How To Create A Successful Utility-Sponsored CHP Program By Aligning Electric And Natural Gas Goals

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ABSTRACT

In Illinois, the Energy Efficiency Portfolio Standard (EEPS) requires both electric and natural gas investor owned utilities (IOUs) to offer energy efficiency programs to their customers. As programs become more mature (9th year of electric programs and 6th year of natural gas programs) and the "low-hanging fruit" is fully captured by utilities, there is an increased necessity to promote and implement innovative programs that capture deeper, long lasting savings. In May 2014, a pilot program for combined heat and power (CHP) was launched in Illinois by the Department of Commerce and Economic Opportunity, which manages the IOUs' funds for the public sector, encouraging investments in conventional or topping cycle CHP systems as well as waste heat-to-power or bottoming cycle CHP systems for public sector customers. The program generated 17 applications through a one-time request for proposals (RFP) (Nov 2014) for over 30 MW of installed capacity. Through a rigorous screening process, seven applications were selected (Feb 2015) and five of them proceeded with the program and have either installed systems or are in the process of installing them. This paper will discuss the benefits of CHP and in particular utility-sponsored CHP programs, describe in detail the cost-effectiveness considerations for a complex measure like CHP, and discuss the policy considerations that emerged from an 18-month stakeholder process that sought to answer whether electric and natural gas utilities can work together on a fuel switch measure and capture the benefits while properly allocating energy savings.

Introduction

Currently 26 states[1] across the country have established long-term electric energy efficiency resource standards and 16 of those states have established natural gas energy efficiency resource standards to help offset energy consumption while reducing greenhouse gases, saving customers' money and creating new jobs[2]. These programs generally focus on the efficiency of particular end uses and do not address the efficiency of electric generation or the total efficiency of energy delivered at a site.

[1] http://aceee.org/sites/default/files/state-eers-0117.pdf
[2] http://www.e2.org/wp-content/uploads/2016/12/EnergyEfficiencyJobsInAmerica_FINAL.pdf

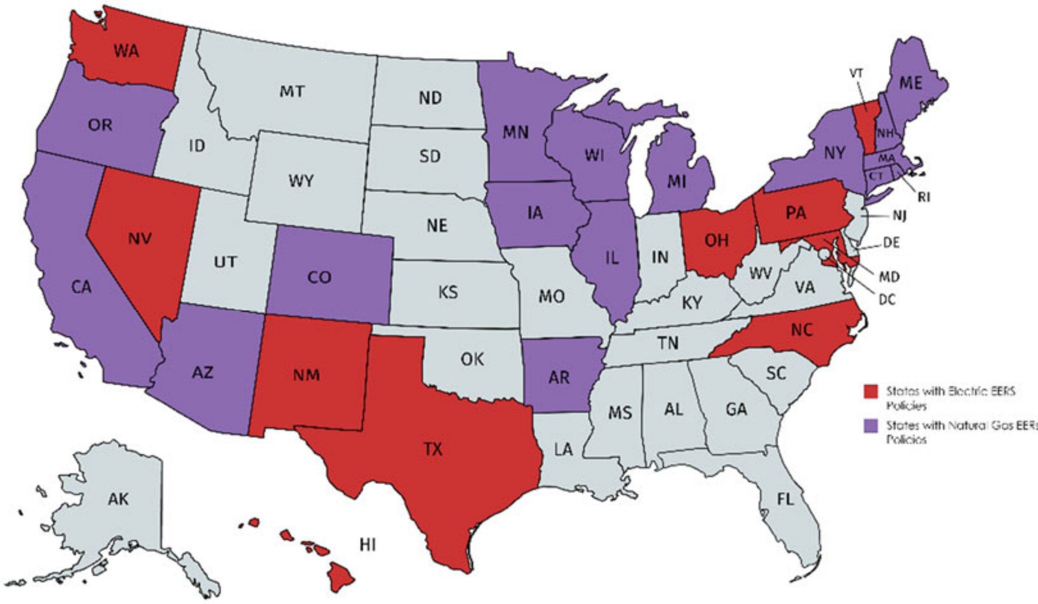

Figure 1: States with electric and/or natural gas policies in place as of January 2017

Traditionally electricity is generated at a central power plant and then transmitted to the customer's site. On average two thirds of the energy used to produce power is wasted in the generation and transmission process.

