CHAPTER 9: COGENERATION FACILITIES

(Guidance for Regulation Section 95112)

Operators of cogeneration facilities have sector-specific reporting obligations specified in section 95112 of the mandatory greenhouse gas reporting regulation. This chapter of the guidance explains compliance requirements and, in addition, provides information on best practices or ARB staff recommendations to assist operators where there is operator discretion.

Cogeneration facility operators are referred to Chapters 1 through 6 for general guidance that pertains to all entities. Chapters 1 through 6 provide guidance on reporting thresholds, reporting and verification schedules, data collection and quality requirements, general emissions data reports, and verification. Where cogeneration facilities share common requirements with the electric power sector, such as emissions calculation methods, readers are referred to Chapter 8 of this guidance. General guidance on common emissions calculation methods is provided in Chapter 13 of this document.

9.1 Applicability

Section 95112 applies to operators of cogeneration facilities that are located in California. Applicability extends to out-of-state cogeneration facilities if they are operated by a California-only retail provider or a multi-jurisdictional retail provider.

A cogeneration facility is any facility that includes one or more cogeneration systems configured as either a topping cycle or bottoming cycle plant. A cogeneration system provides sequential generation of multiple forms of useful energy. At least one form of the useful energy produced (usually mechanical or thermal) is consumed on-site or is provided to others for an end-use other than electricity generation.

Operators of cogeneration facilities are subject to mandatory reporting only if the facility has a nameplate generating capacity greater than or equal to 1 MW and the facility also emits greater than or equal to 2,500 metric tonnes of CO_2 from electricity generating activities in any calendar year after 2007. Threshold emissions from "electricity generating activities" are determined using specified equations to distribute CO_2 emissions associated with cogeneration systems. The procedure for distribution of CO_2 emissions is described in section 9.4 of this chapter. Note, however, that additional emissions sources are included when determining applicability. To determine applicability, include CO_2 emissions from stationary combustion of both fossil fuels and biomass-derived fuels in the total CO_2 direct

The purpose of this chapter is to provide guidance on the requirements of section 95112 of the mandatory GHG reporting regulation. As described more specifically in Chapter 1 of this document, this guidance does not add to, substitute for, or amend the regulatory requirements as written in these or other sections of the regulation [Subchapter 10, Article 2, sections 95100 to 95133, title 17, California Code of Regulations].

emissions term. Do not include pass-through CO_2 emissions associated with biogas generation and combustion. If applicable, also include process CO_2 emissions from acid gas scrubbers in the total CO_2 direct emissions term.

See the guidance on general requirements in Chapter 2 for a general procedure to determine reporting obligations based on emissions, primary and secondary sector considerations, and operational control relationships. See Chapter 12, guidance on general stationary combustion facilities, for a discussion of reporting requirements for various primary and secondary sector scenarios. Note that if cogeneration falls below the reporting threshold, but is under common operational control at a larger facility, then the operator will report emissions from the cogeneration system(s) according to the requirements for the primary sector.

9.2 Reported Information

The regulation lists certain information that must be provided at the facility level and also at the generating unit level. Some cogeneration operators have the option to submit an abbreviated report. This section provides information on the data categories needed at the facility level versus the generating unit level as well as for the full report versus the abbreviated report. Since the on-line reporting tool will be customized for each sector, operators of cogeneration facilities will enter the data identified into the appropriate data fields provided in the reporting tool. In some cases, there may be an option to have the tool calculate certain information for the reporter. Alternatively, the reporter may override the calculating tool and enter the data directly.

Emissions data report for cogeneration facilities, section 95112(a)

1. ARB-designated ID number*
2. Nameplate generating capacity*
3. Net power generated*
4. Wholesale electricity sales exported directly out-of-state, if known*+
5. Cogeneration system information*
6. Electricity generation and end-use information*
7. Thermal energy production and end-use information*+
8. Indirect energy purchases+
9. Fuel information
    a. Fuel consumption by fuel type*
    b. Average higher heating values by fuel type, if measured+
    c. Average carbon content by fuel type, if measured+
10. Emissions information
    a. Stationary combustion emissions by fuel type of CO_2, CH_4 and N_2O*
    b. Process emissions of CO_2 from acid gas scrubbers or acid gas reagent used in the combustion source, if applicable+
    c. Fugitive emissions of CH_4 from coal storage for coal-fired facilities+
    d. Fugitive emissions of HFC related to the operation of cooling units that support power generation, if applicable+
    e. Fugitive SF_6 emitted from equipment that is located at the facility and that the operator is responsible for maintaining in proper working order+
    f. Distribution of fossil-fuel-based CO_2 emissions to electricity and thermal energy production as well as manufactured product outputs, if applicable*+

*Also reported at the generating unit level, which may be aggregated by fuel type due to metering or monitoring limitations.

