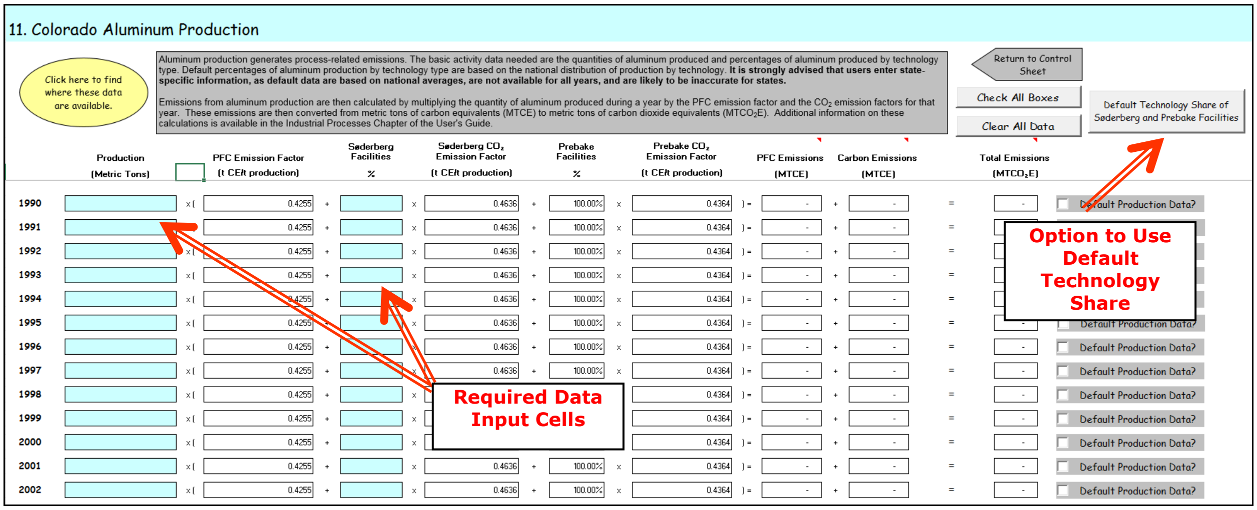
$$\text{Total Emissions } (MTCO_2E) = \text{PFC Emissions } (MTCO_2E) + CO_2 \text{ Emissions } (MTCO_2E)$$

$$\text{PFC Emissions } (MTCO_2E) = \text{Production of Aluminum (metric tons)} \times \text{Emission Factor (MT CE/MT production)}$$

$$CO_2 \text{ Emissions } (MTCO_2E) = \text{Production of Aluminum (metric tons)} \times [(\text{Percent of Production}_{Prebake} \times EF_{Prebake}) + (\text{Percent of Production}_{Søderberg} \times EF_{Søderberg})] \text{ (MT CE/MT production)}$$

2 Perfluorinated carbons are not emitted during the smelting of recycled aluminum.

Figure 13. Example of Activity Data Applied in the Aluminum Production Worksheet



Step (12) Enter Emission Factors and Activity Data for HCFC-22 Production

Control Worksheet

The next emission factor required for the control worksheet is for HFC-23 emissions resulting from HCFC-22 production, in metric tons of HFC-23 emitted per metric ton of HCFC-22 produced.

