Cogeneration: Proposed Approach for Mandatory Greenhouse Gas Emissions Reporting
California Air Resources Board (ARB): Climate Change Reporting

Cogeneration/Combined Heat and Power (CHP) Facilities in California

- 9,200 MW CHP capacity
- 917 CHP installations in California
- 333 Sites $\geq$ 1 MW

Mandatory Reporting Threshold

- Grid connected cogeneration and stand-alone/self-generation facilities $\geq$1 MW
- Cogeneration and self-generation facilities that are part of sectors mandated for reporting including refineries (17 sites), cement plants, power/utilities, or facilities that meet the General Reporting Protocol (GRP) threshold of 25,000 metric tons

Who Would Report

- Grid connected Cogeneration facilities that deliver electricity and/or usable thermal energy (steam, hot water, hot air for drying or chilled water for process cooling) to a thermal host
- Self-Generation/Stand-Alone Commercial/Industrial Co-generation Facilities that do not sell to the grid

Responsible Reporting Party

- Management/Operation Control
- Required to implement health, environmental, and safety rules for the facility

Reporting Requirements

- Cogeneration Facilities
  - Type of Facility: Grid Connected or Self-Generation
  - Fuel Type and Amount Consumed
  - CHP Technology Type(s)
  - Total CO_2, CH_4, N_20
  - Total electricity (MWh) output, sold to the grid, sold or provided to other users, and consumed on-site
    - Of the electricity sold to the grid, report the purchasers SIC code
  - Total thermal energy (BTUs) output, usable thermal energy[1], and consumed on-site
  - Indirect electricity purchases
  - Allocated emissions based on each energy stream output
- Utilities
  - Utilities that purchase electricity from cogeneration facilities would report indirect electricity purchases/imports (kWh)
- Industry
  - Industry that purchases or receives thermal energy from cogeneration facilities would report indirect thermal energy received/imported (BTU)

Other Reporting Requirements

- Cogeneration facilities would report greenhouse gas (GHG) emissions from biomass combustion in a separate carbon neutral category

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[1] Usable thermal energy is based on Federal Energy Regulatory Commission (FERC) definition, which is thermal energy delivered to a thermal host and not remaining thermal energy exhausted as waste heat.

GHG Emissions Allocation

ARB staff proposes that cogeneration facilities report all GHG emissions generated on-site as direct emissions. Reporters would allocate emissions based on the output of each energy stream. ARB staff evaluated the following methodologies available to allocate GHG emissions from electricity and thermal energy produced at cogeneration facilities.

Work Potential Method

This method allocates emissions based on the useful energy represented by electric power and heat, and defines useful energy on the ability of heat to perform work. The work potential method may be most appropriate for systems that use heat to produce mechanical work.

Energy Content Method

This method allocates emissions based on the useful energy contained in each CHP output stream. The best application of this method may be at cogeneration facilities where heat is used for a specific industrial process. This method may not be appropriate for systems that use heat to produce mechanical work because it could overestimate the amount of useful energy in the heat, which would result in lower GHG emissions associated with the heat stream.

Public Utilities Commission (PUC) Conversion Method

This method allocates emissions based on the net power output and useful energy delivered to a thermal host. An emission rate is used to estimate emissions associated with power production. The remaining emissions are allocated to thermal energy. The PUC Conversion Method assigns the same efficiency to both electricity and thermal energy outputs.

Efficiency Method to Allocate GHG Emissions

The efficiency method allocates GHG emissions based on the amount of fuel used to produce each final energy stream. Emissions are allocated based on the efficiencies of thermal energy and electricity production. This method assumes that conversion of fuel energy to thermal energy generation is more efficient than electricity generation. It is the preferred method recommended by:

- California Climate Action Registry (Registry)
- WRI/WBCSD
- UK Emissions Trading Scheme (ETS)
- U.S. EPA Climate Leaders

Actual efficiencies of thermal energy and power vary between the two most common cogeneration systems; steam boiler/turbines and combustion turbines. A steam boiler/turbine can generate up to 5 times more thermal energy than electric energy. A combustion turbine can generate from 1 to 2 times more thermal energy than electric energy. The Registry, U.S. EPA, and WRI/WBCSD recommend cogeneration facilities identify actual thermal energy and electricity production efficiencies. If actual efficiencies of heat and power production are unknown, they allow for the use of default values of 80% for steam and 35% for electricity.