+Optional for operators eligible to submit an abbreviated report.

See Chapter 8 for guidance on the following topics that are common for cogeneration facilities and electricity generation facilties:

- Process and Fugitive Emissions
- Aggregating Generating Units
- Facility Totals
- Wholesale Power Exported Directly Out-of-State
- ARB ID Numbers

Abbreviated Reporting Option. Section 95112 stipulates that operators of certain self-generation unit(s) less than 10 MW may submit an abbreviated report. This option is not available to operators whose primary business is generating electricity or any other of the industrial sectors required to report GHGs. Thus, an operator referred to section 95112 from sections 95110, 95111, 95113, 95114, or 95115 may not submit an abbreviated report and is required to calculate and report distributed emissions for each of their cogeneration systems. Less rigorous emissions calculation methods are allowed for abbreviated reports.

9.3 Emissions Calculation Methods

The methodologies required for use when calculating greenhouse gas emissions from electric generating facilities and cogeneration facilities are specified in section 95111(c). These methods are dependent on the greenhouse gas and the type of fuel being combusted. They were selected with the goal of achieving a level of accuracy that would be acceptable in future trading programs, whether statewide, regional, national, or international. Table 8.8, provided in Chapter 8, is a matrix of methodologies that maps the greenhouse gas and fuel type to the appropriate suite of methods. More detail on these methods is provided in section 8.8 as well as Chapter 13.

The use of default factors for CO_2 emissions calculations, specified in section 95125(a), is not allowed for most sectors, including the electric power and cogeneration sectors. An exception is provided for eligible cogeneration operators who choose to use the abbreviated reporting option, as well as for application to start-up fuels.

See chapter 8, section 8.8, for guidance on the following topics that are common for cogeneration facilities and electricity generation facilties:

- Stationary combustion emissions by fuel type of CO_2, CH_4 and N_2O
- CO_2 Process Emissions Calculation Methodology for Acid Gas Scrubbers
- SF_6 Fugitive Emissions Calculation Methodology
- HFC Compounds Fugitive Emissions Calculation Methodology
- HFC Fugitive Emissions Calculation Methodology for an Individual Cooling Unit

In addition to reporting greenhouse gas emissions by gas and by fuel type, as well as total biogenic CO_2, cogeneration operators must distribute CO_2 emissions from fossil fuel combustion. A general procedure and examples are presented next.

9.4 Distributed Emissions Calculations

CO_2 emissions from combustion of fossil fuels are allocated to the generation of electricity, thermal energy, and, for bottoming cycle plants, to the manufacturing process that produces the waste heat used for cogeneration. Operators who combust primarily biomass-derived fuels, but also combust fossil fuels above *de minimis* levels, are required to distribute the emissions from the fossil fuels. Reporters who choose the abbreviated reporting option may also elect to report distributed emissions.

CO_2 emissions from combustion of fossil fuels are allocated based on the energy flows for the cogeneration system configuration. Topping cycle plant operators calculate distributed emissions for electricity generation and thermal energy production separately using the Efficiency Method provided in section 95112(b)(4)(A). Bottoming cycle plant operators calculate distributed emissions for electricity generation, thermal energy production, and manufactured product outputs using the Detailed Efficiency Method provided in section 95112(b)(4)(B). The general procedure is outlined in four steps below.

General procedure for distribution of emissions:

1. Determine the total direct CO_2 emissions from stationary combustion for the cogeneration system. For bottoming cycle plants, include the combustion source for the manufacturing process that generates the initial waste heat.
2. Determine energy flows for the cogeneration system configuration expressed in MMBtus, including output flows of useful thermal energy and electric energy. For bottoming cycle plants, input fuel energy is required.
3. Determine the efficiencies of thermal energy and electricity production.
4. Determine the fraction of emissions allocated to thermal energy production and electricity generation and report the distributed emissions. For bottoming cycle plants, also include emissions allocated to the manufacturing process.

