1. * 1. Combined Heat and Power

**Description**

The Combined Heat and Power (CHP) measure can provide energy savings within the State of Illinois through the development and operation of CHP projects. This measure is applicable for Conventional or Topping Cycle CHP systems, as well as Waste Heat-to-Power (WHP) or Bottoming Cycle CHP systems. The measure will reduce the total Btus of energy required to meet the end use needs of the facility. In all cases estimates of the saved energy will account for any additional fuel utilized at the site in order to operate the CHP system.

It is recognized that CHP system design and configuration may be complex, and as such the calculation of energy savings may not be reducible to the equations within this measure. In such cases a more comprehensive engineering and financial analysis may be developed that more accurately incorporates the attributes  of  complex CHP configurations such as variable-capacity systems, and partial combined-cycle CHP systems. Where noted, the use of values that are determined through an external engineering analysis may be substituted by agreement between the participant, the program administrator and independent evaluator. This substitution of values does not eliminate ex post evaluation risk (retroactive adjustments to savings claims) that exists when using custom inputs.

This measure was developed to be applicable to the following program types: Retrofit (RF), New Construction (NC). If applied to other program types, the measure savings should be verified.

**Definition of Efficient Equipment**

Conventional or Topping Cycle CHP is defined as an integrated system that is located at or near the building or facility (onsite, on the customer side of the meter) that utilizes a prime mover (reciprocating engine, gas turbine, micro-turbine, fuel cell, boiler/steam turbine combination) for the purpose of generating electricity and useful thermal energy (such as steam, hot water, or chilled water) where the primary function of the facility where the CHP is located is not to generate electricity for use on the grid. An eligible system must demonstrate a minimum total system efficiency of 60% (HHV)[[1]](#footnote-1) with at least 20% of the system’s total useful energy output in the form of useful thermal energy on an annual basis.

*Measuring and Calculating Conventional CHP Total System Efficiency:*

CHP efficiency is calculated using the following equation:

$$CHP \_{Efficiency}\left(HHV\right)= \frac{\left[CHP\_{thermal} \left(\frac{kBtu}{yr}\right)+ E\_{CHP} \left(\frac{kWh}{yr}\right)\*3.412 \left(\frac{kBtu}{kWh}\right)\right]}{F\_{totalCHP}\left(\frac{kBtu}{yr}\right)}$$

Where:

CHPthermal = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.

ECHP = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process. The measurement of this term will be based on the “date of commercial operation” (DCO) method. In particular, the customer and Program Administrator decide on the DCO, preferably after the system has been tested and commissioned and the early bugs worked out with some steady state operation – perhaps several hundred hours until the first service shut-down is finished. The DCO starts the test clock for the program. ALL data from the DCO until the verification visit is used for the incentive calculation – minimum 2 weeks. Furthermore, ALL data from the DCO until the EM&V date is used for the evaluated savings – minimum 2 months. No exceptions, no data tossed. Downtime for any type of service or failure must be assumed to represent future operation. If distinct daytypes are observed (say weekend operation different from weekday) data are extrapolated to yearly based on the number of annual days of each daytype. For example if Sundays operate at 75% capacity but the other days consistently show 97% capacity on average, savings is Capacity x [(52\*6\*0.97)+(52\*1\*0.75)].

FtotalCHP = Total annual fuel consumed by the CHP system. Fuel consumption will be based on metered data concurrent with the timeframe used for determining ECHP.

For further definition of the terms, please see “Calculation of Energy Savings” Section below.

Waste Heat-to-Power or Bottoming Cycle CHP is defined as an integrated system that is located at or near the building or facility (onsite, on the customer side of the meter) that does one of the following:

* Utilizes exhaust heat from an industrial/commercial process to generate electricity (except for exhaust heat from a facility whose primary purpose is the generation of electricity for use on the grid); or
* Utilizes the pressure drop in an industrial/commercial facility to generate electricity through a backpressure steam turbine where the facility normally uses a pressure reducing valve (PRV) to reduce the pressure in their facility; or
* Utilizes the pressure reduction in natural gas pipelines (located at natural gas compressor stations) before the gas is distributed through the pipeline to generate electricity, provided that the conversion of energy to electricity is achieved without using additional fossil fuels.

