Accounting for CHP in Output-Based Regulations

U.S. Environmental Protection Agency

Combined Heat and Power Partnership

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Contents

1.0 Introduction

Output-based regulations (OBR)[1] encourage energy efficiency and clean energy supply, such as combined heat and power (CHP), by relating emissions to the productive output of the process rather than the amount of fuel burned. OBR include output-based emissions limits (OBEL)[2] that are expressed in terms of mass pollutant per unit of electrical, thermal, or mechanical output (e.g., lb/MWh, lb/$MMBtu_{output}$ or lb/bhp-hr), rather than in terms of the heat input of fuel burned (e.g. lb/$MMBtu_{fuel}$) or pollutant concentration in the exhaust.

When there is a single type of output for equipment covered by OBR, emissions rates are calculated using the measured emissions and output of the subject equipment. CHP systems, however, produce both electrical and thermal output (e.g., process steam), which are typically measured in different units. An OBR can be developed to account for the secondary output of a CHP system when calculating emissions per unit of output and therefore recognize the emissions benefits of CHP.

The goal of this paper is to:

- Educate air regulators and others about the importance of including a secondary output for CHP when developing OBR.
- Present two approaches for calculating an emission rate that includes secondary output.
- Provide examples of existing state and federal OBR that include secondary output.

2.0 Two Approaches to Account for Secondary Output

The secondary output concept has been introduced as a way to consider CHP as a regulated emissions unit. It is built on the premise that combustion units are typically regulated either as an electric generating unit or as a thermal generating unit. As an emissions unit, a CHP system can be thought of in one of two ways for the purpose of determining whether the secondary output is thermal or electric output:

- When fuel is consumed by a combustion turbine, reciprocating engine, or microturbine, the CHP system functions as an electric generator that also produces useful thermal energy. The secondary output, in this case, would be a thermal output.
- Conversely, when fuel is consumed by a boiler, the CHP system functions as a thermal generator that also produces electricity. The secondary output, in this case, would be an electric output.

Two common approaches can be used to calculate an emissions rate that includes the primary and secondary output of CHP in OBR: the *equivalence approach* and the *avoided emissions approach*. Either approach can be effectively applied to address various CHP technologies and configurations. See Section 3.0 of this document for examples of state and federal rules that utilize these approaches. The appropriate choice could involve either approach and would be governed by the overall regulatory structure and objectives as determined by policymakers and the legislative process.

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[1] Details on OBR can be found in the EPA's "Output-Based Environmental Regulations" Fact Sheet, available at www.epa.gov/chp.

[2] OBR can also take the form of output-based allocations, a component of cap-and-trade programs. However, such provisions are not addressed in this document.

2.1 Equivalence Approach

The *equivalence approach* is structured to express the secondary CHP system output in terms of the primary CHP system output, and it includes both outputs in determining the total productive CHP system output used in the denominator when calculating the emissions rate. Specifically:

1. In the case of OBR applying to an emissions unit that is primarily an electric generator (e.g., combustion turbine, reciprocating engine, or microturbine) that also produces useful thermal energy, the thermal output of the CHP system (usually measured in $MMBtu_{thermal}$) is converted into MWh and added to the CHP system's measured electric output in MWh.

2. In the case of OBR applying to an emissions unit that primarily produces useful thermal energy (e.g., boiler) that also produces electricity, the electric output of a CHP system is converted into MMBtu and added to the CHP system's measured thermal output in $MMBtu_{thermal}$.

3. The value of the conversion factor depends on the underlying regulatory objectives:
   a) The conversion into equivalent units of measure can be based on straight unit conversions (e.g., 3412 Btu equals 1 kWh).
   b) To reflect the relative value of the energy outputs (e.g., 1 kWh of electricity equals 10,000 Btu of thermal energy based on typical power generation efficiencies).
   c) To account for only a portion of the secondary output (e.g., only 75 percent of the thermal output is credited).