See text box for more information on distributing CO_2 emissions when both biomass-derived and fossil fuels are combusted in a cogeneration system. More detailed explanations of the general procedure are provided separately for topping and bottoming cycle plants below. Each discussion includes data needs, a general procedure with equations, and an example.

Emissions distribution when both biomass-derived and fossil fuels are combusted. Biomass-derived fuels include wood and biogas from a landfill or anaerobic digester. Waste-derived fuels include municipal solid waste that contains a portion of biomass. Examples of emitting activities that may combust primarily biomass-derived fuels, but also combust fossil fuels, include co-firing biomass-derived fuel and fossil fuel, using a fossil fuel for periods of start-up and malfunction, and using natural gas in a duct burner of a heat recovery steam generator.

Operators who combust both biomass-derived fuels and fossil fuels or utilize the resulting waste heat must distribute the fossil fuel emissions when fossil fuel emissions are above the *de minimis* level. CO_2 emissions from biomass-derived fuels, including pass-through emissions, are reported, but not distributed.

All parameters used in the distribution methods—H, P_{MWh}, F_{MMBtu}, F_S, HRSG, and H_{ST}—are based on the total energy flows from the combustion of both fuel types. In the final distribution, the fractions of emissions determined in step 4 are multiplied by the CO_2 emissions from fossil fuel combustion only (E_T), to calculate E_H, E_P, and for bottoming cycle plants E_M.

9.4.1 Efficiency Method to Distribute Emissions for Topping Cycle Plants

Table 9.4.1a is a summary of the data needed to distribute emissions for topping cycle plants. The general procedure consists of four steps, described below. An example follows.

**Table 9.4.1a Data Needs for Distributed CO_2 Emissions—
Topping Cycle Cogeneration**

Required Data	*Optional data*	*Units/Value*	*Data Source*
$E_{T\ CO2}$ - Total direct CO_2 emissions from the cogeneration system from stationary combustion		Metric tonnes emitted in the report year	operator measured - determine CO_2 emissions based on fuel quantities and fuel types or CEMS.
H - total useful thermal output		MMBtu	operator measured
P_{MWh} - power generated		MWh for the report year	operator measured
	F - total fuel input, higher heating value weighted average	MMBtu	operator (or fuel supplier) measured – higher heating value based on method in section 95125(c)
	e_p – efficiency of electricity generation	Percent	operator determined facility-specific value or default value provided
	e_H – efficiency of thermal energy production	Percent	equipment manufacturer's rating or default value provided

1. *First, determine the total direct CO_2 emissions from stationary combustion for the cogeneration system.* Determine total direct CO_2 emissions from stationary combustion using a fuel-based method or CEMS. The operator selects the appropriate emissions calculation method based on the regulatory requirements specified in section 95112 for cogeneration facilities and the conditions at the facility.

Equation 1:

$$E_{T\text{-}CO2} = \sum_{n=1}^{n} E_{SOURCE\ n\text{-}CO2}$$

Where:
$E_{T\text{-}CO2}$ = CO_2 emissions summed over the number of sources, n, within the generating unit or system, metric tonnes

$E_{SOURCE\ n}$ = CO_2 emissions for each source (such as boiler, combustion turbine, heat recovery steam generator) within the generating unit or system, metric tonnes

2. *Determine energy flows for the cogeneration system configuration, expressed in MMBtus.* Include output flows of useful thermal energy (H) and electric energy (P_{MMBTU}). For topping cycle plants, total fuel input (F) is required, if measured. Total fuel input (F) includes supplemental fuel fired (F_S) in the duct burner of the heat recovery steam generator, if applicable.

   Convert units of electric energy from power generated during the report year from units of MWh to MMBtu using equation 2.