Since these type of systems utilize waste heat as their fuel, they do not have to meet any specific total system efficiency level (assuming they use no additional fossil fuel in their operation – if additional fuel is used onsite, it should be properly accounted for). These systems may export power to the grid.

**Definition of Baseline Equipment**

Electric Baseline: The baseline facility would be a facility that purchases its electric power from the grid.

Heating Baseline (for CHP applications that displace onsite heat): The baseline equipment would be the boiler/furnace operating onsite, or a boiler/furnace meeting the baseline equipment standard defined in the High Efficiency Boiler (Section 4.4.10)/Furnace (Section 4.4.11) measures of this TRM.

Cooling Baseline (for CHP applications that displace onsite cooling demands): The baseline equipment would be the chiller (or chillers) operating onsite, or a chiller (or chillers) meeting the baseline equipment standard defined in the Electric Chiller (Section 4.4.6) measure of this TRM.

Facilities that use biogas or waste gas: Facilities that use (but are not purchasing) biogas or waste gas that is not otherwise marketable, whether they are using biogas or waste gas only or a combination of biogas or waste gas and natural gas to meet their energy demands are also eligible for this measure. If additional fuel is purchased, then it should be taken into account in the fuel savings calculations. Consumption of any biogas or waste gas that would not otherwise being wasted (*e.g.,* flared) will be accounted for in the overall net Btu savings calculations the same as for purchased natural gas or other fuels.

**Deemed Lifetime of Efficient Equipment**

Measure life is a custom assumption, dependent on the technology selected and the system installation.

**Deemed Measure Cost**

Custom installation and equipment cost will be used. These costs should include the cost of the equipment and the cost of installing the equipment. Equipment costs include, but are not limited to: prime mover, heat recovery system(s), exhaust gas treatment system(s), controls, and any interconnection/electrical connection costs.

The installations costs include labor and material costs such as, but not limited to: labor costs, materials such as ductwork, piping, and wiring, project and construction management, engineering costs, commissioning costs, and other fees.

Measure costs will also include the present value of expected maintenance costs over the life of the CHP system.

**Loadshape**

Use Custom Loadshape. The loadshape should be obtained from the actual CHP operation strategy, based on the On-Peak and Off-Peak Energy definitions specified in Table 3.3 of “Section 3.5 Electrical Loadshapes” of the TRM.

**Coincidence Factor**

Custom coincidence factor will be used. Actual value based on the CHP operation strategy will be used.

**Algorithm**

**Calculation of Energy Savings**

1. **Conventional or Topping Cycle CHP Systems:**

***Step 1: (Calculating Total Annual Source Fuel Savings in Btus)***

The first step is to calculate the total annual source fuel savings associated with the CHP installation, in order to ensure the CHP project produces positive total annual source fuel savings (i.e., reduction in source Btus):

SFuelCHP = Annual fuel savings (Btu) associated with the use of a Conventional CHP system to generate the useful electricity output (kWh, converted to Btu) and useful thermal energy output (Btu) versus the use of the equivalent electricity generated and delivered by the local grid and the equivalent thermal energy provided by the onsite boiler.

= (Fgrid + FthermalCHP) – Ftotal CHP

Where

Fgrid = Annual fuel in Btu that would have been used to generate the useful electricity output of the CHP system if that useful electricity output was provided by the local utility grid.

 = ECHP \* Hgrid

Where

ECHP  = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process.[[2]](#footnote-2)

= ( CHPcapacity \* Hours ) - EParasitic

CHPcapacity = CHP nameplate capacity

 = Custom input

Hours = Annual operating hours of the system

 = Custom input

Eparasitic = The electricity required to operate the CHP system that would otherwise not be required by the facility/process

 = Custom input

Hgrid = Heat rate of the grid in Btu/kWh, based on the average fossil heat rate for the EPA eGRID subregion and includes a factor that takes into account T&D losses.