Equation 1 can be used to calculate the emissions rate of a CHP system with <u>secondary thermal output using the equivalence approach</u>. Appendix A includes a corresponding example.

Equation 1: Equivalence Approach with Secondary Thermal Output

$$ER_C = ER_m \times 1/[EO_m + (TO_m \times 1/CF)]$$

Where:

ER_C = Adjusted CHP Emissions Rate (lb/MWh)
ER_m = Measured CHP Emissions Rate (lb/hr)
EO_m = CHP Electric Output (MW)
TO_m = CHP Thermal Output (MMBtu/hr)
CF = Conversion Factor (MMBtu/MWh)

Compliance Procedures

Step 1: Determine EO_m, TO_m and ER_m. (Note: These quantities are typically measured, e.g., electric meter, steam meter, emission testing.)

Step 2: Identify the OBR-specified value of CF.

Step 3: Calculate ER_C. (Note: ER_C will be compared to the output-based emissions limits and therefore should have the same units.)

Equation 2 can be used to calculate the emissions rate of a CHP system with secondary electricity output using the equivalence approach. Appendix B includes a corresponding example.

Equation 2: Equivalence Approach with Secondary Electricity Output

$$ER_C = ER_m \times 1/[TO_m + (EO_m \times CF)]$$

Where:

ER_C	=	Adjusted CHP Emission Rate (lb/MMBtu)
ER_m	=	Measured CHP Emission Rate (lb/hr)
TO_m	=	CHP Thermal Output (MMBtu/hr)
EO_m	=	CHP Electric Output (MWh)
CF	=	Conversion Factor (MMBtu/MWh)

Compliance Procedures

Step 1: Determine EO_m, TO_m and ER_m. (Note: These quantities are typically measured, e.g., electricity meter, steam meter, emission testing.)

Step 2: Identify the OBR-specified value of CF.

Step 3: Calculate ER_C. (Note: ER_C will be compared to the output-based emissions limits and therefore should have the same units.)

2.2 Avoided Emissions Approach

The avoided emissions approach incorporates an assumption about the emissions associated with the avoided separate production of heat or power, as compared to the emissions of a CHP system. This approach therefore requires an assessment of the emissions associated with avoided electric output or avoided thermal output depending on the type of emission units.

1. In the case of OBR applying to a regulated emissions unit that is primarily an electric generator that also produces useful thermal energy, the assumed emissions associated with an equivalent stand-alone thermal generating unit (e.g., boiler) are deducted from the CHP system emissions for the purposes of calculating the adjusted emissions rate. In these cases, a regulated CHP system is treated as an electric generator that also produces thermal energy. Accordingly, the CHP system emissions are reduced by the amount of emissions that would have been created by the combustion of fuel in a conventional thermal generating unit that produced the same amount of thermal energy.

   The avoided emissions for the thermal output of a CHP system can be based on the site's specific characteristics or on a broader default value representing typical conditions. For example, the avoided thermal emissions for a greenfield gas turbine CHP system could be based on the emission limits applicable to a new natural gas boiler. Similarly, for a retrofit gas turbine system, the avoided emissions could be based on the emission rate of the boiler actually displaced by the system. A ceiling can also be placed on the avoided emissions rate for retrofit applications to avoid basing the emissions displacement on old, very high-emitting boilers. The Regulatory Assistance Project used this approach in developing their Distributed Generation Model Rule in 2002[3]; Connecticut adopted this approach in their small distributed generation emissions standard[4].

2. In the case of OBR applying to a regulated emissions unit that is primarily a thermal energy generating unit (e.g., a boiler) that also generates electricity, the emissions associated with the equivalent output from an electric generating unit (e.g., fossil fuel fired central station plant) are deducted from the CHP system emissions for the purposes of calculating the emissions rate.