   Equation 2: $P_{MMBtu} = 3.413 * P_{MWh}$

3. *Determine the efficiencies of thermal energy and electricity production.* Determine whether you must use a facility-specific or default value for electricity generation efficiency. If using the fuel-based, measured heat content method (section 95125(c)) to determine CO_2 emissions, then F (higher heating value) is known and you must calculate the facility-specific electricity generation efficiency value using Equation 3, below. If the cogeneration system is based on a boiler and steam turbine combination, F can be calculated from steam output in MMBtu divided by the manufacturer's boiler efficiency rating.

   If F (higher heating value) is unknown, use default electricity generation efficiency value, e_P = 35%.

   Equation 3:

$$e_P = \frac{P_{MMBtu}}{F_{MMBtu}} * 100$$

   Where:
   e_P = Efficiency of electricity generation, percent
   P = Power generated for the report year, expressed as MWh or MMBtu
   F = Total fuel input, higher heating value, MMBtu

   Determine the percent efficiency of thermal energy production (e_H,). Use heat recovery steam generator (HRSG) or boiler manufacturer's equipment rating, if known; otherwise, use default value of 80 percent.

4. *Determine the fraction of emissions allocated to thermal energy production and electricity generation and report the distributed emissions.* Report fossil fuel emissions distributed to thermal energy production (E_H) and to electricity generation (E_P) in metric tonnes CO_2.

   Equation 4a:

$$E_H = \frac{H/e_H}{H/e_H + P/e_P} * E_T$$

Equation 4b:

$$E_P = E_T - E_H$$

Where:
E_H = Distributed emissions to thermal energy production, metric tonnes CO_2
E_P = Distributed emissions to electricity generation, metric tonnes CO_2
E_T = Total direct emissions from the cogeneration system from stationary combustion, metric tonnes CO_2
H = Total useful thermal output, MMBtu

Example 1. A topping cycle cogeneration facility uses a gas turbine as the prime mover and combusts only natural gas. Nameplate generating capacity is greater than 10 MW. The gas turbine is the only source of direct stationary combustion emissions for this cogeneration system. There is no supplemental firing within the duct burner of the heat recovery steam generator.

The operator selects the appropriate emissions calculation method based on the regulatory requirements and the conditions at the facility. Referring to section 95112, which specifies the emissions calculations methods for cogeneration facilities, the operator has decided to use method 95125(c). Method 95125(c) specifies the calculation of CO_2 emissions using measured heat content.

During the report year, approximately 970 million scf of natural gas are combusted. Monthly measurements of quantity of fuel combusted and associated higher heating values are recorded. Total CO_2 emissions from combustion are calculated and summed for the report year, then distributed between electricity generation and thermal energy production.

Step 1. The operator determines the total direct CO_2 emissions from stationary combustion for the cogeneration system.

$$E_{T\text{-}CO2} = \sum_{s=1}^{2} E_{Gas\ Turbine} + E_{HRSG}$$

$$E_{T\text{-}CO2} = E_{Gas\ Turbine}$$

Where:
$E_{T\text{-}CO2}$ = CO_2 emissions from combustion summed over the number of sources within the generating unit or system, metric tonnes
$E_{SOURCE\ n}$ = CO_2 emissions from combustion for each source within the generating unit or system, metric tonnes

The equation below is used to calculate CO_2 stationary combustion emissions for this example, natural gas with a higher heating value (HHV) between 975 and 1100 Btu/scf.

The calculation method in section 95125(c) requires the reporter or fuel supplier to measure fuel consumption and associated HHV at a particular frequency, based on the variability of the fuel. The product of fuel consumption and HHV is then multiplied by an ARB-supplied CO_2 emissions factor and summed over the year. CO_2 emissions then are converted from kilograms to metric tonnes for reporting purposes. The fuel-specific CO_2 emission factors are found in the rightmost column of Table 4 in Appendix A of the mandatory GHG reporting regulation. For additional guidance, see Chapter 13 on section 95125(c) of the regulation.

Equation specified in section 95125(c):

$$E_{CO_2-NaturalGas} = 0.001 * \sum_{1}^{n} Fuel_{Natural\ Gas-n} * HHV_n * EF_{Natural\ Gas-n}$$

The subscript *n* designates the frequency with which the fuel consumption and HHV must be determined. Since this operator combusts natural gas with an HHV within the 975 – 1100 Btu/scf range, fuel consumption and HHV are measured on a monthly basis, n = 12. This calculation is repeated twelve times in Table 9.4.1b, once for each month of the calendar year reporting cycle. Total CO_2 emissions from fossil fuel combustion are summed for the report year and then distributed between electricity generation and thermal energy production.

