

1.2 MODULE OVERVIEW

This User's Guide accompanies and explains the Natural Gas and Oil Systems module of the SIT. The SIT was originally developed in conjunction with EPA's Emissions Inventory Improvement Program (EIIP) in order 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 result was a user-friendly and comprehensive set of eleven modules that help users estimate greenhouse gas emissions at the state level.

Because most state inventories developed today rely heavily on the SIT, 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 (EPA 2023a). Users can refer to the chapters and annexes of the U.S. Inventory to obtain additional information not found in the SIT or in the companion User's Guide.

In 2021, EPA began publishing the results of the Inventory of U.S. Greenhouse Gas Emissions and Sinks disaggregated by U.S. state (EPA 2023b) to make consistent state-level GHG data available for all states for use by states, researchers, and the general public. However, EPA recognizes that there will be differences between the state-level estimates published by EPA and inventory estimates developed by states using the SIT or other tools. Inventories compiled by states may differ for several reasons, and differences do not necessarily mean that one set of estimates is more accurate, or "correct." In some cases, the Inventory of U.S. Greenhouse Gas Emissions and Sinks may be using different methodologies, activity data, and emission factors, or may have access to the latest facility-level information through the Greenhouse Gas Reporting Program (GHGRP). In other cases, because of state laws and regulations, states may have adopted accounting decisions that differ from those adopted by UNFCCC and IPCC to ensure comparability in national reporting (e.g., use of different category definitions and emission scopes consistent with state laws and regulations). Users of state GHG data should take care to review and understand differences in accounting approaches to ensure that any comparisons of estimates are equivalent or an apples-to-apples comparison of estimates.

The Natural Gas and Oil Systems module calculates methane (CH₄) and carbon dioxide (CO₂) emissions from all phases of natural gas systems (including production, transmission, venting and flaring, and distribution) and petroleum systems (including production, refining, and transport). The module provides default data for all emission factors and provides some activity data; however, EPA encourages the use of more comprehensive data sources if they are available. Currently default data are not available in the SIT for the transmission, and distribution of natural gas or the refining, and transportation of oil. If using outside data sources, or for a more thorough understanding of the module, please refer to the following discussion for data requirements and methodology.

1.2.1 Data Requirements

To calculate CH₄ and CO₂ emissions from natural gas and oil systems, the following data are required:

- The number of wells and offshore platforms;
- Amount of natural gas vented and flared;
- The number of miles of gathering pipeline;

- The number of gas processing plants and compressor stations;
- The number of miles of transmission pipeline;
- The number of miles of distribution pipeline, if possible, by type (e.g., cast iron, steel, plastic)
- The total number of services (e.g., gas meters);
- Data on oil production, refining, and transportation; and
- Emission factors for each of the above activities.

A complete list of the activities for which activity data and emission factors are necessary to complete the Natural Gas and Oil Systems module is provided in Table 1.

Table 1. Data Requirements for the Natural Gas and Oil Systems Module

Module Worksheet	Activity Data and Emission Factors Required
Natural Gas - Production	Number of wells Number of shallow-water off-shore platforms Number of deep-water off-shore platforms Emission factors for all of the above (MT CH ₄ /well or platform)
Natural Gas - Transmission	Miles of gathering pipeline Number of gas processing plants Number of gas transmission compressor stations ¹ Number of gas storage compressor stations ¹ Miles of transmission pipeline Number of LNG storage compressor stations Emission factors for all of the above (MT CH ₄ /unit)
Natural Gas - Distribution	Miles of cast iron distribution pipeline ² Miles of unprotected steel distribution pipeline ² Miles of protected steel distribution pipeline ² Miles of plastic distribution pipeline ² Number of services Number of unprotected steel services Number of protected steel services Emission factors for all of the above (MT CH ₄ /unit) Emission factor for alternate method* (MT CH ₄ /per mile of distribution pipeline)
Natural Gas - Venting and Flaring	Billion BTUs of natural gas vented and flared Emission factor (MT CO ₂ /Billion Btu natural gas vented and flared)
Petroleum Systems	Barrels of oil produced Barrels of oil refined Barrels of oil transported Emission factor (kg CH ₄ /1000 barrels)