3. Regulations that use the avoided emissions approach would typically specify the avoided emissions quantities associated with separate heat and power (SHP), such as the Avoided Emission Factor (AEF), Avoided Thermal Efficiency (ATE), and Avoided Central Station Emission Factor (ACEF) in Equations 3 and 4.[5] The AEF and ATE would be derived based on the CHP system characteristics, while the ACEF could be based on data available on EPA's eGRID database[6].

Equation 3 can be used to calculate the emissions rate of a CHP system using <u>secondary thermal output using the avoided emissions approach</u>. Appendix A includes a corresponding example.

[3] Regulatory Assistance Project. *Model Regulations for the Output of Specified Air Emissions from Small-Scale Electric Generation Resources*. Issues letter, July 2003. Montpelier, VT.

[4] Connecticut's Sec. 22a-174-42 regulations for distributed generators.

[5] The value of these factors depends on the underlying regulatory objectives. Please contact the EPA CHP Partnership for more information.

[6] The Emissions & Generation Resource Integrated Database (eGRID) is a comprehensive source of data on the environmental characteristics of almost all electric power generated in the United States. The database can be accessed on the EPA website at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

Equation 3: Avoided Emissions Approach with Secondary Thermal Output

ER_C = $(ER_m – AER) \times 1/EO_m$

Where:

AER = $AEF \times 1/ATE \times TO_m$
ER_C = Adjusted CHP Emission Rate (lb/MWh)
ER_m = Measured CHP Emission Rate (lb/hr)
AER = Avoided Emissions Rate (lb/hr)
AEF = Avoided Emission Factor (lb/MMBtu)
ATE = Avoided Thermal Efficiency (percentage expressed as a decimal)
TO_m = CHP Thermal Output (MMBtu/hr)
EO_m = CHP Electric Output (MW)

Compliance Procedures

Step 1: Determine EO_m, TO_m and ER_m. (Note: These quantities are typically measured, e.g., electric meter, steam meter, emission testing)

Step 2: Identify the OBR-specified value for AEF and ATE.

Step 3: Calculate AER.

Step 4: Calculate ER_C. (Note: ER_C will be compared to the output-based emissions limits and therefore should have the same units.)

Equation 4 can be used to calculate the emissions rate of a CHP system using secondary electricity output using the avoided emissions approach. Appendix B includes a corresponding example.

Equation 4: Avoided Emissions Approach with Secondary Electricity Output

ER_C = $(ER_m – AER) \times 1/TO_m$

Where:

AER = $ACEF \times EO_m$
ER_C = Adjusted CHP Emission Rate (lb/MMBtu)
AER = Avoided Emissions Rate (lb/hr)
$ACEF$ = Avoided Central Station Emission Factor (lb/MWh)
EO_m = CHP Electric Output (MW)
ER_m = Measured CHP Emission Rate (lb/hr)
TO_m = CHP Thermal Output (MMBtu/hr)

Compliance Procedures

Step 1: Determine ER_m, TO_m and EO_m. (Note: These quantities are typically measured, e.g., electric meter, steam meter, emission testing.)

Step 2: Identify the OBR-specified value for ACEF.

Step 3: Calculate AER.

Step 4: Calculate ER_C. (ER_C will be compared to the output-based emissions limits and therefore should have the same units.)

3.0 State and Federal Examples of OBR with Secondary Output for CHP

3.1 State OBR with Secondary Output for CHP

Table 1 lists the states with OBR that allow for the inclusion of secondary output for CHP.

Table 1: States with OBR That Allow for the Inclusion of CHP Secondary Output

Approach	State - Type of regulation
Equivalence Approach	California – Conventional emissions limits and emissions performance standard
	Texas – Permit by Rule (PBR) and Standard Permit
Avoided Emissions Approach	Connecticut – Small DG Rule
	Delaware – Conventional emissions limits
	Massachusetts – Small DG Rule and performance standards
	Rhode Island – Conventional emissions limits

- In **California**, CHP systems may be subject to emission limitations pursuant to the state's Distributed Generation Regulation. This regulation includes NO_X, CO, VOC, and PM emission limits (lb/MWh), and it allows CHP systems to account for 100 percent of their secondary thermal output using the *equivalence approach*. A CHP system can take into account the secondary thermal output if the CHP system achieves a minimum efficiency of 60 percent.