Table 9.4.1b Fossil Fuel Consumption and CO_2 Emissions

Month (1)	Measured Fuel Consumption, million scf (2)	Measured HHV, Btu/scf (3)	Natural Gas Fuel Consumption, MMBtu (2)*(3)=(4)	Natural Gas Heat Content Range, Btu/scf, Table 4 Appendix A (5) →	Emission Factor, kg CO2/ MMBtu, Table 4 Appendix A (6)	Emissions, metric tonnes CO2 (4)*(6)*0.001=(7)
1	81.19	1010	82,000	1000-1025	52.87	4,335
2	78.92	1020	80,500	1000-1025	52.87	4,256
3	79.41	1020	81,000	1000-1025	52.87	4,282
4	80.58	1030	83,000	1025-1050	53.02	4,401
5	83.17	1010	84,000	1000-1025	52.87	4,441
6	83.82	1020	85,500	1000-1025	52.87	4,520
7	82.08	1060	87,000	1050-1075	53.42	4,648
8	80.66	1060	85,500	1050-1075	53.42	4,567
9	77.57	1070	83,000	1050-1075	53.42	4,434
10	81.07	1030	83,500	1025-1050	53.02	4,427
11	81.37	1020	83,000	1000-1025	52.87	4,388
12	78.85	1040	82,000	1025-1050	53.02	4,348
SUM =	968.69		F = 1,000,000			E_{T-CO2} = 53,048

$\boxed{E_{T-CO2} = 53{,}048 \text{ metric tonnes}}$

Step 2. Determine energy flows for the cogeneration system configuration expressed in MMBtus, including total fuel input (F) if measured and output flows of total useful thermal output (H) and electricity (P).

$\boxed{F = 1{,}000{,}000 \text{ MMBtu}}$

$\boxed{H = 340{,}680 \text{ MMBtu}}$

$P_{MMBtu} = 3.413 * P_{MWh}$
$P_{MMBtu} = 3.413 * 144{,}390$

$\boxed{P_{MMBtu} = 492{,}800 \text{ MMBtu}}$

Step 3. Determine the efficiencies of thermal energy and electricity production.

The facility obtains higher heating values of its natural gas from its fuel supplier, who uses the method provided in section 95125(c). The operator then must use the facility-specific electricity generation efficiency.

$$e_P = \frac{P_{MMBtu}}{F_{MMBtu}} * 100$$

$$e_P = \frac{492,800}{1,000,000} * 100$$

$$\boxed{e_P = 49\%}$$

Where:
e_P = Efficiency of electricity generation, percent
P = Power generated for the report year, expressed as MWh or MMBtu
F = Total fuel input, higher heating value, MMBtu

The HRSG manufacturer's equipment efficiency rating is 85%.

$$\boxed{e_H = 85\%}$$

Step 4. Determine the fraction of emissions allocated to thermal energy production and electricity generation and report the distributed emissions.

$$E_H = \frac{H/e_H}{H/e_H + P/e_P} * E_T$$

$$E_H = \frac{340,680/85}{340,680/85 + 492,800/49} * 53,048$$

$$E_H = 0.29 * E_T$$

$$E_P = (1\text{-}0.29) * E_T = 0.71 * E_T$$

$$E_H = 0.29 * 53,048 = 15,180 \text{ MT } CO_2$$

Where:
E_H = Distributed emissions to thermal energy production, metric tonnes CO_2
E_P = Distributed emissions to electricity generation, metric tonnes CO_2
E_T = Total direct CO_2 emissions from the cogeneration system from stationary combustion
H = Total useful thermal output, MMBtu
Other terms are defined above.