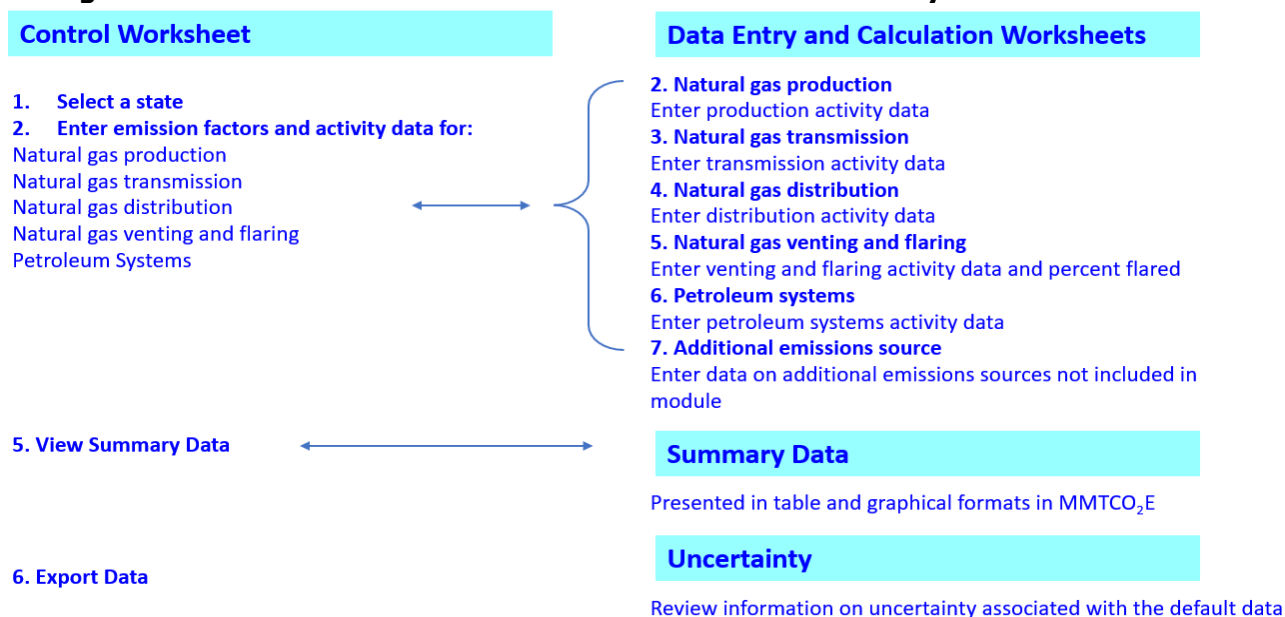
¹ An alternate method is available in which only total transmission pipeline miles are required, and the number of gas transmission and storage compressor stations is calculated based on this entry.

² An alternate method is available in which only total distribution pipeline miles are required, rather than by pipeline type.

1.2.2 Tool Layout

Because there are multiple sections to complete within the Natural Gas and Oil Systems module, it is important to understand the module's overall design. The layout of the Natural Gas and Oil Systems module and the purpose of its worksheets are presented in Figure 3.

Figure 3. Flow of Information in the Natural Gas and Oil Systems Module*



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

1.3 METHODOLOGY

This section provides instructions for using the Natural Gas and Oil Systems module of the SIT to estimate fugitive emissions from natural gas and oil systems. Emissions are calculated for several subcategories, including the production, flaring, transmission, and distribution of natural gas and the production, refining, and transportation of oil. Within the Natural Gas and Oil Systems module, it is important to account for emissions from natural gas and petroleum systems separately because the emission factors and methods are fuel specific. Because the methodology differs for each subcategory, they are discussed separately, and specific examples are provided.

Box 1: State Energy Data Sources

Note that no default activity data are available for the transmission or distribution of natural gas. If state-specific data sources are not available, users can obtain much of the required data from the Energy Information Administration (EIA) (<http://eia.doe.gov>). The Mineral Management Services (MMS) also provides a comprehensive source of data for off-shore oil and gas production activities (<http://www.mms.gov>). In addition, the Office of Pipeline Safety (OPS) has detailed and exhaustive data on all kinds of pipeline (transmission, gathering, distribution, services) that is accessible to the public on its website (<http://ops.dot.gov/stats.htm>). The SIT has more detailed recommendations for data sources for each activity on the gas and oil data sources worksheets.

The Natural Gas and Oil Systems module automatically calculates emissions after you enter activity data for each worksheet (and select or enter the emission factors on the control worksheet). The tool provides default data for venting and flaring of natural gas and the number of natural gas wells, but data must be obtained for the remaining subcategories (see Box 1 for suggestions on where to find data). The exclusion of default data for transmission and distribution and refining and transportation of oil causes the NGO module’s estimates to be much lower than U.S. Inventory.

The Natural Gas and Oil Systems module follows the general methodology from the National Inventory Report (NIR) GHG Inventory by U.S. State. However, not all GHG Inventory by U.S. State sources are included in SIT (e.g., meters in distribution segment). SIT does not have default data for the transmission and distribution of natural gas or the refining and transportation of oil, while the Inventory by U.S. State includes emissions estimates for all components of fossil fuel related activities, including production, transmissions, storage, and distribution as well as abandoned wells.

This User's Guide provides an overview of the estimation methodology used in the Natural Gas and Oil Systems module by walking through the following steps: (1) select a state; (2) enter emission factors and activity data for natural gas production; (3) enter emission factors and activity data for natural gas transmission; (4) enter emission factors and activity data for natural gas distribution; (5) enter emission factors and activity data for natural gas venting and flaring; (6) enter emission factors and activity data for petroleum systems; (7) enter additional emission sources; (8) review summary information; and (9) export data.

For all subcategories, the basic process is to multiply the activity data by the emission factor to obtain the emission estimate, which is then converted to million metric tons carbon dioxide equivalent (MMT_{CO₂E}) by multiplying by the GWP of CH₄ (28) and dividing by 10⁶. The general equation used to calculate emissions from natural gas systems is shown in Equation 1. The equation used for venting and flaring of natural gas is similar but includes the flaring percent and does not include the GWP because emissions are already in units of CO₂, as shown in Equation 2. The equation used for petroleum systems is shown in Equation 3.