  Information on California's multi-pollutant regulations are available at: http://www.arb.ca.gov/regact/dg06/finalfro.pdf

- **Connecticut's** Distributed Generators Rule establishes emissions limits (lb/MWh) for NO_X, PM, CO, and CO_2 from small distributed generation systems that are less than 15 MW in capacity, including CHP systems. The rule allows a CHP system to account for its secondary thermal output using the *avoided emissions approach*. A CHP system can take into account the secondary thermal output if it meets the following criteria:

  - At least 20 percent of the fuel's total recovered energy is thermal and at least 13 percent is electric, with a resulting power-to-heat ratio between 4.0 and 0.15.
  - The design system efficiency is at least 55 percent.

  Additional information on the Connecticut rule can be obtained at: http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec42.pdf

- In **Delaware**, new and existing distributed generators may be subject to emissions limits (lb/MWh) pursuant to state air quality Regulation No. 1144. Using the *avoided emissions approach*, the rule allows a CHP system to account for its secondary thermal output when determining compliance with NO_X, CO, and CO_2 emission limits. A CHP system can take into account the secondary thermal output if it meets the following criteria:

- At least 20 percent of the fuel's total recovered energy is thermal and at least 13 percent is electric, with a resulting power-to-heat ratio between 4.0 and 0.15.
- The design system efficiency is at least 55 percent.

Additional information on the Delaware rule can be obtained at: http://www.dnrec.state.de.us/air/aqm_page/docs/pdf/Final%20Regulation%201144.pdf

- In **Massachusetts**, industry performance standards for small distributed generation include output-based emission limits and allow a CHP system to account for its secondary thermal output using the *avoided emissions approach.* A CHP system can take into account the secondary thermal output if it meets the following criteria:

  - The power-to-heat ratio is between 4.0 and 0.15.
  - The design system efficiency is at least 55 percent.
  - Engine systems have a rated power output equal to or greater than 50 kW; turbine systems have a rated power output less than or equal to 10 MW.

  Additional information on the Massachusetts rule (the CHP provisions are outlined in 310 CMR 7.26(45)) is available at: http://www.mass.gov/dep/service/regulations/310cmr07.pdf

- In **Rhode Island**, new and existing distributed generators may be subject to emissions limits (lb/MWh) pursuant to state air pollution control Regulation No. 43. Using the *avoided emissions approach*, the rule allows a CHP system to account for its secondary thermal output when determining compliance with NO_X, CO, and CO_2 emission limits. A CHP system can take into account the secondary thermal output if it meets the following criteria:

  - The power-to-heat ratio is between 4.0 and 0.15.
  - The design system efficiency is at least 55 percent.

  Additional information on the Rhode Island rule can be obtained at: http://www.dem.ri.gov/pubs/regs/regs/air/air43_07.pdf

- **Texas** offers a streamlined construction air permitting program, termed a permit by rule (PBR), which was issued in July 2012 for certain types of natural gas-fired CHP systems up to 15 MW. The CHP PBR, codified in 30 TAC 106.513, allows CHP systems that meet the rule's eligibility requirements to comply with NO_X emission limits using the *equivalence approach*. A CHP system can take into account the secondary thermal output if "the heat recovered equals at least 20 percent of the total heat energy output of the CHP system."

  Additional information on the PBR is available at: http://info.sos.state.tx.us/pls/pub/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=106&rl=513

- **Texas** also has a standard permit program for electric generating units that meet the applicability requirements of the standard permit. The program includes NOx emission limits and allows CHP systems to comply using the *equivalence approach*. A CHP system can take into account its secondary thermal output if "the heat recovered equals at least 20 percent of the total heat energy output of the CHP unit."