HCFC-22 Production Sector Worksheet

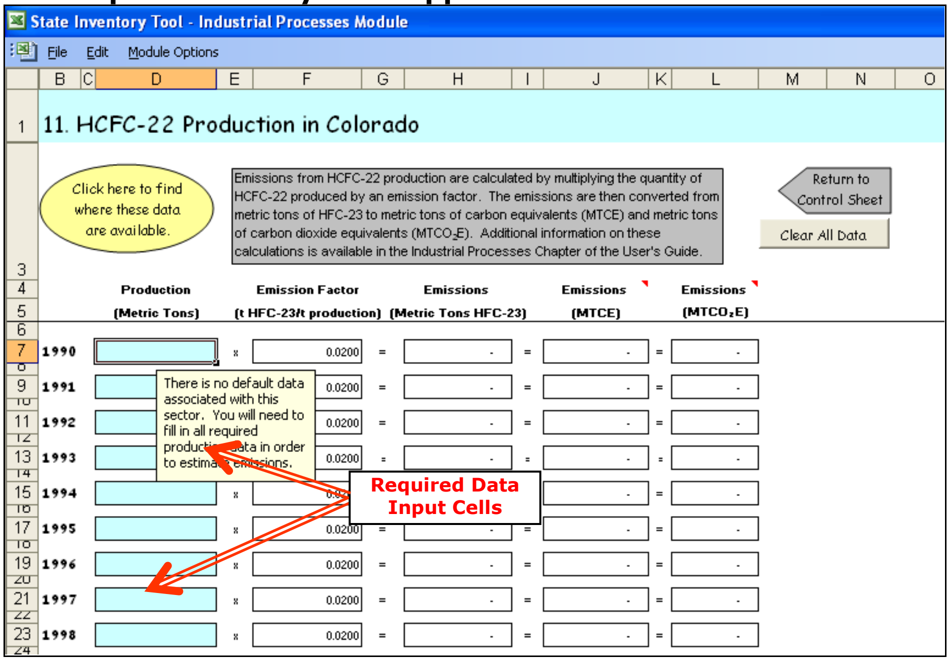
HFC-23, one type of HFC, is known to be emitted in significant quantities as a by-product of HCFC-22 production. Data for the production of HCFC-22 are required inputs in the blue cells on the HCFC-22 production worksheet, shown in Figure 14. In order to obtain activity data, in-state manufacturers of HCFC-22 should be consulted first. Additionally, the Chemical Manufacturers Association (Washington, D.C.), Alliance for Responsible CFC Policy (Arlington, VA), and Grant Thorton Consulting (Washington, D.C.) can be contacted for information on state-by-state production numbers.

Emissions from HCFC-22 production are calculated by multiplying the quantity of HCFC-22 produced by an emission factor. The emissions are then converted from metric tons of HFC-23 to metric tons of carbon equivalents (MTCE) and then metric tons of carbon dioxide equivalents ($MTCO_2E$) as in Equation 12.

Equation 12. Emission Equation for HCFC-22 Production

Emissions ($MTCO_2E$) =
Production of HCFC-22 (metric tons) × Emission Factor (MT HFC-23/MT production) x GWP of HFC-23

Figure 14. Example of Activity Data Applied in the HCFC-22 Production Worksheet



Step (13) Review Sector Worksheet for Consumption of Substitutes for Ozone-Depleting Substances (ODS)

Control Worksheet

There are no emission factor inputs required for the consumption of substitutes for ozone-depleting substances (ODS) as the calculations for this sector are performed on the sector-specific worksheet. Hydrofluorocarbons (HFCs) are used primarily as alternatives to several classes of ODS that are being phased out under the terms of the Montreal Protocol and the Clean Air Act Amendments of 1990. ODSs, which include chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, and hydrochlorofluorocarbons (HCFCs), are used in a variety of industrial applications including refrigeration and air conditioning equipment, aerosols, solvent cleaning, fire extinguishing, foam blowing, and sterilization. Although their substitutes, HFCs, are not harmful to the stratospheric ozone layer, they are powerful GHGs.

Consumption of ODS Sector Worksheet

There are no inputs required for this worksheet, though you are able to input your own emissions estimates in the blue cells. You should review this worksheet to learn your state's contribution to emissions resulting from the consumption of ODS substitutes. The major end uses that consume substitutes for ozone-depleting substances include motor vehicle air conditioning, commercial and industrial refrigeration and air conditioning, residential refrigeration and air conditioning, aerosols, solvent cleaning, fire extinguishing equipment, foam production, and sterilization.

Emissions of HFCs, PFCs, and SF_6 from ODS substitute production are estimated by apportioning regional HFC emissions estimates to each state based on population. State population data were provided by U.S. Census Bureau (2021), and regional HFC emissions estimates were provided by Hu et al. (2017). The resulting state emissions are then converted to metric tons of carbon dioxide equivalents ($MTCO_2E$) as shown in Equation 13.