For systems operating less than 6,500 hrs per year:

Use the Non-baseload heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

For systems operating more than 6,500 hrs per year:

Use the All Fossil Average heat rate provided by EPA eGRID for RFC West region for ComEd territory, and SERC Midwest region for Ameren territory. Also include any line losses.

FthermalCHP = Annual fuel in Btu that would have been used onsite by a boiler or heater to provide the useful thermal energy output of the CHP system.[[3]](#footnote-3)

= CHPthermal ÷ Boilereff

CHPthermal = Useful annual thermal energy output from the CHP system, defined as the annual thermal energy output of the CHP system that is actually recovered and utilized in the facility/process.

 = Custom input

Boilereff = Efficiency of the onsite boiler or heater that is displaced by the CHP system or if unknown, the baseline equipment value stated in the High Efficiency Boiler (Section 4.4.10) measure in the TRM.

= Custom input

Ftotal CHP = Total fuel in Btus consumed by the CHP system

 = Custom input

***Step 2: (Savings Allocation to Program Administrators for Purposes of Assessing Compliance with Energy Savings Goals (Not for Use in Load Reduction Forecasting))***

Savings claims are a function of the electric output of the CHP system (ECHP), the used thermal output of the CHP system (FthermalCHP), and the CHP system efficiency (CHPEfficiencyHHV). The percentages of electric output and used thermal output that can be claimed also differ slightly depending on whether the project was included in both electric[[4]](#footnote-4) and gas[[5]](#footnote-5) energy efficiency portfolio standard (EEPS)[[6]](#footnote-6) efficiency programs, only an electric EEPS program or only a gas EEPS program. The tables below provide the specific percentages of electric and/or thermal output that can be claimed under each of those three scenarios.

1)      For systems participating in both electric EEPS and gas EEPS programs:

|  |  |  |
| --- | --- | --- |
| **CHP Annual System Efficiency (HHV)** | **Allocated Electric Savings** | **Allocated Gas Savings** |
| 60% | 65% of ECHP (kWh) | No gas savings |
| >60% to 65% | 65% of ECHP (kWh) + one percentage point increase for every one percentage point increase in CHP system efficiency (max 70% of ECHP in kWh) | No gas Savings |
| >65% | 70% of Echp (kWh) | 2.5% of Fthermal (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 65%. |

Example: System with measured annual fuel use efficiency of 70%:  Electric savings (kWh) = 70% of ECHP measured over 12 months, and Gas savings (therms) = 12.5% of Fthermal measured over 12 months (70% - 65% = 5 X 2.5% = 12.5%)

2)      For systems participating in only an electric EEPS program:

| **CHP Annual System Efficiency (HHV)** | **Allocated Electric Savings** | **Allocated Gas Savings** |
| --- | --- | --- |
| 60% | 65% of ECHP (useful electric output of CHP system in kWh) | No gas savings |
| Greater than 60% | 65% + one percentage point increase for every one percentage point increase in CHP system efficiency (no max) | No gas savings |

Example: System with measured annual fuel use efficiency of 75%:  Electric savings (kWh) = 65% + 15% = 80% of ECHP measured over 12 months (15% = 1% for every 1% increase in system efficiency). No gas savings (therms).

3)      For systems participating in only a gas EEPS program:

|  |  |  |
| --- | --- | --- |
| **CHP Annual System Efficiency (HHV)** | **Allocated Electric Savings** | **Allocated Gas Savings** |
| 60% or greater | No electric savings | 2.5% of Fthermal (useful thermal output of the CHP system) for every one percentage point increase in CHP system efficiency above 60%. |