Additional information on the standard permit program is available at:
http://www.tceq.texas.gov/permitting/air/newsourcereview/combustion/egu_sp.html#claim

3.2 Federal OBR with Secondary Output for CHP

- EPA's New Source Performance Standard (NSPS) for Electric Utility Steam Generating Units (40 CFR Part 60, Subpart Da) limits emissions from electric generating units. When originally promulgated in 1998, it was the first NSPS for boilers that incorporated output-based emission limits. The regulation currently establishes NO_X emissions limits and uses the *equivalence approach*. It allows CHP systems to account for 75 percent of their secondary thermal output.

  Additional information about the rule is available at:
  http://www.epa.gov/ttn/atw/nsps/boilernsps/boilernsps.html

- EPA's New Source Performance Standard (NSPS) for Stationary Combustion Turbines (40 CFR Part 60, Subpart KKKK) limits emissions from stationary combustion turbines. Affected units have the option of meeting concentration- based or output-based NO_X and SO_2 emissions limits. Using the *equivalence approach*, the rule allows CHP systems to account for 100 percent of their secondary thermal output.

  Additional information about the rule is available at:
  http://www.epa.gov/ttn/atw/nsps/turbine/turbnsps.html

- On December 20, 2012, EPA finalized changes to the National Emissions Standard for Hazardous Air Pollutants (NESHAP) for Major Sources: Industrial, Commercial, and Institutional Boilers and Process Heaters, 40 CFR Part 63, Subpart DDDDD, This rule is commonly referred to as the "Boiler MACT". Using the *equivalence approach*, the rule contains provisions for boiler/steam turbine CHP to account for their secondary electricity output with a value of 10,000 Btu/kWh.

  Additional information about the rule is available at:
  http://www.epa.gov/ttn/atw/boiler/boilerpg.html

4.0 Conclusion

The equivalence approach is a simpler method than the avoided emissions approach, because it relies on the measured emissions and the measured electricity and thermal output of the system. When considering this approach, the rule language would need to state that the output will be calculated as the electric output plus the thermal output (in common units of measure) based on a specified conversion rate. The avoided emissions approach, on the other hand, provides for a more complete accounting of the environmental benefits of CHP by including the emissions avoided by the CHP system's secondary output in the calculation. The avoided emissions approach, however, requires additional measured data or assumptions. Regardless of the approach selected, the approach by which compliance is demonstrated should be consistent with the approach used to develop the output-based emissions limit.

The appropriate choice of an approach will be governed by the overall regulatory structure and objectives. As an example, in one case, there may be a separate rule proposed for CHP systems, while in another case, provisions for a secondary output (and so for CHP) are proposed as part of a broader steam or electric generating rule. There may, therefore, be more flexibility in the selection of the approach in the first case, while in the second case the approach may need to maintain compatibility with the overall rule. Regulatory objectives will also determine how much of the secondary output is accounted, for example, whether only a portion of the thermal output or all of the thermal output is credited. The regulatory objectives may also reflect a desire to harmonize a state's energy and environmental objectives.

Both approaches to accounting for secondary output – the equivalence approach and the avoided emissions approach – have their own distinct benefits, and are preferable to an OBR that recognizes only a single output for a CHP system.