Equation 13. Emission Equation for Apportioning Emissions from the Consumption of Substitutes for ODS

Emissions ($MTCO_2E$) =
National ODS Substitute Emissions ($MTCO_2E$) × Regional Emissions Share (%) × [State Population / Regional Population]

Step (14) Review Sector Worksheet for Semiconductor Manufacture

Control Worksheet

There are no emission factor inputs required for semiconductor manufacture on the control worksheet as the calculations for this sector are performed on the sector-specific worksheet. The semiconductor industry employs multiple long-lived fluorinated gases in the plasma etching and chemical vapor deposition processes. These include the PFCs CF_4, C_2F_6, and C_3F_8; HFC-23; NF_3, and SF_6. With present industry growth and the increasing complexity of microchips, emissions from the semiconductor industry are expected to increase significantly.

Semiconductor Manufacture Sector Worksheet

There are no inputs required for this worksheet. You should review this worksheet to learn your state's contribution to emissions resulting from the manufacture of semiconductors. The semiconductor industry employs multiple long-lived fluorinated gases in the plasma etching and chemical vapor deposition processes and include PFCs CF_4, C_2F_6, and C_3F_8; HFC-23; NF_3, and SF_6.

Emissions of HFCs, PFCs, NF_3, and SF_6 from semiconductor production are estimated by apportioning national emissions to each state. National emissions are multiplied by a ratio of the value of a state's semiconductor shipments, as found in U.S. Census Bureau (1997, 2002, 2007, 2012, and 2017), to the value of national semiconductor shipments. The resulting state emissions are then converted into metric tons of CO_2 equivalents ($MTCO_2E$) as shown in Equation 14.

Equation 14. Emission Equation for Apportioning Emissions from Semiconductor Manufacture

Emissions ($MTCO_2E$) =
National Semiconductor Manufacture Emissions ($MTCO_2E$) × [Value of State Semiconductor Shipments / Value of National Semiconductor Shipments]

Step (15) Enter Emission Factors and Activity Data for Electric Power Transmission and Distribution

Control Worksheet

The emission factor for electric power transmission and distribution is required on the control worksheet. The largest use for SF_6, both domestically and internationally, is as an electrical insulator in electricity transmission and distribution equipment, such as gas-insulated high-voltage circuit breakers, substations, transformers, and transmission lines.

Electric Power Transmission and Distribution Sector Worksheet

This worksheet requires inputs for the amount of SF_6 consumed for electric power transmission and distribution as shown in Figure 15. Activity data for electric transmission and distribution are available from U.S. EPA (2021) and EIA (2021).

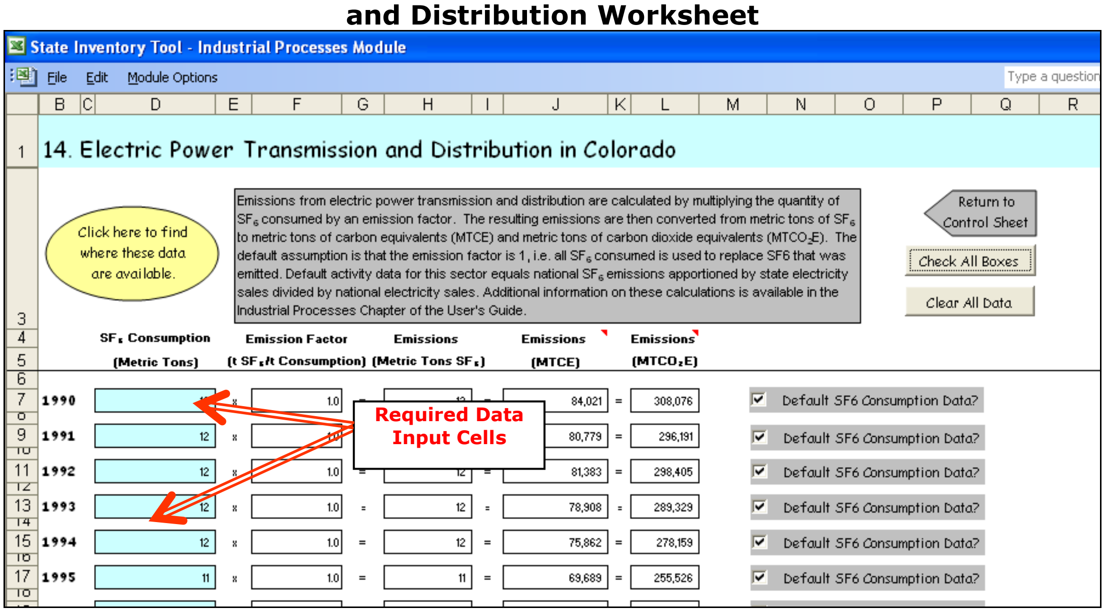
The largest use for SF_6, both domestically and internationally, is as an electrical insulator in electricity transmission and distribution equipment, such as gas-insulated high-voltage circuit breakers, substations, transformers, and transmission lines. The electric utility industry uses the gas because of its high dielectric strength and arc-quenching abilities. Not all of the electric utilities in the United States use SF_6; use of the gas is more common in urban areas where the space occupied by electrical distribution and transmission facilities is more valuable.

