Calculating cogeneration unit emissions and compliance with GHG performance standard per ESSB 6001

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Policy questions to be considered by the advisory committee.

1. Should a facility that proposes or wishes to use the cogeneration opportunity to demonstrate compliance with the performance standard be required to qualify as a cogeneration facility under 18 CFR 292 first?
2. What should be the heat rate used to convert Btu of useful thermal energy to equivalent MW of electrical energy? Why is this the preferred or best rate?
3. What are the units of the performance standard? The law says lb of GHG/MWh. Is the lb GHG expressed as CO_2 equivalent pounds, as carbon equivalent pounds, or the simple total of the mass emissions of each GHG emitted?

Definitions

"Steam host" means the operation or entity that makes use of the useful thermal energy supplied by cogenerator.

First the process in words:

Determine the useful annual thermal energy used by the 'steam host' and convert this annual quantity of thermal energy used to an equivalent annual average MWh. The annual total energy used is converted to the hourly annual average energy used by using the actual hours of operation in cogeneration mode and the total useful thermal energy used.

Determine the annual electrical production sold and convert to an annual average MWh based on the annual total electricity sold and the total actual hours of operation.

For a cogeneration facility, the total MWh is the sum of the annual average MWh of electricity sold plus ½ the annual average MWh of useful thermal energy.

Determine the annual emissions of CO_2, N2O, CH4, etc emitted. Convert all GHGs to CO_2 equivalent using the warming potential of each chemical.

Convert the annual total CO_2 equivalent emissions to an hourly rate using the annual total hours that electricity is generated.

Determine emissions in the units of the performance standard by dividing the annual average hourly CO_2 equivalent emissions by the annual average hourly electrical production.

Procedure in formulas

1. Calculate useful energy used

$$Btu_{used} = Btu_{supplied} - Btu_{returned}$$

Where

Btu_{used} = actual heat energy used by the 'steam host' plus any transmission losses, Btu/year

$Btu_{supplied}$ = total heat energy sent to the steam host for use, Btu/year

$Btu_{returned}$ = heat energy returned by the steam host as unused or unusable , Btu/year

2. Convert the Btu_{used} energy to MW electrical equivalent.

$$MW_{\underline{cogen}} = \quad Btu_{used} \; / \text{ Heat rate}$$

Where

Heat rate = 3.413 MMBtu/MW (value based on considerations discussed elsewhere)

3. Calculate net MW produced for sale

$$MW_N = MW_G - MW_P + \frac{MW_{cogen}}{2}$$

Where

MW_N = Net electrical power produced (power sold plus equivalent from cogeneration), in MW/year
MW_G = Gross electrical production, nameplate rating of generator(s), in MW/year
MW_P = Parasitic load on the generation system i.e. operation of pumps, motors, emission control equipment, etc., in MW/year

4. Calculate GHG emissions

In this example we assume that the total GHG emissions are the total CO_2 equivalent using warming potential as the method to convert from pollutant mass to CO_2 equivelance.

a. First the direct GHG emissions resulting from combustion

$$E_d = CO_2 + N_2O\,(K_{N2O}) + CH_4(K_{CH4})$$

Where

E_d = tons per year of GHG expressed as CO_2 equivalent emitted from combustion
N_2O = tons per year of N_2O expressed as CO_2 equivalent emitted from combustion
CH_4 = tons per year of CH_4 expressed as CO_2 equivalent emitted from combustion
K_{N2O} = N_2O to CO_2 equivalency conversion factor
K_{CH4} = CH_4 to CO_2 equivalency conversion factor

b. Second the indirect GHG emissions resulting from operations of support systems, switchyards and transformers

$$E_i = HFC(K_{HFC}) + PFC(K_{PFC}) + SF_6(K_{SF6})$$

Where

E_i = tons per year of GHG expressed as CO_2 equivalent emitted from combustion
HFC = tons per year of HFC expressed as CO_2 equivalent emitted from combustion
PFC = tons per year of PFC expressed as CO_2 equivalent emitted from combustion
SF_6 = tons per year of SF_6 expressed as CO_2 equivalent emitted from combustion
K_{HFC} = HFC to CO_2 equivalency conversion factor
K_{PFC} = PFC to CO_2 equivalency conversion factor

K_{SF6} = SF_6 to CO_2 equivalency conversion factor

5. Calculate emissions of GHG in units of the performance standard

$$\frac{lbGHG}{MWh} = \left(\frac{(E_d + E_i)\frac{2000lb}{ton}}{MW_N} \right) \frac{Operatinghours}{year}$$

Where

Operating hours per year = the actual number of hours the generation facility operated and produced useful heat energy that was used.