5.0 Additional Resources

Output-Based Environmental Regulations: An Effective Policy to Support Clean Energy Supply is a fact sheet explaining how OBR promote clean energy supply technologies. It includes additional information about the benefits of OBR, how to account for the secondary output of CHP systems, lists best practices determined from OBR implementation and presents a comprehensive list of state OBR. The fact sheet is available at: www.epa.gov/chp/state-policy/output.html

Output-based Regulations: A Handbook for Air Regulators explains the benefits of output-based emissions limits, how to develop OBR, and the experience of several states in implementing OBR. This document provides detailed examples of the two approaches used to account for secondary output of CHP as described in this fact sheet. This handbook is intended as a resource for air regulators in evaluating opportunities to adopt OBR and in writing regulations. The handbook is available at: http://www.epa.gov/chp/documents/obr_final_9105.pdf

The Regulatory Assistance Project developed a model emissions regulation that uses the avoided emissions approach to calculate a secondary thermal output. An overview of the model rule, *Output-Based Emissions Standards for Distributed Generation*, is available at:
http://www.raponline.org/document/download/id/176
The model rule itself, *Model Regulations for the Output of Specified Air Emissions from Small-Scale Electric Generation Resources*, is available at:
http://www.raponline.org/document/download/id/174.

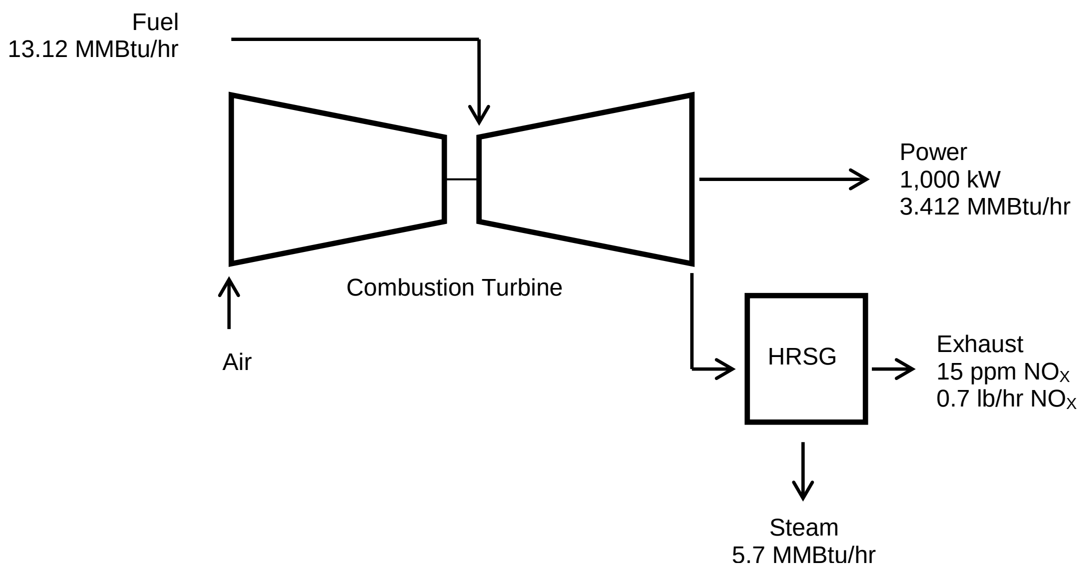
EPA's *Clean Energy-Environment Guide to Action* provides an overview of clean energy supply technology options and presents a range of policies, including OBR, which states have adopted to encourage continued growth of clean energy technologies and energy efficiency. The guide is available at: www.epa.gov/cleanenergy/stateandlocal/guidetoaction.htm.

The EPA CHP Partnership is a voluntary program that seeks to reduce the environmental impact of power generation by promoting the use of cost-effective CHP. The Partnership assists state policy makers and regulators to evaluate opportunities to encourage CHP through the implementation of policies and programs. Information about the Partnership and resources related to CHP are available at: www.epa.gov/chp.

Appendix A: Example Calculations for Secondary Thermal Output

A gas turbine-based CHP system (as shown in Figure A-1 below) is permitted to operate in a state with an output-based regulation. The regulation limits NO_X emissions from electric generators and accounts for secondary thermal output from CHP.