Emissions from electric power transmission and distribution are calculated by multiplying the quantity of SF_6 consumed by an emission factor. The resulting emissions are then converted from metric tons of SF_6 to metric tons of carbon dioxide equivalents ($MTCO_2E$) as shown in Equation 15. The default assumption is that the emission factor is 1, i.e. all SF_6 consumed is used to replace SF_6 that was emitted. Default activity data for this sector equals national SF_6 emissions apportioned by state electricity sales divided by national electricity sales.

Equation 15. Emission Equation for Electric Power Transmission and Distribution

$$\text{Emissions } (MTCO_2E) = SF_6 \text{ Consumption (metric tons } SF_6) \times \text{Emission Factor (MT } SF_6\text{/MT Consumption)} \times \text{GWP of } SF_6$$

Figure 15. Example of Activity Data Applied in the Electric Power Transmission and Distribution Worksheet



Step (16) Enter Emission Factors and Activity Data for Magnesium Production and Processing

Control Worksheet

Primary and secondary production, as well as casting emission factors for magnesium production and processing are required in the control worksheet. The Mg metal production and casting industry uses SF_6 as a cover gas to prevent the violent oxidation of molten Mg in the presence of air.

Magnesium Production and Processing Sector Worksheet

In the blue input cells on the magnesium worksheet, enter the quantity of primary magnesium produced, secondary magnesium produced, and magnesium cast during a given year as shown in Figure 16. Activity data for the production and processing of magnesium are available at USGS (2021a).