$$E_P = E_T - E_H$$

$$E_P = 53,048 - 15180$$

$$\boxed{E_P = 37,870 \text{ MT } CO_2}$$

**Table 9.4.1c Data Summary for Example 1—
Topping Cycle Cogeneration Emissions Distribution**

Required Data	*Optional data*	*Data Source*	*Input Value*	*Calculated Value*
$E_{T\ CO2}$ - Total direct CO2 emissions from the cogeneration system from stationary combustion		operator measured - determine CO_2 emissions based on fuel quantities and fuel types or CEMS.		53,048 metric tonnes CO_2
H - Total useful thermal output		operator measured	340,680 MMBtu	
P_{MWh} - Power generated converted to units of MMBtu		operator measured	P_{MWh} = 144,390 MWh	P_{MMBtu} = 492,800 MMBtu
	F - total fuel input, higher heating value weighted average	operator (or fuel supplier) measured – higher heating value based on method in section 95125(c)	1,000,000 MMBtu	
	e_p – efficiency of electricity generation	operator determined facility-specific value or default value provided		49%
	e_H – efficiency of thermal energy production	equipment manufacturer's rating or default value provided	85%	
E_H - Distributed emissions to thermal energy production				15,180 metric tonnes CO_2
E_P - Distributed emissions to electricity generation				37,870 metric tonnes CO_2

9.4.2 Detailed Efficiency Method to Distribute Emissions for Bottoming Cycle Plants

Table 9.4.2a is a summary of the data needed to distribute emissions for bottoming cycle plants. The general procedure consists of four steps, which are described. An example follows.

Table 9.4.2a Data Needs for Distributed CO_2 Emissions—Bottoming Cycle Cogeneration

Required Data	*Optional data*	*Units/Value*	*Data Source*
$E_{T\ CO2}$ - Total direct CO2 emissions from the cogeneration system from stationary combustion		Metric tonnes CO_2 emitted in the report year	operator measured - determine CO_2 emissions based on fuel quantities and fuel types or CEMS.
H - Total useful thermal output		MMBtu	operator measured
HRSG – output of heat recovery steam generator		MMBtu	operator measured
	H_{ST} - input steam to steam turbine, if measured	MMBtu	operator measured
H_e – exothermic heat from manufacturing process, if applicable		MMBtu	calculated or operator determined
P_{MWh} - Power generated		MWh for the report year	operator measured
F - total fuel input, higher heating value weighted average		MMBtu	• operator (or fuel supplier) measured – higher heating value based on method in section 95125(c) • default HHVs allowed when HHV not measured • metering is required for fuel quantity measurements used to calculate emissions
F_S - Fuel fired for supplemental firing in the duct burner of the HRSG		MMBtu	• operator (or fuel supplier) measured – higher heating value based on method in section 95125(c) • default HHVs allowed when HHV not measured • engineering estimates allowed when not separately metered
	e_p – efficiency of electricity generation	Percent	operator determined facility-specific value or default value provided
	e_H – efficiency of thermal energy production	Percent	equipment manufacturer's rating or default value provided

1. Determine the total direct CO_2 emissions from stationary combustion for the cogeneration system.

   Include the combustion source for the manufacturing process that generates the initial waste heat and, if applicable, supplemental fuel fired in the duct burner of the heat recovery steam generator.

   Equation 1:

$$E_{T\text{-}CO2} = \sum_{n=1}^{n} E_{SOURCE\ n\text{-}CO2}$$

   Where:
   $E_{T\text{-}CO2}$ = CO_2 emissions summed over the number of sources, n, within the generating unit or cogeneration system, metric tonnes

2. *Determine the energy flows for the cogeneration system configuration, expressed in MMBtus. Include output flows of useful thermal energy (H) and electricity (P). For bottoming cycle plants, input fuel energy is required.*

   Step 2a. Determine the fuel input for the cogeneration system, expressed as energy input in MMBtus.

   Include the fuel combusted in the manufacturing process that generates the initial waste heat and, if applicable, supplemental fuel fired (F_S) in the duct burner of the heat recovery steam generator. If the operator or fuel supplier measures higher heating values, per 95125(c), then those values are used in Equation 2a. If the operator does not have measured values, then default HHVs are allowed if provided in Appendix A of the regulation. See example 1 provided for topping cycle plant.

   Equation 2a:

$$F_{MMBtu} = \sum_{n=1}^{n} F_{SOURCE\ \ n}$$

   Where
   F_{MMBtu} = Higher heating value of total fuel input, summed over the number of sources, n, and expressed as MMBtus

   Step 2b. Record the measured value of total useful thermal output (H) for the report year. Additional thermal energy data may be needed, as applicable.