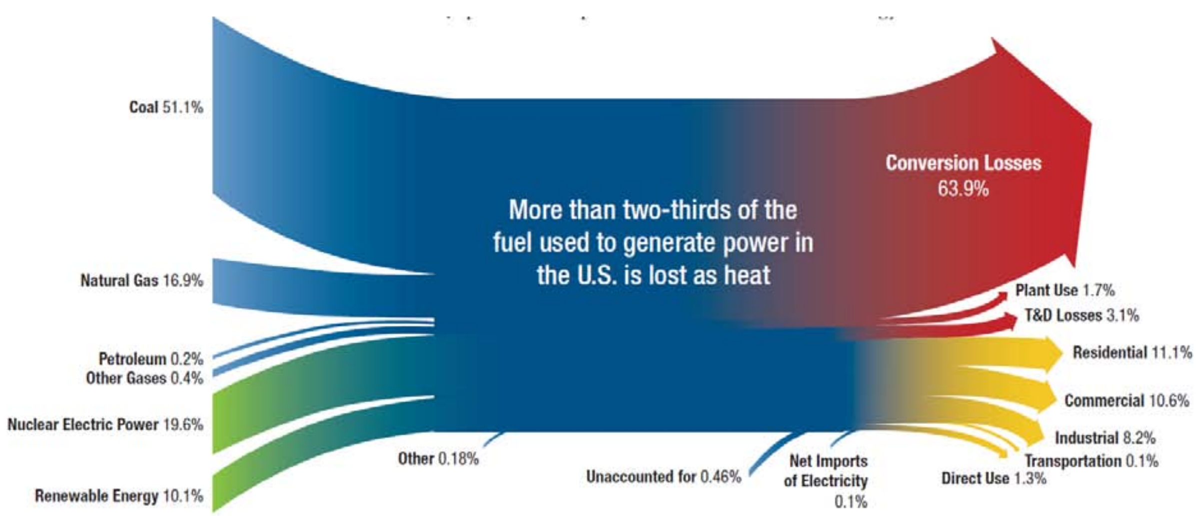

Figure 2: Energy diagram for US power generation. Source: US DOE Energy Information Administration Annual Energy Review 2007

Combined Heat and Power (CHP) or cogeneration refers to the production of electricity and thermal power (used for heating, cooling and/or dehumidification) simultaneously from a single energy source. A CHP system produces power at the site of consumption and thus reduces waste by eliminating transmission losses, while recovering the heat normally lost in central generation to displace onsite heating needs.

Utility funded efficiency programs usually incentivize customers to reduce on-site energy consumption, and may not include a measure like CHP which offers total energy savings along with peak load and Green House Gas (GHG) reduction, as well as providing higher grid resiliency by means of a fuel switch. Savings from a CHP system are realized because the customer decreases its electricity consumption from the grid while decreasing its natural gas (or other heating fuel) consumption by offsetting thermal demand previously supplied by an on-site boiler with the thermal energy from the CHP system. However, there is usually a net increase in onsite natural gas (or other fuel) to power the CHP system and produce electric and thermal energy.

The net increase in natural gas consumption is the energy penalty incurred in offsetting the site electric consumption by an amount equal to the CHP system production.

It should be noted that other states including New York[3] and Massachusetts[4] incent CHP programs, but in each of those states only the electric savings are counted towards the programs, making it an inaccurate assessment of the site impacts. The increase in natural gas usage is either ignored or penalized[5]. Illinois has energy efficiency targets for both electric and natural gas IOUs, and credit both the utilities for their efforts to promote CHP systems. The electric utility gets credit for promoting the installation of the CHP system and achieve a baseline efficiency, while any increase in efficiency of the system above the baseline is credited to the natural gas utility.