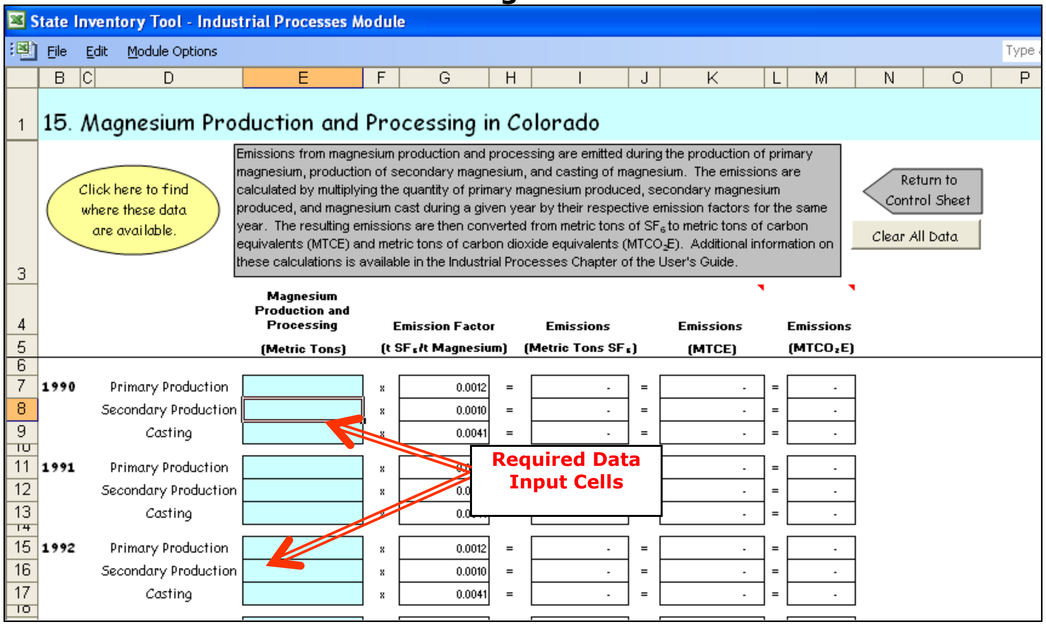
The Mg metal production and casting industry uses SF_6 as a cover gas to prevent the violent oxidation of molten Mg in the presence of air. A gas mixture consisting of CO_2, air, and a small concentration of SF_6 is blown over the molten Mg metal to induce the formation of a protective crust. Most producers of primary Mg metal and most Mg part casters use this technique. SF_6 replaced the previously used sulfur dioxide due to the numerous health and safety risks associated with sulfur dioxide.

Emissions from magnesium production and processing are emitted during the production of primary magnesium, production of secondary magnesium, and casting of magnesium. The emissions are calculated by multiplying the quantity of primary magnesium produced, secondary magnesium produced, and magnesium cast during a given year by their respective emission factors for the same year. The resulting emissions are then converted from metric tons of SF_6 to metric tons of carbon dioxide equivalents ($MTCO_2E$) as shown in Equation 16.

Equation 16. Emission Equation for Magnesium Production and Processing

Emissions ($MTCO_2E$) =
Quantity of Magnesium Produced (metric tons) × Emission Factor (MT SF_6 /MT Magnesium) x GWP of SF_6

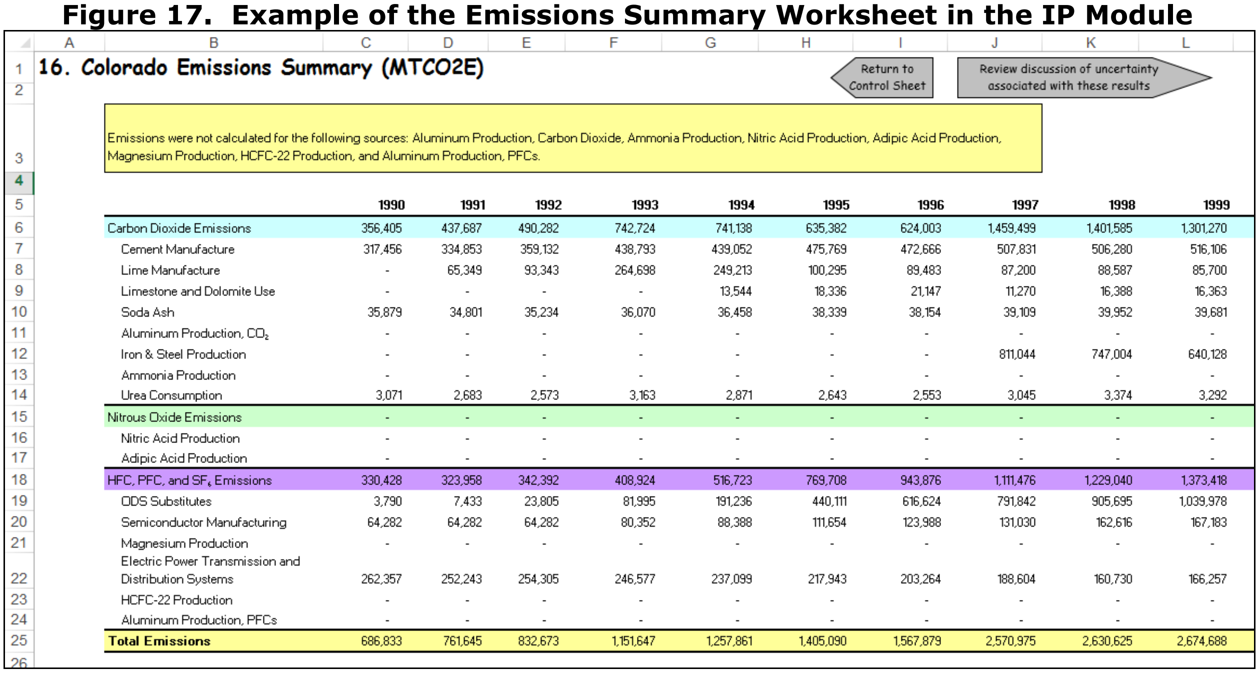
Figure 16. Example of Activity Data Applied in the Magnesium Production and Processing Worksheet