Figure A-1: Gas Turbine CHP system



CHP System Power to Heat Ratio = 3.412 MMBtu/hr / 5.7 MMBtu/hr = 0.6

CHP Efficiency = (3.412 MMBtu/hr + 5.7 MMBtu/hr) / 13.12 MMBtu/hr) = 69%

Calculations for Secondary Thermal Output Using the Equivalence Approach

The regulation specifies that the conversion factor used to calculate the adjusted CHP emissions rate is equal to 3.412 MMBtu/MWh. Using Equation 1 from Section 2 of this document:

Step 1: Determine the Electric Output, the Thermal Output and the Measured CHP Emissions Rate:

Electric Output (EO_m)	=	1 MW
Thermal Output (TO_m)	=	5.7 MMBtu/hr
CHP Emissions Rate (ER_m)	=	0.7 lb NO_X/hr

Step 2: Identify the Conversion Factor specified in the regulation:

3.412 MMBtu/MWh

Step 3: Calculate the Adjusted CHP Emissions Rate (ER_C):

$$\mathbf{ER_C} = ER_m \times 1/[EO_m + (TO_m \times 1/CF)]$$
$$= 0.7 \times 1/[1 + (5.7 \times 1/3.412)]$$
$$= 0.7 \times 1/2.67$$
$$= \mathbf{\sim 0.26\ lb\ NO_X/MWh}$$

Calculations for Secondary Thermal Output Using the Avoided Emissions Approach

The regulation specifies that the avoided emissions are calculated based on the emissions of a new natural gas-fired boiler with a thermal efficiency of 80% and NO_X emissions of 0.05 $lb/MMBtu_{fuel}$.** Using Equation 3 from Section 2 of this document:

(**0.05 lb/MMBtu is an assumed emission rate and does not represent a value recommended by EPA. The design and intent of an OBR should determine the value of the Avoided Emissions Factor [AEF].)

Step 1: Determine the Electric output, the Thermal Output and the Measured CHP Emission Rate:

Electric Output (EO_m)	=	1 MW
Thermal Output (TO_m)	=	5.7 MMBtu/hr
Measured CHP Emissions Rate (ER_m)	=	0.7 lb NO_X/hr

Step 2: Identify Avoided Emissions Factor and Avoided Thermal Efficiency specified in the regulation:

Avoided Emissions Factor (AEF)	=	0.05 $lb/MMBtu_{fuel}$
Avoided Thermal Efficiency (ATE)	=	80%

Step 3: Calculate the Avoided Emissions Rate (AER):

$$AER = AEF \times 1/ATE \times TO_m$$
$$= 0.05 \times 1/0.8 \times 5.7$$
$$= \sim 0.36 \text{ lb } NO_X/\text{hr}$$

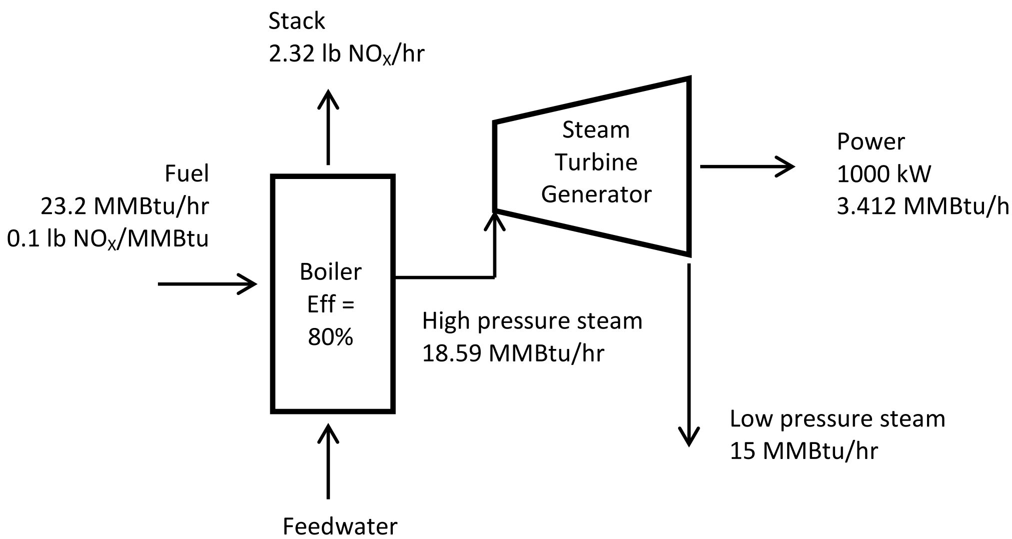
Step 4: Calculate the Adjusted CHP Emissions Rate (ER_C):