Energy Efficiency in Illinois

Energy efficiency is the cheapest resource available to the utilities to replace power generation cost effectively and rapidly[6]. Utilities across the country have been implementing energy efficiency programs that promote energy saving measures since the early 1980s. Illinois' Public Act 095-0481[7] enacted in 2007 created an Energy Efficiency Resource Standard (EERS) for Illinois IOUs. Referred to as the Energy Efficiency Portfolio Standard (EEPS), the legislation assigned considerable budgets for energy efficiency incentive programs.

The original legislation established goals for the electric utilities to reduce their incremental annual sales over the previous year, focusing on first year savings achieved by the energy efficiency measures. Emphasis on first year savings tends to result in a portfolio of measures like behavior changes and lamp replacements without special focus on longer lifetime measures.

The most recent Future Energy Jobs Bill (SB 2814)[8] passed by the Illinois legislature on December 01, 2016 requires electric utilities to achieve cumulative persisting annual savings beginning 2018 instead of first year savings. These new goals take into account the measure lifetimes and ramp up annually until 2030. These legislative changes help promote long lasting

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[3] https://portal.nyserda.ny.gov/servlet/servlet.FileDownload?file=00Pt0000002BHMDEA4
[4] www.masssave.com/business/eligible-equipment/combined-heat-and-power
5 Southwest Energy Efficiency Project (SWEEP), Calculating Net Electricity Savings from Utility-Supported CHP Projects, April 2013
[6] http://aceee.org/blog/2016/01/yes-saving-energy-cheaper-making
[7] http://www.ilga.gov/legislation/publicacts/95/095-0481.htm
[8]
http://www.ilga.gov/legislation/fulltext.asp?DocName=&SessionId=88&GA=99&DocTypeId=SB&DocNum=2814&GAID=13&LegID=96125&SpecSess=&Session=

measures like CHP which has a typical measure life of 20-25 years[9], depending on the technology used. Energy efficiency advocates are trying to encourage more jurisdictions[10] to move towards this trend of moving to cumulative savings that will ensure more robust energy efficiency savings.

Illinois' Public Act 096-0033[11] created the natural gas energy efficiency standard[12] where starting in 2012 natural gas IOUs were required to meet annual reduction goals that increased annually until 2019. Beyond 2019, the natural gas utilities are required to achieve efficiency reductions of 1.5% annually.

The goals have been steadily increasing while the budgets have stayed fairly consistent. As programs mature the "low hanging fruit" measures, like replacing highly inefficient incandescent bulbs or linear fluorescent T12 lamps or installing low-flow water fixtures, are disappearing fast due to changing standards and increased market penetration of these simple measures. This means that new measures need to be introduced and promoted by the programs, and because of the law of diminishing returns, it is becoming increasingly difficult for the utilities to achieve long lasting energy savings to meet their required goals.

CHP as an efficiency measure

A CHP system produces power at the site of consumption and thus reduces waste by eliminating generation and transmission losses, while recovering the heat normally lost in central generation to displace onsite heating needs. CHP systems are typically designed to meet the site's thermal baseload to maximize the overall system efficiency and system utilization, and eliminate energy waste. The technology is ideally suited for customers that have coincident thermal and electric demands of comparable magnitude, as well as a consistent consumption profile throughout the year. In such cases, the higher CHP system efficiency displaces the maximum amount of onsite fossil fuel possible through the CHP investment.

Figure 3 shows an example that compares the fuel required to generate the same amount of electricity and thermal energy by both conventional power generation and a CHP system to a hypothetical site. The CHP system uses fewer units of primary fuel than conventional separate generation of electricity and heat, in this example offering a 32% reduction in primary energy (from 147 units to 100 units of energy). Different technologies that power the system, also known as prime movers[13], and different operating strategies used in specific applications will dictate the overall reduction in primary energy, though the example in Figure 3 is achievable by most technologies under the right operating conditions.