   If the manufacturing process that generates the waste heat recovered for cogeneration generates exothermic heat (H_e), such as in a calcination process, then use equation 2c. If input steam to the steam turbine (H_{ST}) is measured, then it will be used to calculate the facility-specific electricity generation efficiency value, e_P, in step 3. The operator determines, based on the configuration of the cogeneration system, whether steam output from the heat recovery steam generator (HRSG) and steam input to the steam turbine (H_{ST}) are the same value.

Step 2c. If applicable, calculate exothermic heat from the manufacturing process (H_e). H_e shall only be included if an exothermic manufacturing process, such as calcination, provides the waste heat for cogeneration. If H_e is less than zero, then the exothermic heat of the process is not sufficient to overcome the process use and/or loss of the input fuel heat, and the H_e value is set to zero in step 4.

Equation 2c:

$$H_e = \frac{HRSG}{e_H} * 100 - F$$

Where:
H_e = Exothermic heat from manufacturing process, MMBtu
HRSG = Output of heat recovery steam generator, MMBtu
Other terms are defined above.

Step 2d. Convert the electric energy output from power generation in the report year from units of MWh to MMBtus.

Equation 2d: $P_{MMBtu} = 3.413 * P_{MWh}$

3. *Determine the efficiencies of thermal energy and electricity production.*

Step 3a. Use the manufacturer's equipment rating for efficiency of thermal energy production (e_H), if known. Otherwise, use the default value of 80 percent.

Step 3b. Determine whether you must use a facility-specific or default value for electricity generation efficiency (e_P). If input steam to the steam turbine is measured, calculate the facility-specific electricity generation efficiency value using equation 3. If input steam to steam turbine is not measured, use the default value of 35 percent.

Equation 3:

$$e_P = \frac{P_{MMBtu}}{(H_{ST})} * 100$$

4. *Determine the fraction of emissions allocated to thermal energy production and electricity generation and report the distributed emissions. For bottoming cycle plants, include the emissions allocated to the manufacturing process.*

Step 4a. Distribute emissions to the manufacturing process.

Equation 4a:

$$\frac{E_M}{E_T} = 1 - \frac{P_{MMBtu} + H + F_{S\text{-}MMBtu} * ((100 - e_H)/100)}{F_{MMBtu} + H_e} \quad \text{or}$$

$$E_M = E_T \left[1 - \frac{P_{MMBtu} + H + F_{S\text{-}MMBtu} * ((100 - e_H)/100)}{F_{MMBtu} + H_e} \right]$$

Where
E_M = Distributed emissions to manufacturing product, metric tonnes CO_2
E_T = Emissions from stationary combustion, metric tonnes CO_2
P = Power generated, expressed as MMBtu
H = Total useful thermal output, MMBtu
F_S = Fuel fired for supplemental firing in the duct burner of the HRSG, MMBtu
Other terms are defined above.

Step 4b. Distribute emissions to thermal energy production.

Equation 4b:

$$\frac{E_H}{E_T} = \frac{H/e_H}{H/e_H + P/e_P} * \left(1 - \frac{E_M}{E_T}\right) \text{ or}$$

$$E_H = \frac{H/e_H}{H/e_H + P/e_P} * (E_T - E_M)$$

Where:
E_H = Distributed emissions to thermal energy production, metric tonnes CO_2
Other terms are defined above.

Step 4c. Distribute emissions to electricity generation.

Equation 4c: $E_P/E_T = 1 - E_H/E_T - E_M/E_T$ or

$$E_P = E_T - E_H - E_M$$

Where:
E_P = Distributed emissions to electricity generation, metric tonnes CO_2
Other terms are defined above.

Example 2. Distributed emissions are calculated for a cement plant that combusts coal for cement manufacture and combusts natural gas in the duct burner of the heat recovery steam generator (supplemental firing).

Steps 1 and 2. The input data and calculated values for emissions and energy flows for the cogeneration system configuration are shown in the table below. In this configuration, the output of the heat recovery steam generator (HRSG) is the same as the input to the steam turbine (H_{ST}).