Equation 1. General Emission Equation for Natural Gas Systems

$$\text{Emissions (MMT}_{\text{CO}_2\text{E}}) = \text{Activity Data} \times \text{Emission Factor (MT CH}_4\text{/unit activity data)} \times 28 \text{ (GWP)}$$

Equation 2. Emission Equation for Venting and Flaring of Natural Gas

$$\text{Emissions (MMT}_{\text{CO}_2\text{E}}) = \text{Activity Data (BBtu)} \times \text{Emission Factor (MT CO}_2\text{/BBtu)} \times \% \text{ flared} \div 10^6 \text{ (MT/MMT)}$$

Equation 3. General Emission Equation for Petroleum Systems

$$\text{Emissions (MMT}_{\text{CO}_2\text{E}}) = \text{Activity Data ('000 barrels)} \times \text{Emission Factor (kg CH}_4\text{'000 barrels)} \div 1,000 \text{ (kg/MT)} \times 28 \text{ (GWP)} \div 10^6 \text{ (MT/MMT)}$$

Step (1) Select a State

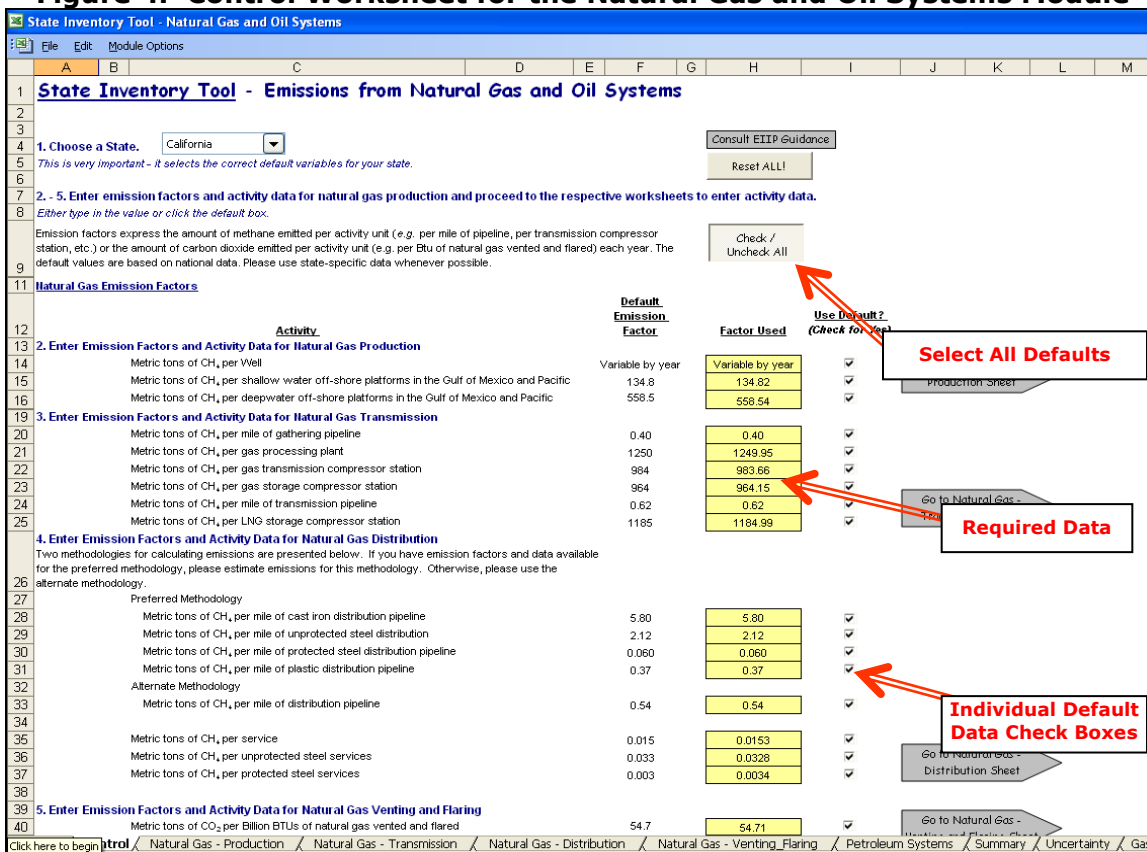
To begin, select the state for which you would like to perform the analysis. This step will automatically select the appropriate state default data for the remainder of the calculations throughout the tool.

Step (2) Enter Emission Factors and Activity Data for Natural Gas Production

Control Worksheet

On the control worksheet, either select the default data provided or enter user-specified gas and activity-specific emission factors that will be used throughout the tool. To proceed with the default emission factors, select the “Check/Uncheck All” button or check the default box directly to the right of individual yellow input cells. Note that these numbers can be overwritten if you 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. See Figure 4 for locations of the “Check/Uncheck All” buttons, individual default check boxes, and yellow input cells. Information on emission factors is discussed below.

Figure 4. Control Worksheet for the Natural Gas and Oil Systems Module



Default emission factors are provided in the Natural Gas and Oil Systems module for all natural gas and petroleum system activities, or they can be provided by the user. Examples of the emission factors being used are shown in each of the specific sector worksheet figures shown in subsequent steps.