[9] https://iea-etsap.org/E-TechDS/PDF/E04-CHP-GS-gct_ADfinal.pdf
[10] http://aceee.org/files/pdf/conferences/eer/2013/5C-Mosenthal.pdf
[11] http://www.ilga.gov/legislation/publicacts/96/096-0033.htm
[12] 220 ILCS 5/8-104 http://www.ilga.gov/legislation/ilcs/fulltext.asp?DocName=022000050K8-104
[13] Common prime movers are reciprocating engines, gas turbines, steam turbines, micro-turbines and fuel cells. https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf

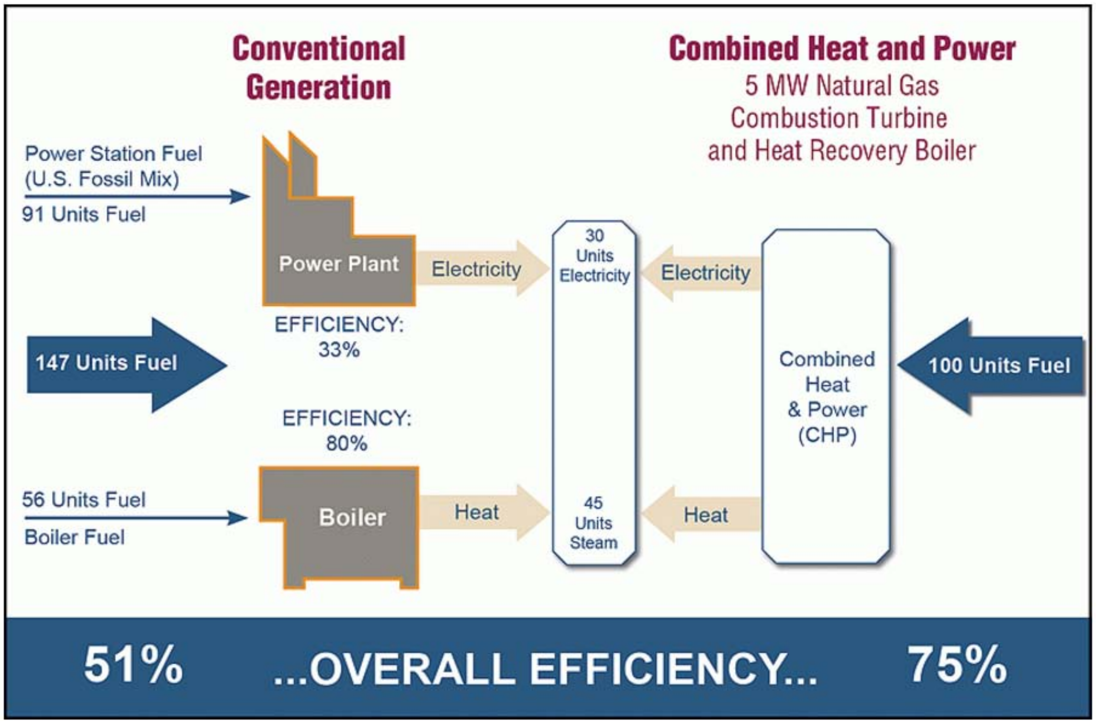

Figure 3[14]: Example showing a typical CHP system as compared to conventional generation.

CHP systems can offer additional non-energy benefits (NEBs) to customers, which may be quantifiable and claimed for cost-effectiveness purposes in some jurisdictions. In Illinois, an effort is underway through the Illinois stakeholder advisory group (ILSAG) to properly evaluate NEBs and currently a 10% adder is applied to the benefit side of the total resource cost (TRC) equation. Examples of NEBs that result from the implementation of CHP are:

- A possible reduction in CO2 emissions and other pollutants due to reduced fuel use required to generate the same amount of energy
- Increased grid resiliency, both as a distributed energy resource and in particular for microgrid / island mode applications
- May provide congestion and transmission relief for the transmission and distribution network
- Increased resiliency for critical infrastructure, particularly for energy assurance purposes such as providing power to hospitals, airports and community centers during brown or blackouts, or potentially being part of an emergency black start program, for larger CHP plants.
- Infrastructure development deferral (since CHP constitutes additional capacity)