Note, the conversion from annual rates to hourly rates could be made separately for the electricity sold, and the useful thermal energy produced, and the GHG emissions converted to hourly rates based on annual operating hours for each operation. i.e. useful work may not be used every hour it is available, conversely electricity may not be generated every hour either, but useful thermal energy may be required by contract to be produced anyway.

Alternate calculation of the performance standard based on calculating annual average hourly generation and emission rates.

Calculate the hourly average MW equivalent for useful thermal energy

$MW_C = MW_{cogen}/ hours_{cogen}$

Where

MW_{cogen} = the annual hourly average energy used in the form of useful thermal energy.
$Hours_{cogen}$ = the annual number of hours energy supplied or used as useful thermal energy
MW_C = the annual total useful thermal energy used converted to MWh

Calculate the hourly average MWe produced

$MWe = (MW_G – MW_P)/hours_{generation}$

Where

MWe = net electricity produced for sale
$hours_{generation}$ = the annual total hours electricity produced for sale

Total Net electricity produced

$MW_{Nh} = MWe + MW_C/2$

Where

MW_{Nh} = the annual average hourly equivalent net generation for the cogeneration facility

Annual average GHG emission rate

$GHG = (E_d + E_i)/hours_{generation}$

Note this assumes that no useful thermal energy is produced except when electricity is being generated.

Where

GHG = the annual average GHG emissions in ton/hour

Calculate the performance standard

$lb\ GHG/MWh = (GHG * 2000)/MW_{Nh}$

Policy discussion

1. Should a facility that proposes or wishes to use the cogeneration opportunity to demonstrate compliance with the performance standard be required to qualify as a cogeneration facility under 18 CFR 292 first?

This is an entry point question. The law does not require that a facility wishing to use cogeneration as part of its compliance with the performance standard to be a cogeneration unit. The law only directs that these units have their emissions and electrical generation be determined in a consistent manner with that regulation.

If only facilities that qualify as cogeneration under 18 CFR 292 can have emission rates determined consistently with that rule's criteria, then the number of qualifying sources will likely be limited and relatively easily determined.
If the context is applied to a larger universe such as contemplated in RCW 80.70, then the regulators must rely on representations by the companies that they now and into the future will operate as cogeneration operations. This is easy in the case of operations that provide useful thermal energy for their internal industrial uses and sell excess electrical production on the market. Where the 'steam host' and the electrical generator components of the process are not under common control or ownership, this reliance on representations by the source owner are valid only as long as there is a valid contract between the parties. Thus do we need some sort of guarantee that a cogeneration relationship will exist into the future?

2. What should be the heat rate used to convert Btu of useful thermal energy to equivalent MW of electrical energy? Why is this the preferred or best rate?

The heat rate used to generate the performance standard could be used for this conversion; similarly the heat rate for a new standalone natural gas boiler or natural gas combined cycle combustion turbine could be used also.

The heat rate for a new combined cycle natural gas fired combustion turbine is on the order of 6800 -7200 Btu/kW, depending on make, model, site elevation, ambient temperatures, and

HRSG configuration. Oil and pulverized coal based electrical generation typically have higher to much higher heat rates.

Based on the use of only natural gas and the CO_2 emission factor for natural gas contained in WAC 173-407-050(1)(e) of 117.6 lb/MMBtu, the heat rate used for the performance standard in the law is calculated to be 9353 Btu/kWh, much higher than a new combined cycle natural gas unit.