$$\mathbf{ER_C} = (ER_m - AER) \times 1/EO_m$$
$$= (0.7 - 0.36) \times 1/1$$
$$\mathbf{= \sim 0.34 \text{ lb } NO_X/MWh}$$

Appendix B: Example Calculations for Secondary Electricity Output

A boiler/steam turbine-based CHP system (as shown in Figure B-1 below) is permitted to operate in a state with an output-based regulation. The regulation limits NO_X emissions from electric generators and accounts for secondary electricity output from CHP.

Figure B-1: Boiler/Steam Turbine CHP system



CHP System Power to Heat Ratio = 3.412 / 15 = 0.23
CHP Efficiency = (3.412 MMBtu/hr + 15 MMBtu/hr)/23.24 MMBtu/hr) = 79.2%

Calculations for Secondary Electricity Output Using the Equivalence Approach

The regulation specifies that the Conversion Factor used to calculate the adjusted CHP emissions rate is equal to 10 MMBtu/MWh. Using Equation 2 from Section 2 of this document:

Step 1: Determine the Electric Output, the Thermal Output and the CHP Emission Rate:

Electric Output (EO_m)	=	1 MW
Thermal Output (TO_m)	=	15 MMBtu/hr
Measured CHP Emission Rate (ER_m)	=	2.32 lb NO_X/hr

Step 2: Identify the Conversion Factor specified in the regulation:
10 MMBtu/MWh

Step 3: Calculate the Adjusted CHP Emission Rate (ER_C):

$$\mathbf{ER_C} = ER_m \times 1/[TO_m + (EO_m \times CF)]$$
$$= 2.32 \times 1/[15 + (1 \times 10)]$$
$$= 2.32 \times 1/25$$
$$\mathbf{= \sim 0.093\ lb\ NO_X/MMBtu}$$

Calculations for Secondary Electricity Output Using the Avoided Emissions Approach

The regulation specifies that the electric output of the CHP system is presumed to avoid the emissions of a new coal-fired central station power plant with NO_X emissions of 0.8 lb/MWh**. Using Equation 4 from Section 2 of this document:

(**0.8 lb/MWh is an assumed emission rate and does not represent a value recommended by EPA. The design and intent of an OBR should determine the value of the Avoided Central Station Emissions Factor [ACEF].)

Step 1: Determine the Electric Output, the Thermal Output and the CHP Emission Rate:

Electric Output (EO_m)	=	1 MW
Thermal Output (TO_m)	=	15 MMBtu/hr
CHP Emission Rate (ER_m)	=	0.1 $lb/MMBtu_{fuel}$ x 23.2 $MMBtu_{fuel}/hr$
	=	2.32 lb NO_X/hr

Step 2: Identify Avoided Central Station Emission Factor specified in the regulation:

Avoided Central Station Emissions Factor (ACEF) = 0.8 lb/MWh

Step 3: Calculate the Adjusted Emission Rate (AER):

AER	=	ACEF	x	EO_m
	=	0.8	x	1
	=	~0.8 lb NO_X/hr		

Step 4: Calculate the Adjusted CHP Emission Rate (ER_C):

ER_C	=	(ER_m – AER)	x	1/ TO_m
	=	(2.32 – 0.8)	x	1/15
	=	**~0.10 lb NO_X/MMBtu**		