[14] https://www.epa.gov/chp/chp-benefits

Calculating CHP savings

The ILSAG included the CHP measure into the Illinois Technical Reference Manual (ILTRM) after much deliberation. The measure savings calculation includes the following three steps:

Step 1: Calculate primary fuel savings

State run efficiency programs need to quantify the energy savings to be able to get credit towards their savings goals. To calculate the savings associated with a CHP system, we first need to calculate the fuel savings at the source in order to ensure the CHP project produces positive total annual source fuel savings (i.e. reduction in source Btus). The following equation is used to calculate these fuel savings.

$$S_{FuelCHP} = \left(F_{grid} + F_{thermalCHP}\right) - F_{totalCHP}$$

Where:

$S_{FuelCHP}$ = Annual fuel savings in Btus 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/furnace.

F_{grid} = 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.

$$F_{grid} = E_{CHP} * H_{grid}$$

E_{CHP} = 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.

$$E_{CHP} = (CHP_{capacity} * Hours) - E_{Parasitic}$$

$CHP_{capacity}$ = CHP nameplate capacity

Hours = Annual operating hours of the system

$E_{parasitic}$ = The electricity required to operate the CHP system that would otherwise not be required by the facility/process

H_{grid} = 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.

$F_{thermalCHP}$ = Annual fuel in Btu that would have been used on-site by a boiler/furnace to provide the useful thermal energy output of the CHP system.

$$F_{ThermalCHP} = \frac{CHP_{Thermal}}{Boiler_{eff}}$$

$CHP_{thermal}$ = 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.

$Boiler_{eff}$ = Efficiency of the on-site Boiler/Furnace that is displaced by the CHP system

$F_{totalCHP}$ = Total fuel in Btus consumed by the CHP system.

Once it is determined that there are fuel savings the next step is to assign savings to the utilities for their efforts to promote the measure.

Step 2: Savings allocation to Program Administrators

The authors of this paper believe that proper savings allocation to program administrators is one of the most important aspects of a successful CHP program. In territories served by a different electric and natural gas utility, competing priorities and unresolved “fuel switching” issues often thwart the implementation of CHP measures. The primary innovation in the approach in Illinois was to devise a system that aligned electric and natural gas utilities towards a common objective. The resulting attribution methodology involved in this fuel-switch application, attributes energy savings to the program administrator of the fuel that the measure is switching from up until a baseline or reference efficiency, while energy savings are attributed to the program administrator of the fuel that the measure is switching to beyond the baseline or reference efficiency.

This approach provides a mechanism to distinguish between savings claimed by the electric utility, which will be able to claim a certain amount of kWh that arise from the displacement of electricity delivery, and the savings claimed by the natural gas utility, which will arise from maximizing the heat recovery and thermal efficiency of the CHP system (usually a combination of proper sizing of the system, based on the thermal needs of the facility, and operational strategy aimed at maximum overall efficiency).

Thus, the savings are aligned with the natural ability of the program administrators to influence the size and operational strategy of the system. It should be noted that the “certain amount” of kWh and Therms savings alluded to in the previous paragraph needs to take into account the additional fuel used by the CHP system to produce electricity and heat, since there will generally be an increased consumption of fuel at the site.

The tables[15] below provide the percentages of electric and/or thermal output that can be claimed under three different scenarios: when the system is installed in a territory with both an electric and natural gas EEPS programs (

[15] State of Illinois. 2016. *Energy Efficiency Technical Reference Manual: Combined Heat and Power New Measure.* Springfield, IL. http://ilsagfiles.org/SAG_files/Technical_Reference_Manual/Version_6/Final/IL-TRM_Effective_010118_v6.0_Vol_2_C_and_I_020817_Final.pdf

Table 1), when the system is installed in a territory with only an electric EEPS program (Table 2), and finally when the system is installed in a territory with only a natural gas EEPS program (Table 3). A combination of these scenarios is possible in different states depending on whether the state has only electric, only natural gas, or both electric and natural gas programs. Illinois has both electric and natural gas programs but some counties are served by non-participating utilities, and therefore all three scenarios are applicable to the state.