Conventional or topping cycle CHP systems virtually always require an increase in the use of fuel onsite in order to produce electricity. Different jurisdictions and experts across the country have employed and/or put forward a variety of approaches to addressing how increased onsite fuel consumption should be reflected in the attribution of electric savings to CHP systems. Those approaches range from ignoring the increased fuel use (i.e., no “penalty”) to roughly 40-60% “penalties”, depending on the CHP efficiency, based on the number of kWh that could have been produced had the increased fuel Btus been used on the grid (a grid “Btu equivalency”). Several other approaches produce results in between those two extremes. The approach reflected in the tables above is generally consistent with approaches recently put forward by the Southwest Energy Efficiency Project (SWEEP), Institute for Industrial Productivity (IIP) and others which essentially establish an electric savings “penalty” that is equal to the amount of kWh that could be produced by the electric grid with a “carbon emissions budget” that is equal to the emissions associated with the increased onsite fuel consumption. The result of this “carbon equivalency” approach is a savings penalty that will typically range from 20% to 35%.[[7]](#footnote-7) That result is also solidly in the middle of the two extremes discussed above.

There are also a variety of ways one could treat the potential for gas utilities to claim savings from CHP projects in their EEPS portfolios. For projects in which a natural gas EEPS program is involved, the tables above treat savings from CHP installations in two steps: (1) a fuel-switch from electricity to natural gas (i.e., using more natural gas to eliminate the need to generate as much electricity on the grid); and (2) possible increases in CHP efficiency above a “benchmark” level. When both electric EEPS and gas EEPS programs are involved in a project, all the savings associated with a fuel-switch up to a “benchmark” 65% efficient CHP system is allocated to electric. All the savings associated with increasing CHP efficiencies above that benchmark level is allocated to natural gas (e.g., if the CHP efficiency is 75%, the natural gas savings associated with an increase in CHP efficiency from 65% to 75% is allocated to natural gas). That is consistent with the notion that CHP efficiency typically increases primarily by increasing use of the thermal ouput of the system (increasing the displacement of baseline gas use). For projects that involve only a natural gas EEPS program, the “benchmark” above which the gas utility can claim savings is lowered to 60%.

1. **Waste-Heat-to-Power CHP Systems:**

**Electric Energy Savings:**

ΔkWh = ECHP

Where

ECHP = Useful annual electricity output produced by the CHP system, defined as the annual electric energy output of the CHP system that is actually utilized to replace purchased electricity required to meet the requirements of the facility/process. The measurement of this term will be based on the “date of commercial operation” (DCO) method. In particular, the customer and Program Administrator decide on the DCO, preferably after the system has been tested and commissioned and the early bugs worked out with some steady state operation – perhaps several hundred hours until the first service shut-down is finished. The DCO starts the test clock for the program. ALL data from the DCO until the verification visit is used for the incentive calculation – minimum 2 weeks. Furthermore, ALL data from the DCO until the EM&V date is used for the evaluated savings – minimum 2 months. No exceptions, no data tossed. Downtime for any type of service or failure must be assumed to represent future operation. If distinct daytypes are observed (say weekend operation different from weekday) data are extrapolated to yearly based on the number of annual days of each daytype. For example if Sundays operate at 75% capacity but the other days consistently show 97% capacity on average, savings is Capacity x [(52\*6\*0.97)+(52\*1\*0.75)].

 = Custom input

**Natural Gas Energy Savings:**

ΔTherms = FthermalCHP ÷ 100,000

Where

FthermalCHP = Net savings in annual purchased fuel in Btu, if any, that would have been used onsite by a boiler or heater to provide some or all of the useful thermal energy output of the CHP system[[8]](#footnote-8).

100,000 = Conversion factor for Btu to therms

**Summer Coincident Peak Demand Savings**

ΔkW = CF \* CHPcapacity

Where

CF = Summer Coincidence factor. This factor should also consider any displaced Chiller capacity[[9]](#footnote-9)

= Custom input

CHPCapacity = CHP nameplate capacity

= Custom input

**Water Impact Descriptions and Calculation**

N/A

**Deemed O&M Cost Adjustment Calculation**

Custom leveled maintenance costs that will be incurred for the life of the measure will be used**.** Maintenance costs vary with type and size of the prime mover. These costs include, but are not limited to:

* Maintenance labor
* Engine parts and materials such as oil filters, air filters, spark plugs, gaskets, valves, piston rings, electronic components, etc. and consumables such as oil
* Minor and major overhauls

For screening purposes, the US EPA has published resource guides that provide average maintenance costs based on CHP technology and system size[[10]](#footnote-10).