The emission factors for natural gas systems, except production, are based on a study by the Gas Research Institute and the U.S. Environmental Protection Agency (GRI 1996). The study conducted a large survey of emissions from the natural gas industry and developed emission factors for three of the four natural gas activities in the SIT: processing, transmission (including storage), and distribution. Within each segment, industry facilities and operations were analyzed to identify fugitive emissions, leaks, and vented emissions. The study identified approximately 100 components of natural gas systems that are CH₄ emission sources. For each component, the study developed an emission factor.

This finely grained GRI data on emission factors is the “Tier 3” approach developed by the Intergovernmental Panel on Climate Change (IPCC 1997) and is used to develop emission estimates for the annual Inventory of U.S. Greenhouse Gas Emissions and Sinks. However, to simplify the amount of data required in the SIT, each of the default emission factors provided accounts for emissions from several activities. For example, the default emission factor for natural gas production per well approximates emissions not just from wells but also from pneumatic devices, dehydrator vents, Kimray pumps, gas engines, and well clean-ups. Therefore, if users are supplying state-specific emission factors, all aspects of emissions must be considered.

For the natural gas production sector, enter emission factors on the control sheet in the yellow cells. The default emission factors for natural gas wells vary by year and region, while the default emission factors for offshore deep-water and shallow-water platforms do not vary by region or year. The emission factors for natural gas well production are based on the emission factors used in U.S. EPA (2023a) and are ultimately based on GRI data source estimates.

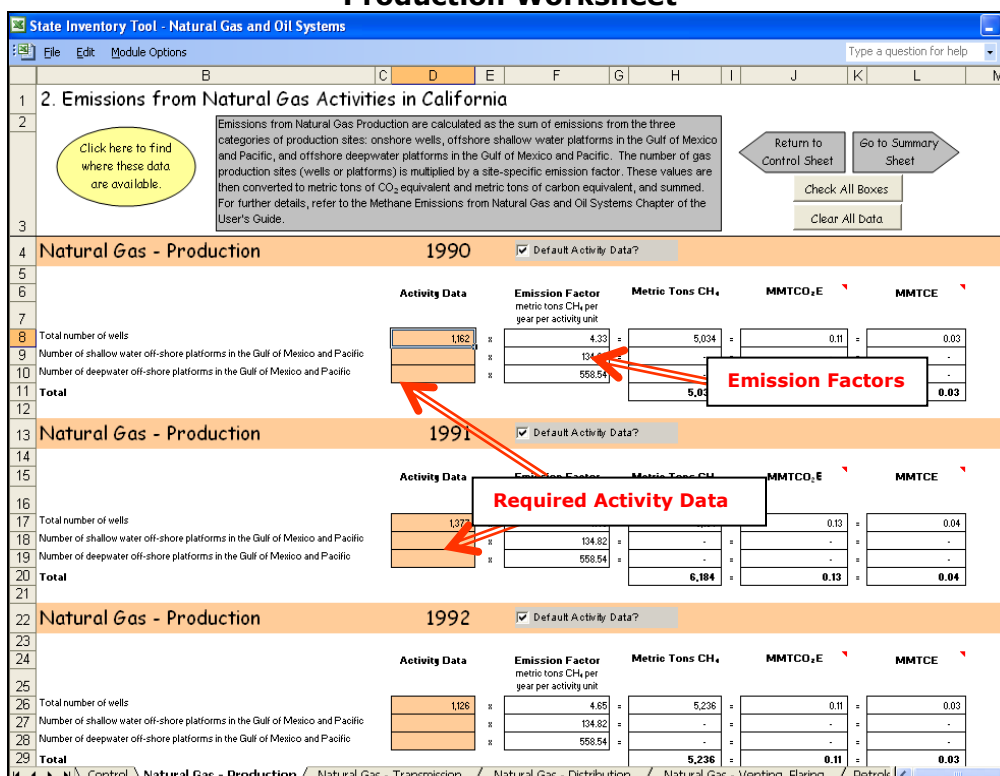
Natural Gas Production Worksheet

Most gas production is from gas or oil wells. Gathering lines are used to bring raw gas to a collection point or points within a production field. Because CH₄ is the major component of natural gas, leaks or venting from the gathering systems result in CH₄ emissions.

Natural gas is usually processed in gas plants to remove and process the natural gas liquids and to prepare the natural gas for pipeline transportation. During processing, natural gas is dried, and a variety of processes may be used to remove most of the heavier hydrocarbons, or condensate, from the gas. Processed gas is then injected into the natural gas transmission system, and the heavier hydrocarbons are marketed separately. Major CH₄ emission sources in the gas processing are compressor fugitives, compressor exhaust, vents, pneumatic devices, and blowdown.

On the natural gas production worksheet, shown in Figure 5, the orange cells indicate where the required activity data are entered manually. Default data for natural gas well production from EIA (2022c) is available for most states. Emissions are calculated by multiplying activity data by the appropriate emission factor to obtain the total CH₄ emissions in metric tons. Then, the total emissions are converted into MMTCO₂E, by multiplying by the GWP for CH₄ (28) and dividing by 10⁶ (Equation 1).