Table 1: Savings allocation for systems in territories participating in both electric and natural gas EEPS programs

CHP Annual System Efficiency (HHV[16])	Allocated Electric Savings	Allocated Gas Savings
60%	65% of E_{CHP} (kWh)	No gas savings
>60% to 65%	65% of E_{CHP} (kWh) + one percentage point increase for every one percentage point increase in CHP system efficiency (max 70% of E_{CHP} in kWh)	No gas Savings
>65%	70% of E_{CHP} (kWh)	2.5% of $F_{thermalCHP}$ for every one percentage point increase in CHP system efficiency above 65%.

Table 2: Savings allocation for systems in territories participating in only electric EEPS programs

CHP Annual System Efficiency (HHV)	Allocated Electric Savings	Allocated Gas Savings
60%	65% of E_{CHP}	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

Table 3: Savings allocation for systems in territories participating in only natural gas EEPS programs

CHP Annual System Efficiency (HHV)	Allocated Electric Savings	Allocated Gas Savings
60% or greater	No electric savings	2.5% of $F_{thermalCHP}$ for every one percentage point increase in CHP system efficiency above 60%.

For example, consider a hypothetical CHP system that has a net generation of 26,750 kWh annually, consumes 79,119 kBtu of gas annually to generate that electricity (i.e. electric efficiency of approximately 34.5% HHV), reduces on-site gas use for space heating by 43,452 kBtu of gas (displacing natural gas used in a 75% efficient space heating boiler) and has a total annual CHP efficiency of 75% HHV. This system in a territory participating in both electric and natural gas EEPS programs, with a measured annual system efficiency (HHV) of 75%, the

[16] 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

electric savings (kWh) would be 70% of E_{CHP} measured over 12 months, and natural gas savings (therms) would be 25% of $F_{thermalCHP}$ measured over 12 months (75% - 65% = 10 X 2.5% = 25%). If the same system is in a territory participating in only electric EEPS programs, the electric savings would be 80% of E_{CHP} measured over 12 months (65% + (75% - 60%)), and no natural gas savings; and if that CHP system was in a territory participating in only natural gas EEPS program, there would be no electric savings and natural gas savings of 37.5% of $F_{thermalCHP}$ measures over 12 months (75% - 60% = 15 x 2.5% = 37.5%). Typical overall CHP efficiencies range anywhere from 60% to 80% depending on the prime mover[17].

The amount of energy savings claimed is based on a CO2 emission equivalency that compares the CO2 intensity of the grid (using e-Grid data, non-baseload[18]) to the CO2 intensity of the CHP system, since CHP systems tend to burn a different fuel than the typical generation mix of the grid, which includes a mix of coal, nuclear, natural gas and renewable resources[19]. At a CO2 emission rate of 53.06 kg/MMBtu for burning natural gas, in the absence of the example CHP system described above, the electric grid would have emitted 8,608 tons of CO2 and on-site boiler would have emitted 2,541 tons of CO2 for a total of 11,150 tons of CO2. The total fuel consumed by the CHP system emits 4,628 tons of CO2 resulting in a reduction of 6,522 tons. Using the savings allocation methodology described above, the CHP system's CO2 reductions would be equivalent to 6,661 tons which is comparable to the actual CO2 savings due to the CHP system.

Step 3: Cost-benefit analysis considerations

For any measure to be considered a good energy efficiency investment, it needs to pass the cost-benefit tests. Different tests are available to evaluate measures, and requirements vary based on each jurisdiction. The most widely used cost-benefit test is the Total Resource Cost test (TRC). The TRC is a ratio of costs versus benefits associated with implementing an efficiency measure. The costs in this test include any measure installation costs and any costs associated with day-to-day functioning of the measure incurred by both the utility and the customer. These costs include all equipment costs, installation including permitting and interconnection fees, operation and maintenance and administration costs. The benefits in the TRC include the energy and capacity related costs avoided by the utility along with any additional resource savings like natural gas or water. A ratio of 1 or above indicates that the benefits outweigh the costs associated with the measure and therefore its implementation would benefit both the customer and the utility.