Basic Steps to Allocate Emissions Using the Efficiency Method

1. Determine the total direct emissions from the cogeneration facility
2. Determine output flows of thermal energy and electricity expressed in BTU
3. Estimate the efficiencies of steam and electricity production
4. Determine the fraction of emissions allocated to thermal energy and electricity

The Registry protocol does not require additional calculations beyond this point. However, the WRI/WBCSD protocol includes two additional steps to calculate an emission rate and estimate emissions from purchases or sales. UK ETS states that imported heat, steam, and electricity counts towards direct emissions of the participant. Similarly, a facility that exports heat, steam, and electricity subtracts those allocated emissions from their total direct emissions. The American Petroleum Institute (API) Compendium provides examples for allocating emissions based on onsite usage (imports) and offsite sales (exports). Table 1 provides an overview of allocated GHG emissions based on energy stream outputs in comparison to allocated emissions based on imports and exports. Appendix A and the API compendium provide supporting calculations for this table.

Table 1: Summary of Methodologies and GHG Emissions Allocation Results

Methodology	**PUC Conversion Method** Emissions (metric tons CO2e)	**Registry Efficiency Allocation** Emissions (metric tons CO2e)	**UK ETS Efficiency Allocation** Emissions (metric tons CO2e)	**WRI WBCSD Efficiency Allocation** Emissions (metric tons CO2e)	**Registry Efficiency Allocation** Emissions (metric tons CO2e)	**Work Potential** Emissions (metric tons CO2e)
Efficiency Assumptions	Same for Heat and Electricity	Steam: 80% Electricity: 35%	Heat Generation 2X Electricity	Steam: 77% Electricity: 24%	Same for Heat and Electricity[2]	N/A
Cogeneration Facility – Direct Emissions from fuel consumption	435,982	435,982	435,982	435,982	435,982	435,982
Allocated Emissions Based on Energy Stream Output						
Electricity	253,138	306,796	293,860	335,375	222,162	346,689
Thermal energy	182,844	129,186	141,941	100,607	213,820	89,324
Allocated Emissions Based on Imports and Exports[3]						
Purchased electricity	N/A[4]	N/A	55,002	62,772	41,582	64,890
Purchased steam			106,410	75,441	160,335	66,980
Emissions Associated with Electricity Sold to the Grid			228,579	272,601	180,580	269,672

[2] The API compendium assumes the same efficiency for both heat and electricity production. While the Registry recommends actual efficiencies be used, default values of 80% for steam and 35% for electricity can also be used.
[3] Excerpted from the API Compendium examples to allocate emissions based on onsite usage and offsite sales/exports.
[4] ARB's proposed approach does not require reporters to allocate emissions based on imports or exports.

Proposed Approach
After evaluating the various methodologies available to allocate GHG emissions, ARB is considering adoption of either the PUC Conversion Method or the Registry Efficiency Allocation. If ARB adopts the Registry Efficiency Method, ARB staff proposes that cogeneration facilities calculate GHG emissions based on actual efficiencies of CHP systems. Regardless of either approach that is adopted, all emissions generated by a cogeneration facility would be considered direct emissions. For the purposes of mandatory reporting, ARB staff proposes that facilities allocate emissions based on energy stream outputs.

QUESTIONS:

1. Should ARB adopt the PUC Conversion Method or the Registry's Efficiency Method?

2. Do cogeneration facilities collect data on actual thermal energy and electricity production efficiency values?

3. Are there any recommendations for ARB to adopt another method to allocate GHG emissions?

4. Other comments?

Appendix A: Supporting Calculations
Cogeneration Emissions Allocation

INPUT DATA:
The following calculations use the assumptions and input data outlined in the American Petroleum Institute (API) Compendium, section 4.7.3 *Allocation of Cogeneration Emissions*.

Where: Total GHG Emissions = 435,982 metric tons CO_2e (Exhibit 4.13)

> "The cogeneration facility consumes 8,131,500 million BTU of natural gas, producing 3,614,000 million BTU steam and 1,100,600 megawatt-hr of electricity (gross) on an annual basis. The refinery purchases 2,710,000 million Btu of steam and 206,000 megawatt-hr of electricity. The cogeneration facility itself requires 38,500 megawatt-hr to operate (Parasitic load), with the net electricity (856,100 megawatt-hrs) is sold to the electric grid."