Figure 5. Example of Activity Data and Emission Factors Applied in the Natural Gas Production Worksheet



Step (3) Enter Emission Factors and Activity Data for Natural Gas Transmission

Transmission pipelines are large diameter, high-pressure lines that transport gas from production fields, processing plants, storage facilities, and other sources of supply over long distances to local distribution companies or to large volume customers. A variety of facilities support the overall system, including metering stations, maintenance facilities, and compressor stations located along pipeline routes. Compressor stations, which maintain the pressure in the pipeline, generally include upstream scrubbers, where the incoming gas is cleaned of particles and liquids before entering the compressors. Reciprocating engines and turbines are used to drive the compressors. Major CH₄ emission sources are chronic leaks, compressor fugitives, compressor exhaust, vents, and pneumatic devices.

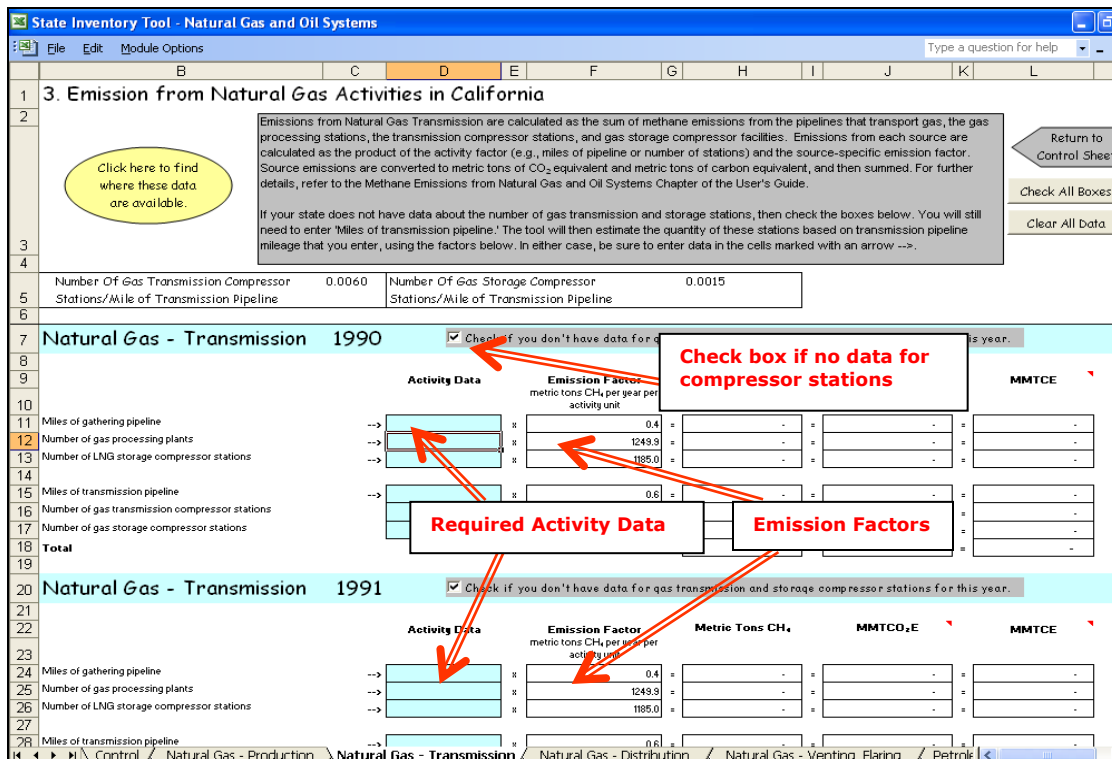
Control Worksheet

On the control sheet, enter emission factors (in metric tons of CH₄ per unit) for gathering pipeline, gas processing plants, gas transmission compressor stations, gas storage compressor stations, transmission pipeline, and LNG storage compressor stations.

Natural Gas Transmission Worksheet

For the transmission worksheet, an alternate method is available if data on the number of gas transmission and storage stations is not accessible. To use the alternate method, check the box at the top of each year’s calculations, and make sure to enter 'miles of transmission pipeline' in the activity data. The tool will then estimate the quantity of these stations based on transmission pipeline mileage. An example of the transmission worksheet is shown in Figure 6 (input cells shown in blue).

Figure 6. Example of Activity Data and Emission Factors Applied in the Natural Gas Transmission Worksheet



Step (4) Enter Emission Factors and Activity Data for Natural Gas Distribution

Distribution pipelines are extensive networks of generally small diameter, low-pressure pipelines. Gas enters distribution networks from transmission systems at city gate stations, where the pressure is reduced for distribution within cities or towns. Major CH₄ emission sources are chronic leaks, meters, regulators, and mishaps.