**Cost-Effectiveness Screening**

For the purposes of screening a CHP measure application for cost-effectiveness, changes in site energy use – reduced consumption of utility provided electricity and the net change in consumption of fuel – should be used. In general, the benefit and cost components used in evaluating the cost-effectiveness of a CHP project would include at least the following terms:

Benefits: ECHP + ΔkW + Fthermal\_CHP

Costs: Ftotal\_CHP + CHPCOSTS +O&MCOSTS

Where

CHPCosts = CHP equipment and installation costs as defined in the “Deemed Measure Costs” section

O&MCosts = CHP operations and maintenance costs as defined in the “Deemed O&M Cost Adjustment Calculation” section

**Measure Code: CI-HVC-\*\*\*\*-V01-150601**

1. Higher Heating Value (HHV): refers to the heating value of the fuel and is defined as the total thermal energy available, including the heat of condensation of water vapors, resulting from complete combustion of the fuel

versus the Lower Heating Value (LHV) which assumes the heat of condensation is not available. [↑](#footnote-ref-1)
2. For complex systems this value may be obtained from a CHP System design/financial analysis study. [↑](#footnote-ref-2)
3. For complex systems this value may be obtained from a CHP System design/financial analysis study. [↑](#footnote-ref-3)
4. 220 ILCS 5/8-103; 220 ILCS 5/16-111.5B. [↑](#footnote-ref-4)
5. 220 ILCS 5/8-104. [↑](#footnote-ref-5)
6. As used in this measure characterization, EEPS programs are defined as those energy efficiency programs implemented pursuant to Sections 8-103, 8-104, and 16-111.5B of the Illinois Public Utilities Act. Technically, EEPS programs pertain to energy efficiency programs implemented pursuant to 220 ILCS 5/8-103 and 220 ILCS 5/8-104. However, for simplicity in presentation, this measure defines EEPS programs as also including those programs implemented pursuant to 220 ILCS 5/16-111.5B (these programs are funded through the same energy efficiency riders established pursuant to Section 8-103). [↑](#footnote-ref-6)
7. Consider, for example, a hypothetical CHP system that produces 5 million kWh annually, consumes 50 million kBtu of gas annually to generate that electricity (i.e., electric efficiency of approximately 34.8% HHV), reduces onsite gas use for space heating by 26 million kBtu of gas (i.e., equivalent to approximately 81.5% CHP thermal output utilization displacing gas used in a 70% efficient space heating boiler) and has a total annual CHP efficiency of 70.6% HHV. In this example, the net increase in onsite gas use is 24 million kBtu. At a carbon dioxide emission rate of 53.06 kg/MMBtu for burning natural gas, that translates to an increase in onsite carbon dioxide emissions of 1404 tons per year. At an estimated marginal emission rate of 1.098 tons of carbon dioxide per MWh in Illinois, that is equivalent to electric grid production of approximately 1.28 million kWh, or penalty of about 25.6% of the CHP system’s electrical output. [↑](#footnote-ref-7)
8. In most cases, it is expected that waste-heat-to-power CHP systems will not provide any new net useful thermal energy output, since the CHP system will be driven by thermal energy that was otherwise being wasted. If additional natural gas or other purchased energy is used onsite, it should be properly accounted for. [↑](#footnote-ref-8)
9. If additional natural gas is used onsite, it should be properly accounted for. [↑](#footnote-ref-9)
10. “EPA Combined Heat and Power Partnership Resources” Oct 07, 2014, http://www.epa.gov/chp/resources.html [↑](#footnote-ref-10)