Conversion Method – Public Utilities Commission (PUC) Adopted Approach

$$\text{Emission Rate} = \frac{\text{Total GHG Emissions}}{\text{Electricity Output (kWh)} + \text{Usable Thermal Energy (kWh)}}$$

$$\text{Emission Rate} = \frac{435{,}982 \text{ metric tons } CO_2e}{1{,}100{,}600{,}000 \text{ (kWh)} + 2{,}710{,}000{,}000{,}000 \text{ BTU} \bullet \frac{1 \text{ kWh}}{3{,}413 \text{ BTU}}}$$

$$\text{Emission Rate} = \frac{435{,}982 \text{ metric tons } CO_2e}{1{,}100{,}600{,}000 \text{ (kWh)} + 794{,}022{,}854 \text{ (kWh)}}$$

$$\text{Emission Rate} = \frac{435{,}982 \text{ metric tons } CO_2e}{1{,}894{,}622{,}854 \text{ (kWh)}} = 0.00023 \text{ metric tons } CO_2e/\text{kWh}$$

Emissions $_{\textbf{Electricity}}$ = Emission Rate • Electricity Output

Emissions $_{Electricity}$ = 0.00023 metric tons CO_2e/kWh • 1,100,600,000 kWh

Emissions $_{Electricity}$ = 253,138 metric tons CO_2e

Emissions $_{\textbf{Steam}}$ = Emissions $_{Total}$ – Emissions $_{Electricity}$

Emissions $_{Steam}$ = 435,982 metric tons CO_2e – 253,138 metric tons CO_2e

Emissions $_{Steam}$ = 182,844 metric tons CO_2e

Allocated Emissions	**Metric Tons CO_2 Eq.**
Electricity	253,138
Steam	182,844

Efficiency Allocation – California Climate Action Registry (Registry) Efficiency Method

Step 1: Direct (On-site) Combustion Emissions from Cogeneration = 435,982 tonnes CO_2Eq

Step 2: Determine the total steam and electricity output in the same units

Electricity Output: 1,100,600 MWh
Steam Output: 3,614,000,000,000 BTU

$$1{,}100{,}600\text{MWh} \bullet \frac{1000\text{kWh}}{\text{MWh}} \bullet \frac{\text{BTU}}{2.931\times10^{-4}\,\text{kWh}}$$

$$1{,}100{,}600{,}000\text{kWh} \bullet \frac{\text{BTU}}{0.0002931\text{kWh}} = 3.755\times10^{12}\ \text{BTU (Electricity Output)}$$

Step 3: Determine the efficiencies of steam and electricity production
In this example, default values of 80% for steam and 35% for electricity were assumed.

Step 4: Determine the fraction of emissions allocated to Steam and Electricity

Steam Allocation

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

$$E_H = \frac{\frac{3.614\times10^{12}\,\text{BTU}}{0.80}}{\frac{3.614\times10^{12}\,\text{BTU}}{0.80} + \frac{3.755\times10^{12}\,\text{BTU}}{0.35}} \times 435{,}982 \text{ metric tons } CO_2e$$

$$E_H = \frac{4{,}517{,}500{,}000{,}000}{4{,}517{,}500{,}000{,}000 + 10{,}728{,}571{,}428{,}571} \times 435{,}982 \text{ metric tons } CO_2e$$

$$E_H = \frac{4{,}517{,}500{,}000{,}000}{15{,}246{,}071{,}428{,}571} \times 435{,}982 \text{ metric tons } CO_2e$$

$E_H = 0.29631 \times 435{,}982$ metric tons CO_2e = 129,186 metric tons CO_2e

Electricity Allocation

$E_P = E_T - E_H$

E_P = 435,982 metric tons CO_2e – 129,186 metric tons CO_2e = 306,796 metric tons CO_2e

Allocated Emissions	**Metric Tons CO_2e**
Electricity	306,796
Steam	129,186

Efficiency Allocation – UK ETS Approach

Step 1: Direct (On-site) Combustion Emissions from Cogeneration= 435,982 metric tons CO_2e