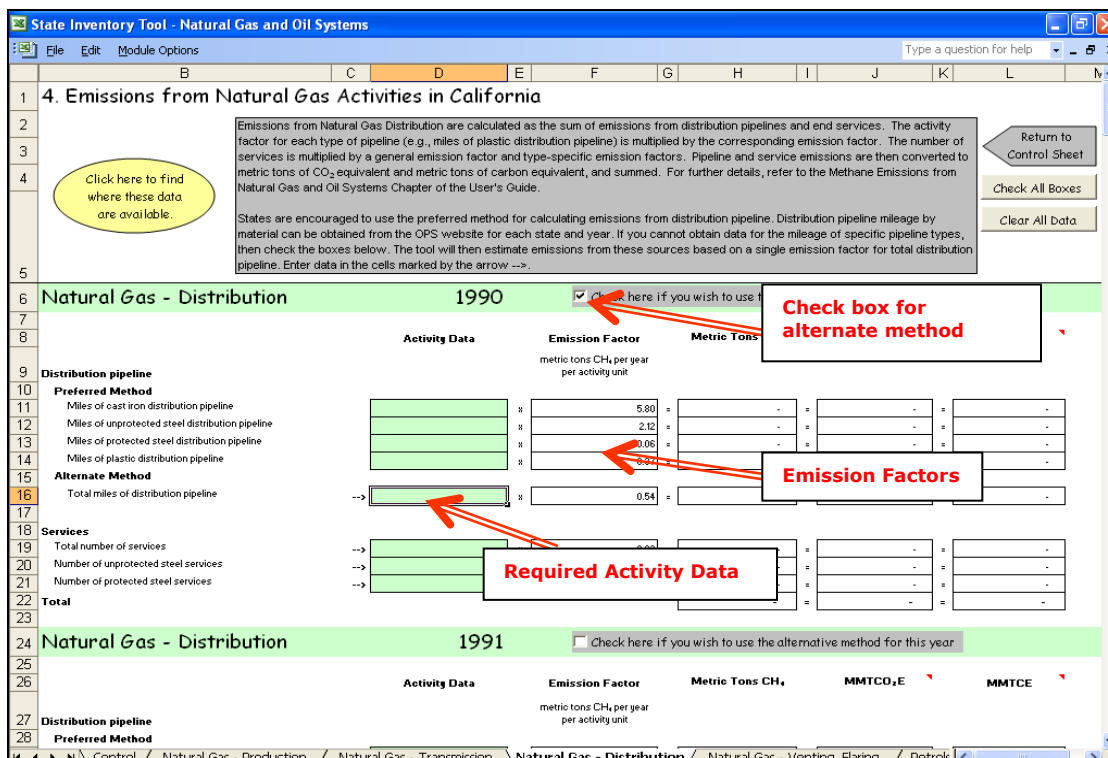
Control Worksheet

If you are using the preferred method of calculating emissions from natural gas distribution, enter emission factors (in metric tons of CH₄ per mile of pipeline) for cast iron distribution pipeline, unprotected steel distribution pipeline, protected steel distribution pipeline, and plastic distribution pipeline. If you are using the alternate method, you need only enter an emission factor of metric tons of CH₄ per mile of distribution pipeline (all types of pipeline). Then for both methods, enter the emission factors for all natural gas services (i.e., end-users), for unprotected steel services, and for protected steel services.

Natural Gas Distribution Worksheet

For distribution, states are encouraged to use the method provided for calculating emissions from specific types of distribution pipeline. However, an alternate method is offered based on a single emission factor for total distribution pipeline. If data are unavailable for the mileage of specific pipeline types, then check the box at the top of each year’s calculations and enter the total pipeline mileage where indicated. The green input cells in Figure 7 show where activity data are required.

Figure 7. Example of Activity Data and Emission Factors Applied in the Natural Gas Distribution Worksheet



Step (5) Enter Emission Factors and Activity Data for Natural Gas Venting and Flaring

Control Worksheet

Enter the emission factor for natural gas venting and flaring on the control worksheet. This emission factor must account for both vented and flared natural gas. The default emission factor is taken from U.S. EPA (2023a).

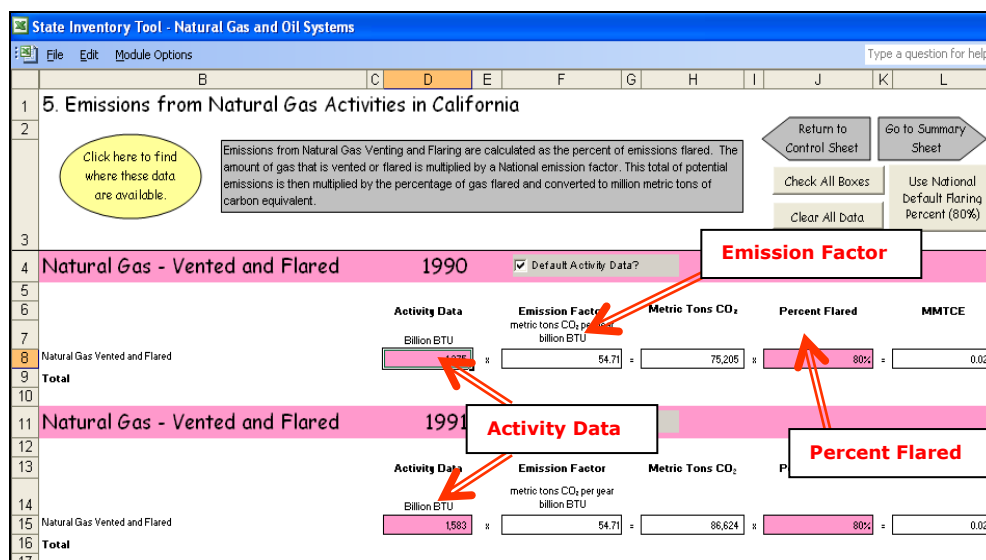
Natural Gas Venting and Flaring Worksheet