In establishing its 1100 lb CO_2 /MWh performance standard, the California Energy Commission stated the following:

> The CPUC {*California Public Utility Commission*} staff proposed 1,100 pounds carbon dioxide per megawatt-hour as an Interim Emissions Performance Standard in its October 2, 2006 Final Workshop Report. The standard was selected from proposals ranging from 800 to 1,400 lbs CO2/MWhr, and the earlier Revised Staff Report's recommendation of 1,000 lbs CO2/MWhr (0.46 metric tons CO2/MWhr)[1]. The CPUC staff proposed EPS's of 1,000 or 1,100 lbs CO2/MWhr (0.50 metric tons CO2/MWhr) appear to be a compromise between the 800 lbs CO2/MWhr that the most efficient modern combustion turbine combined cycle plant could achieve, and the 1,400 lbs CO2/MWhr that might envelope the majority of natural gas burning technologies (e.g., steam cycle boiler, simple cycle combustion turbine, reciprocating engine, and a range of combustion turbine combined cycle units).
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> A proposed standard of 1,100, or 1,000, lbs CO2/MWhr is equivalent to a power plant unit with an effective heat rate, in higher heating value (HHV)[2], of[3]:

	Typical Fuel CO_2 emission factor, (lbs CO_2/mmBtu)	Effective Heat Rate @ an EPS of 1,000 lbs, (lbs CO_2/MWh)	Effective Heat Rate @ an EPS of 1,100 lbs, (lbs CO_2/MWh)
Natural Gas	116.4	8,590 Btu/kWhr	9,450 Btu/kWhr
Fuel Oils	158.0	6,330 Btu/kWhr	6,890 Btu/kWhr
Bituminous Coal	204.0	4,900 Btu/kWhr	5,390 Btu/kWhr
Petroleum Coke	222.9	4,490 Btu/kWhr	4,940 Btu/kWhr

The California Energy commission staff report quoted above questions if any coal based power plant (any size or design) could meet the 1100 lb CO_2/MWh performance standard. The Staff paper also notes that none of the small or microturbines currently available could meet the

[1] Conversion: pounds to metric tons, multiply by 0.454 x 103

[2] Heating Value: traditionally, heat rates in the USA and of boiler units is specified in higher heating value, while Europe and combustion turbines generally use lower heating value. For this discussion and more direct comparison, the higher heating value is used unless otherwise stated.

Natural gas HHV = 1.11 x LHV

Bituminous coal HHV = approx. 1.05 x LHV

[3] Collard, Gary, Implementation of SB 1368 Emission Performance Standard, Staff issue Identification Paper, No. CEC-700-2006-011, November 2006

standard, though the staff paper also questions whether there are any of these units providing baseload electricity.

Similarly to the treatment of cogeneration emissions for CAMR, the California Energy commission utilized in its rule the ;standard engineering conversion factor of 3.413 MMBtu/MWh (3413 Btu/kWh) for converting useful thermal energy used to a MWh equivalent.

Oregon Energy Office's Energy Facility Siting Standards currently uses a standard of 5770 Btu (HHV)/kWh for new baseload natural gas units (equivalent to 0.675 lb CO_2/kWh). This standard is 17 percent below heat rate of the most efficient base-load gas plant operating in the US. The basic heat rate for a new baseload unit would be 6955 Btu (HHV)/kWh or 0.81 lb CO_2 /kWh (810 lb/MWh). A recent project (the COB Energy Facility) located in Klamath County Oregon utilizes a combined cycle combustion turbine with a heat rate of 6842 Btu (HHV) /kWh which equates to a CO_2 rate of 0.834 lb/kWh (834 lb CO_2/MWh).

3. What are the units of the performance standard? The law says lb of GHG/MWh. Is the lb GHG expressed as CO_2 equivalent pounds, as carbon equivalent pounds, or the simple total of the mass emissions of each GHG emitted?

The absolute number used to calculate the GHG emissions could be different whether it is just CO_2, whether it is the CO_2 equivalent of the combustion gases or is the total mass of the individual GHGs. The law is not clear on how to determine this. Reading the definition of "average available greenhouse gases emissions output" and the language in Sections 5and 7 indicate that we could choose either the simple sum of the individual GHG emission rates or use the warming potentials to convert to CO_2 equivalents.

The California regulations which are purported to be the basis of the initial performance standard in Washington law only limits the direct CO_2 emissions resulting from the fuel combustion process[4].

[4] See Chapter 11, Greenhousee Gases Emission Performance Standard, Article 1, §2902