Table 9.4.2b Input Data for Example 2—
Bottoming Cycle Cogeneration Emissions Distribution

Required Data	*Optional data*	*Input Value*	*Calculated Value*
$E_{T\ CO2}$ - Total direct CO2 emissions from the cogeneration system from stationary combustion		89,362 metric tonnes CO_2	
H - Total useful thermal output		0 MMBtu	
HRSG – output of heat recovery steam generator		544,000 MMBtu	
	H_{ST} - input steam to steam turbine, if measured	544,000 MMBtu	
H_e – exothermic heat from manufacturing process, not applicable		0 MMBtu	
P_{MWh} - Power generated		P_{MWh} = 55,787 MWh	P_{MMBtu} = 190,400 MMBtu
F - Total fuel input, higher heating value weighted average		1,000,000 MMBtu	
F_S - Fuel fired for supplemental firing in the duct burner of the HRSG, typically natural gas		100,000 MMBtu	

Step 3. Determine the percent efficiencies of thermal energy and electricity production.

The HRSG manufacturer's equipment rating for efficiency of thermal energy production (e_H) is 85%.

Equation 3:

$$e_P = \frac{P_{MMBtu}}{(H_{ST})} * 100$$

e_P = 190,400/544,000 * 100 = 35%

Where:
P = Power generated for the report year, converted from MWh to MMBtu
e_P = Efficiency of electricity generation, percent
H_{ST} = Input steam to steam turbine, if measured, MMBtu

Step 4. Determine the fraction of emissions allocated to thermal energy production and electricity generation and report the distributed emissions. For bottoming cycle plants, include the emissions allocated to the manufacturing process.

Step 4a. Distribute emissions to the manufacturing process.

Equation 4a:

$$\frac{E_M}{E_T} = 1 - \frac{P_{MMBtu} + H + F_{S\text{-}MMBtu} * ((100 - e_H)/100)}{F_{MMBtu} + H_e} \quad \text{or}$$

$$E_M = E_T\left[1 - \frac{P_{MMBtu} + H + F_{S\text{-}MMBtu} * ((100 - e_H)/100)}{F_{MMBtu} + H_e}\right]$$

Where
E_M = Distributed emissions to manufacturing product, metric tonnes CO_2
E_T = Total direct emissions from the cogeneration system from stationary combustion, metric tonnes CO_2
Other terms are defined above.

$$\frac{E_M}{E_T} = 1 - \frac{190{,}400 + 0 + 100{,}000 * ((100 - 85)/100)}{1{,}000{,}000 + 0}$$

E_M/E_T = 79.46%
E_M = 71,007 metric tonnes CO_2

Step 4b. Distribute emissions to thermal energy production. Since useful thermal energy output from the cogeneration system is zero, E_H = 0.

Step 4c. Distribute emissions to electricity generation.

Equation 4c: $E_P/E_T = 1 - E_M/E_T - E_H/E_T$ or

$E_P = E_T - E_M - E_H$

Where:
E_P = Distributed emissions to electricity generation, metric tonnes CO_2
Other terms are defined above.

E_P/E_T = 20.54%
E_P = 18,355 metric tonnes CO_2

**Table 9.4.2c Data Summary for Example 2—
Bottoming Cycle Cogeneration Emissions Distribution**

Required Data	*Optional data*	*Input Value*	*Calculated Value*
$E_{T\ CO2}$ - Total direct CO2 emissions from the cogeneration system from stationary combustion		89,362 metric tonnes CO_2	
H - Total useful thermal output		0	
HRSG – output of heat recovery steam generator		544,000 MMBtu	
	H_{ST} - input steam to steam turbine, if measured	544,000 MMBtu	
P_{MWh} - Power generated, converted from MWh to MMBtu		P_{MWh} = 55,787 MWh	P_{MMBtu} = 190,400 MMBtu
F - total fuel input, higher heating value weighted average		1,000,000 MMBtu	
F_S - Fuel fired for supplemental firing in the duct burner of the HRSG, typically natural gas		100,000 MBtu	
	e_p – efficiency of electricity generation		35%
	e_H – efficiency of thermal energy production	85%	
E_M - Distributed emissions to manufacturing process			71,007 metric tonnes CO_2
E_H - Distributed emissions to thermal energy production			0
E_P - Distributed emissions to electricity generation			18,355 metric tonnes CO_2