The venting and flaring worksheet is unique because it calculates CO₂ emissions from flaring, and it requires both activity data for the amount of natural gas vented and flared, and the percent of gas flared. Default activity data are available in the SIT for most states

from the EIA Natural Gas Navigator.¹ An example of the use of the activity data, emission factor, and percent flared can be seen in Figure 8 (input cells are shown in pink). While the required activity data for this worksheet is the total amount that is vented and flared, the emissions calculations are for the amount of gas that’s flared. The SIT assumes that 80 percent of this gas is flared and that the remaining 20 percent (i.e., the amount that’s vented) must be accounted for in the petroleum systems production category. Because there is no default data for petroleum systems in the SIT, the user must make sure that the amount of gas flared is not double counted when calculating emissions from the petroleum systems category.

Venting and flaring refer to the disposal of gas that cannot be contained or otherwise handled. Venting and flaring activities are associated with combined oil and gas production and take place in production areas where gas pipeline infrastructure is incomplete, and the natural gas is not injected into reservoirs.

Figure 8. Example of Activity Data and Emission Factor Applied in the Natural Gas Venting and Flaring Worksheet



Step (6) Enter Emission Factors and Activity Data for Petroleum Systems Control Worksheet

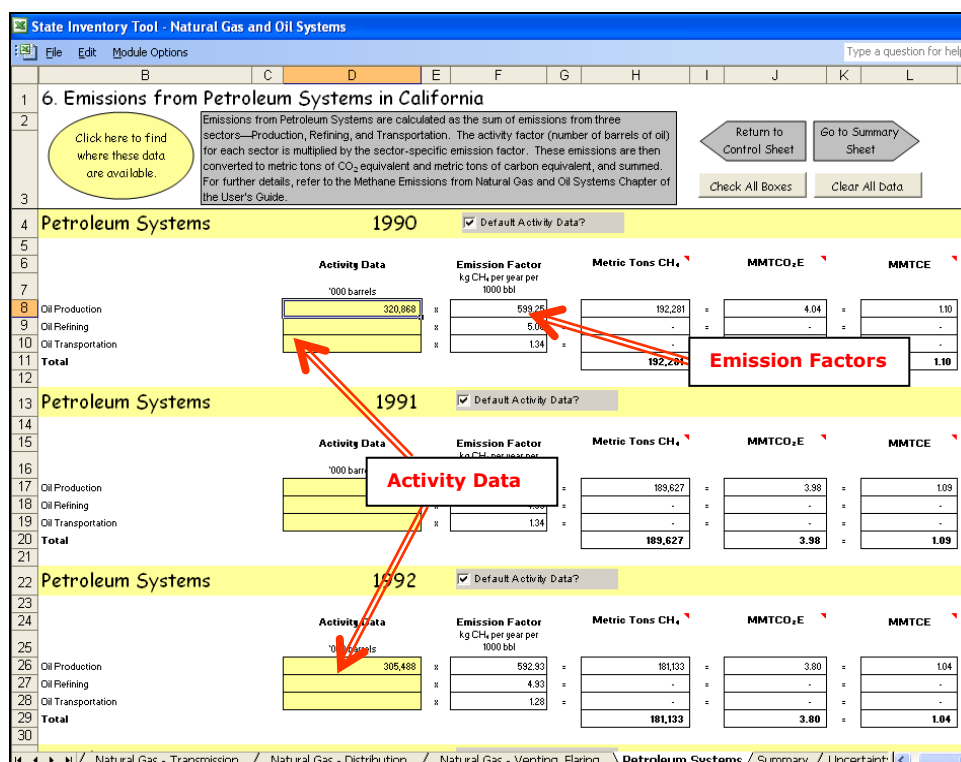
The petroleum system emission factors used in the SIT are implied emission factors derived from U.S. EPA (2023a). Using the available published oil system emission estimates, the implied emission factors were developed by dividing the emission estimates from each of the major activity groups (production, refining, and transportation) by the appropriate activity data at the national level. These implied emission factors are calculated for each year in the SIT. States are encouraged to use state-specific emission factors if data are available, as actual emissions depend on site-specific characteristics including facility design, operation, and maintenance.

¹ Available online at: https://www.eia.gov/dnav/ng/NG_PROD_WELLS_S1_A.htm

Petroleum Systems Worksheet

Required data for the petroleum systems worksheet include the amount of oil produced (including venting), refined, and transported in the state. Figure 9 shows an example of the data used for this sector, the yellow cells are input cells. Default data are not provided in the SIT, so users must input data for emissions to be estimated. If state-specific data sources are not available, users can obtain oil production data from EIA’s Petroleum Supply Annual.² Refining data can be calculated using data from the Petroleum Supply Annual and the calculator provided in the SIT on the oil data sources worksheet. Currently, no uniform data source has been identified for oil transportation activities, so in the absence of other information it is recommended that users assume that the amount of oil transported is equivalent to the amount of oil refined in the state.