Illinois requires measures to be evaluated using the TRC test. For the utilities to have successful programs, the state requires that their entire portfolio of energy efficiency measures has a TRC of 1 or more, but an individual measure does not have to pass the TRC test on its own to be included in the utility's portfolio. The portfolio TRC is a weighted average of all the individual measures. CHP measures in the portfolio usually include a few large systems that require high capital costs. Individual measure screening is important to ensure proper allocation of funds and maximize ex-post savings.

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[17] Reciprocating engines have CHP efficiencies of 77-83%, gas turbines 65-70%, microturbines 64-72%, steam turbines 80%, and fuel cells 75%. In practice depending on whether the site is trying to maximize the electric output or thermal utilization the operating efficiencies can be lower, which is why a minimum required efficiency is essential. (U.S. DOE's Technology factsheet: www.energy.gov/chp-technologies)

[18] https://energy.hawaii.gov/wp-content/uploads/2011/10/EE-Bldgs-Final-Report-12-12-20-InSynergy-Part-1.75.pdf

[19] https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

When calculating the benefits of a measure for TRC, the energy savings in kWh or therms are converted to dollar values by using the avoided costs associated with the savings. In non-fuel switch measures these savings are equal to the savings claimed by the utility towards their efficiency goals. For the CHP measure the savings claimed by the utilities do not accurately represent the measure's effect on the grid i.e. the utility and the customer. 100% of the electricity produced by the CHP system is displaced from the grid and typically additional natural gas is used on site to operate the system. The benefits for TRC should reflect these changes in fuel use.

The following equation is used to screen the CHP measure for its cost-effectiveness:

$$TRC = \frac{Benefits}{Costs}$$

Where $Benefits = E_{CHP} + \Delta kW + \Delta F_{CHP}$

And

$$Costs = F_{totalCHPcosts} + CHP_{costs} + O\&M_{costs}$$

$F_{totalCHPcosts}$ = the net present value of the cost of the total fuel consumed by the CHP system over its lifetime

CHP_{costs} = the net present value of 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.

$O\&M_{costs}$ = the net present value of expected maintenance costs over the life of the CHP system.

Conclusion

CHP reduces the overall energy consumed in Btus by reducing the electricity usage and increasing the fuel usage onsite required to operate the system. Higher efficiencies of the CHP system compared to traditional power generation and distribution system, along with other non-energy benefits including CO2 emissions reductions and increased grid resiliency, make CHP very attractive to utilities to help meet their energy goals. Uncoordinated or conflicting policies and approaches to address the "fuel-switch" nature of the CHP measure, by electric and gas utility energy efficiency programs, hinders the implementation of CHP systems and the realization of benefits that they can bring.

The approach outlined in this paper aligns both the electric and natural gas utilities towards a common objective, where energy savings are attributed to the program administrator of electric utility up until a baseline or reference efficiency, while energy savings are attributed to the program administrator of the natural gas utility beyond the baseline or reference efficiency. This ensures that the electric utility gets credited for its efforts to encourage displacement of electricity delivery, while the natural gas utility is credited for its efforts of maximizing the heat recovery and thermal efficiency of the CHP system. The baseline efficiency depends on whether both electric and natural gas utilities are participating in the program or only electric utility or only natural gas utility.

These claimable savings are not used to evaluate the cost-effectiveness of the measure. The total displacement of electricity delivery and the net natural gas use on site by the CHP system is used to assess the CHP measure's feasibility in the utilities' energy efficiency portfolio. The 3-step approach discussed in this paper to determine fuel savings, assign claimable savings to both electric and natural gas utilities and then perform cost-benefit analysis of the CHP measure will encourage inclusion of the CHP measure in energy efficiency portfolios across jurisdictions.

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