Step 2: Determine the steam thermal equivalent
Electricity Output: 1,100,600 MWh
Steam Output: 3,614,000,000,000 BTU

$$3{,}614{,}000{,}000\ \text{BTU} \bullet \frac{2.931\times10^{-4}\ \text{kWh}}{\text{BTU}} \bullet \frac{\text{MWh}}{1{,}000\text{kWh}} = 1{,}059{,}263\ \text{MWh}$$

Step 3: Calculate Electricity and Steam Emission Factors

CO_2 Electricity Emission Factor ($EF_{Electricity}$)

$$EF_{Electricity} = \frac{2\times CO_2\ \text{direct emissions (metric tons } CO_2)}{[2\times \text{Electricity produced (MWh)}] + \text{Steam produced (MWh)}}$$

$$EF_{Electricity} = \frac{2\times 435{,}982\ \text{(metric tons } CO_2\text{e)}}{[2\times 1{,}100{,}600\ \text{(MWh)}] + 1{,}059{,}263\ \text{(MWh)}}$$

$EF_{Electricity}$ = 0.267 metric tons CO_2e/MWh

CO_2 Steam Emission Factor (EF_{Steam})

$$EF_{Steam} = \frac{CO_2\ \text{direct emissions (metric tons } CO_2)}{[2\times \text{Electricity produced (MWh)}] + \text{Steam produced (MWh)}}$$

$$EF_{Steam} = \frac{435{,}982\ \text{metric tons } CO_2\text{e}}{[2\times 1{,}100{,}600\ \text{(MWh)}] + 1{,}059{,}263\ \text{(MWh)}}$$

EF_{Steam} = 0.134 metric tons CO_2e/MWh

Step 4: Allocate Emissions to Electricity and Steam
Emissions $_{\textbf{Electricity}}$ = $EF_{Electricity}$ • Electricity Output

Emissions $_{\textbf{Electricity}}$ = 0.267 metric tons CO_2e/MWh × 1,100,600 MWh = 293,860 metric tons CO_2e

Emissions $_{\textbf{Steam}}$ = EF_{Steam} • Steam Output

Emissions $_{\textbf{Steam}}$ = 0.134 metric tons CO_2e/MWh ×1,059,263 MWh = 141,941 metric tons CO_2e

Allocated Emissions	**Metric Tons CO_2e**
Electricity	293,860
Steam	141,941

Efficiency Allocation –WRI/WBCSD Approach

Step 1: Direct (On-site) Combustion Emissions from Cogeneration= 435,982 metric tons CO_2e

Step 2: Determine the total steam and electricity output in the same units
1,100,600 MWh of electricity
3,614,000,000,000 BTU of steam

$$1{,}100{,}600\text{MWh} \bullet \frac{1000\text{kWh}}{\text{MWh}} \bullet \frac{\text{BTU}}{2.931\times10^{-4}\,\text{kWh}}$$

$$1{,}100{,}600{,}000\text{kWh} \bullet \frac{\text{BTU}}{0.0002931\text{kWh}} = 3.755\times10^{12}\ \text{BTU (Electricity Output)}$$

Step 3: Determine the efficiencies of steam and electricity production
In this example, efficiency values of 77% for steam and 24% for electricity were assumed.

Step 4: Determine the fraction of emissions allocated to Steam and Electricity

Steam Allocation

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

$$E_H = \frac{\dfrac{3.614\times10^{12}\,\text{BTU}}{0.77}}{\dfrac{3.614\times10^{12}\,\text{BTU}}{0.77} + \dfrac{3.755\times10^{12}\,\text{BTU}}{0.24}} \times 435{,}982 \text{ metric tons } CO_2e$$

$$E_H = \frac{4{,}693{,}506{,}493{,}506}{4{,}693{,}506{,}493{,}506 + 15{,}645{,}833{,}333{,}333} \times 435{,}982 \text{ metric tons } CO_2e$$

$$E_H = \frac{4{,}693{,}506{,}493{,}506}{20{,}339{,}339{,}826{,}839} \times 435{,}982 \text{ metric tons } CO_2e$$

E_H = 0.23076 × 435,982 metric tons CO_2e = 100,607 metric tons CO_2e

Electricity Allocation

$E_P = E_T - E_H$

E_P = 435,982 metric tons CO_2e – 100,607 metric tons CO_2e = 335,375 metric tons CO_2e

Allocated Emissions	**Metric Tons CO_2e**
Electricity	306,796
Steam	129,186