Figure 9. Example of Activity Data and Emission Factors Applied in the Petroleum Systems Worksheet



CH₄ emissions from oil systems are estimated using the “Tier 1” approach developed by the IPCC (IPCC 1997). The approach is simpler than the method used for natural gas systems, but it is also less accurate. The SIT calculates emissions by multiplying the required state-level data on oil production, refining, and transportation by the appropriate emission factors and summing across activity types to calculate total emissions, as shown in Equation 3. The general sources of CH₄ emissions from oil systems that should be accounted for can be categorized into emissions from: (1) normal operations, (2) routine maintenance, and (3) system upsets and accidents.

² Available online at: <http://www.eia.gov/petroleum/supply/annual/volume1/>.

Normal operations include emissions from the day-to-day operations of a facility. Oil production and transportation facilities can emit CH₄ due to a wide variety of operating practices and factors, including emissions from pneumatic devices, leaks from system components, emissions from process vents, emissions from starting and stopping reciprocating engines or turbines, and emissions during drilling activities.

Routine maintenance includes regular and periodic activities performed in the operation of the facility. These activities may be conducted frequently, such as launching and receiving scrapers (pigs) in a pipeline, or infrequently, such as evacuation of pipes (“blowdown”) for periodic testing or repair. In each case, the required procedures release gas from the affected equipment. Releases also occur during maintenance of wells (“well workovers”) and during replacement or maintenance of fittings.

System upsets are unplanned events in the system. The most common upset is a sudden pressure surge resulting from the failure of a pressure regulator. The potential for unplanned pressure surges is considered during facility design, and facilities are provided with pressure relief systems to protect the equipment from damage due to the increased pressure. Relief systems vary in design. In some cases, gases released through relief valves may be collected and transported to a flare for combustion or re-compressed and reinjected into the system. In these cases, CH₄ emissions associated with pressure relief events will be small. In older facilities, relief systems may vent gases directly into the atmosphere or send gases to flare systems where complete combustion may not be achieved. The frequency of system upsets varies with the facility design and the operating practices. In particular, facilities operating well below capacity are less likely to experience system upsets and related emissions. Emissions associated with accidents are also included in the category of upsets.

Step (7) Enter Additional Emissions Sources to Additional Emissions Sources

Worksheet if Applicable

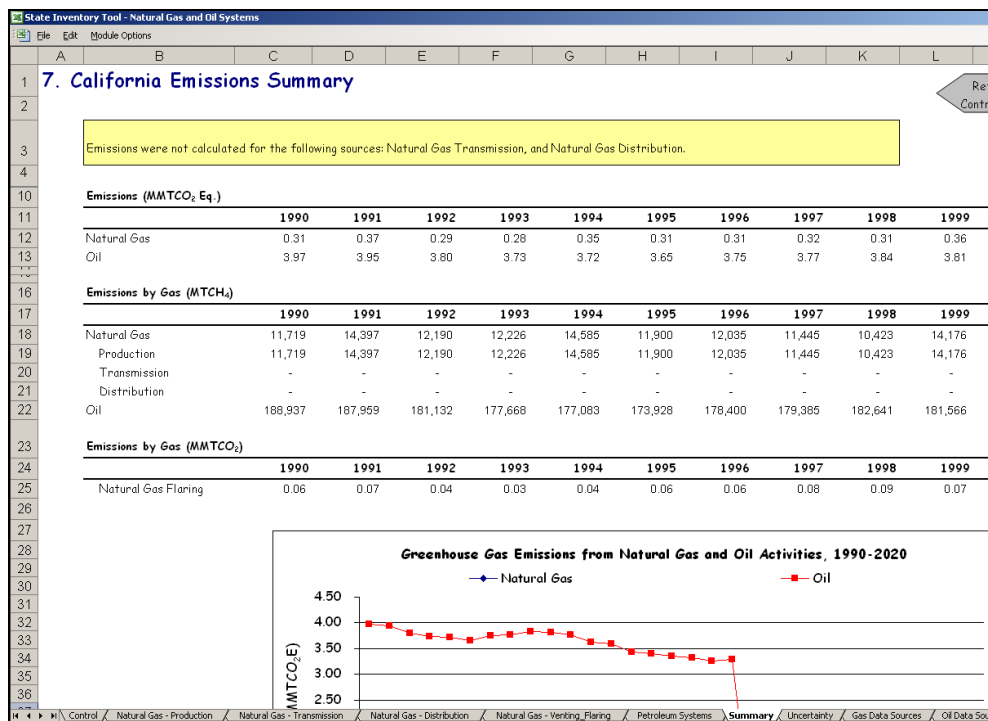
Users may use this worksheet to input data about additional emissions sources that are not included in this module or any other module. Additional emissions sources should be reported in MMTCO_{2e}. Figure 10 shows two options for entering data into this worksheet (please select only one):

Option A: Add up to ten additional emission sources in column B, lines 10-19. Select CO₂ or CH₄ from the dropdown menu in column C. Enter the emissions in MMTCO_{2e} for each year 1990-2021 in the yellow cells.

Option B: Enter the total CO₂ (line 29) and/or total CH₄ emissions (line 30) for all other emissions sources for each year 1990-2021 in the yellow cells in MMTCO_{2e}.

Figure 10. Example Additional Emissions Sources Worksheet

Figure 11. Example of the Summary Worksheet in the Natural Gas and Oil Systems Module



Step (9) 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 worksheet 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 Natural Gas and Oil Systems 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 jeopardizes 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.

1.5 REFERENCES

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