Step (17) Review Summary Information

The steps above provide estimates of total CO_2, N_2O, and HFC, NF_3, PFC, and SF_6 emissions from each IP sector. Total emissions are equal to sum of emissions from each of the fifteen IP sectors, for each year. The information is collected by sector on the summary worksheets. There is a summary worksheet in the IP module that displays results in $MMTCO_2E$. Additionally, the summary worksheet provides an overview of sources excluded from the current emission estimates. Users should review this list to see if they wish to go back and enter data for any of the omitted IP sectors. Figure 17 shows the summary worksheet that sums the emissions from all sectors in the IP module.

Figure 17. Example of the Emissions Summary Worksheet in the IP Module



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Carbon Dioxide Emissions	356,405	437,687	490,282	742,724	741,138	635,382	624,003	1,459,499	1,401,585	1,301,270
Cement Manufacture	317,456	334,853	359,132	438,793	439,052	475,769	472,666	507,831	506,280	516,106
Lime Manufacture	-	65,349	93,343	264,698	249,213	100,295	89,483	87,200	88,587	85,700
Limestone and Dolomite Use	-	-	-	-	13,544	18,336	21,147	11,270	16,388	16,363
Soda Ash	35,879	34,801	35,234	36,070	36,458	38,339	38,154	39,109	39,952	39,681
Aluminum Production, CO_2	-	-	-	-	-	-	-	-	-	-
Iron & Steel Production	-	-	-	-	-	-	-	811,044	747,004	640,128
Ammonia Production	-	-	-	-	-	-	-	-	-	-
Urea Consumption	3,071	2,683	2,573	3,163	2,871	2,643	2,553	3,045	3,374	3,292
Nitrous Oxide Emissions	-	-	-	-	-	-	-	-	-	-
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-
HFC, PFC, and SF_6 Emissions	330,428	323,958	342,392	408,924	516,723	769,708	943,876	1,111,476	1,229,040	1,373,418
ODS Substitutes	3,790	7,433	23,805	81,995	191,236	440,111	616,624	791,842	905,695	1,039,978
Semiconductor Manufacturing	64,282	64,282	64,282	80,352	88,388	111,654	123,988	131,030	162,616	167,183
Magnesium Production	-	-	-	-	-	-	-	-	-	-
Electric Power Transmission and Distribution Systems	262,357	252,243	254,305	246,577	237,099	217,943	203,264	188,604	160,730	166,257
HCFC-22 Production	-	-	-	-	-	-	-	-	-	-
Aluminum Production, PFCs	-	-	-	-	-	-	-	-	-	-
Total Emissions	686,833	761,645	832,673	1,151,647	1,257,861	1,405,090	1,567,879	2,570,975	2,630,625	2,674,688

Step (18) 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 GHG inventory for the state.

To access the "Export Data" button, return to the control worksheet and scroll down to step 17. 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 IP 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 that allows users to view the results, as well as a separate data worksheet with an unformatted version of the results. The second worksheet, the data worksheet, contains the information that is exported to the Synthesis Tool. Users may not modify that worksheet. 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 SIT 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.

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