New and Improved Methods for Evaluating CHP Cost-Effectiveness

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ABSTRACT

Combined Heat and Power (CHP) technologies are becoming more prevalent throughout the United States as a way to increase building energy efficiency and resiliency. Therefore, it is important to assess the cost-effectiveness of CHP installations both individually and, when a CHP program is offered as a component of a utility's portfolio of energy efficiency programs, collectively for the entire fleet of CHP projects. Before approval, utility program administrators are required to prove to their regulators and other policymakers that the program is highly cost-effective for both participants and non-participants. In addition, cost-effectiveness has to be confirmed at semi-annual or annual intervals for the program's duration.

Historically, there are five energy efficiency cost-effectiveness tests: the widely used Total Resource Cost (TRC) test, the Societal Cost Test (SCT), the Ratepayer Impact Measure (RIM) test, the Participant Cost Test (PCT), and the Program Administrator Cost Test (PACT). This paper will describe these tests and explain how they can be adjusted by including non-energy benefits (NEBs) to more accurately assess CHP technologies.

Introduction

Reducing energy consumption to lower carbon emissions and combat global warming has been a goal of local, state, and federal agencies for the last 40 years. Fortunately, technological advancements have created the ability to decrease the amount of electricity and fuel needed by a facility without sacrificing the comfort and productivity of occupants, aesthetics, or the quantity and quality of product output in the case of commercial buildings and manufacturing facilities. At the federal level, the DOE has actively spearheaded a highly successful decades-long cooperative program with manufacturers and building designers to enact an expanding set of energy efficiency codes and standards. At the local and state level, strategies most commonly provide grant and incentive funding opportunities to accelerate the implementation of the newest, most energy-efficient technologies. In many cases, these grant and incentive opportunities are utility rate-payer funded and face regulatory agency scrutiny to ensure these public benefits are achieved, worthwhile and cost-effective.

As both codes & standards and incentive programs have grown and expanded over the years, many states and utilities are now finding that further efficiency savings require deeper retrofits to existing buildings and more holistic approaches to claim the large savings that were more easily captured during the initial years of a utility or state program. To reach the ambitious goals of programs, expansion to incentivize additional technologies is an increasingly common approach.

One of these energy-efficient technologies is Combined Heat and Power (CHP), which is also known as cogeneration. The technology is not new, in fact it was deployed by Thomas Edison at the Pearl Street Station in 1882. Today, the technology is in operation at over 3,300 sites generating over 85 gigawatts of electricity (ORNL 2008, 4). However, its potential is hardly tapped as it only accounts for less than 9% of total electricity generation in the United States

(ORNL 2008, 4). Many policy makers recognize this opportunity and have introduced programs that provide a combination of outreach, information, and incentives and grants to overcome barriers such as the lack of awareness about CHP and its significant initial cost.

One of the remaining barriers that can restrain CHP from more wide-scale adoption by grant and incentive programs is the need to justify the technology through the cost-effectiveness (also called “passing benefit/cost (B/C) tests”) that state and utility regulators require the programs and measures to satisfy. The intent of this paper is to outline a framework for making the B/C tests more accurate for assessing CHP technologies by adding highly relevant “non-energy benefit” (NEB) terms to them.

CHP Benefits

The thermodynamic processes utilized in all fuel-using electricity generating systems – from 1,000-MW utility power plants to a portable 5-kW emergency generator – produce waste heat that must be safely discharged to the natural environment. This waste heat appears in the form of hot exhaust gases, hot water from heat exchangers and steam condensers, and radiation at infra-red frequencies emitted from hot engines, turbine shells, pipes, and ducts. A CHP system sequentially produces electricity and thermal energy from a single fuel source. It captures most of the waste heat and uses it to produce steam, hot water, or hot air to serve one or more end-uses (i.e., space heating, water heating, process heating, space cooling, refrigeration, and dehumidification) at the host facility. Capturing waste heat helps reduce the use of fuel or electricity otherwise produced from a boiler, furnace, or heater. CHP can thus increase overall energy efficiency to typically 75%, but it ranges between 65% and 85% (DOE and EPA 2012, 7). On the contrary, the average efficiency of power delivered to customer facilities via the utility grid is only about 28%, and the typical annual efficiency of heat from fuel-fired boilers is about 70% to 80% (DOE and EPA 2012, 8). From U.S. electric power sector alone, energy lost from wasted heat is more than the total amount of energy used in Japan (Shipley et al. 2009, 73).

Additionally, CHP can reduce greenhouse gas (GHG) emissions. In the Environmental and Energy Study Institute’s fact sheet, it is estimated that the CHP systems currently in operation save approximately 1.8 Quads of energy annually and decreases U.S. carbon dioxide emissions by 240 million metric tons, which is similar to removing 40 million cars (EESI 2013, 2). Not only is CHP beneficial because it reduces emissions, but it also saves money and energy. For example: installing 40 GW of new CHP, the DOE and EPA estimate the U.S. businesses and industry could save $10 billion per year in energy costs and reduce overall national energy demand by one percent (EESI 2013, 1).

CHP also promotes reliability and resiliency to a host facility in the event of a grid outage. While the system itself will always require a fuel source to generate electricity, natural gas and other fuels have been proven to be more reliable than the grid. Accordingly, natural gas fueled CHP systems are commonly an essential component of microgrids.

Benefit/Cost Evaluation Concepts

The cost-effectiveness of every large purchase or investment is routinely calculated (i.e., “evaluated”) by prospective purchasers or investors using familiar methods and metrics or ones specified by their organizations. This paper will not be discussing these calculation methods. Instead, the paper is concerned with policy-related evaluations performed to determine whether funds raised, via taxes imposed by government agencies or via assessments on bills paid by utility rate-payers, should be expended on promoting energy efficiency programs and projects by underwriting a portion of the cost of installing energy-efficient equipment and systems, such as CHP systems. Basically, the evaluation asks, “Are those who provide the funds receiving Benefits that have greater value than the Cost they pay?” Commonly, the evaluation looks at the ratio of Benefits to Costs (B/C), and answers “Yes” to this question when the ratio is greater than 1.0, with a result much larger than 1.0 being given a more resounding “Yes” than a ratio that is only marginally greater than 1.0.

Two of the challenges associated with performing this evaluation are: 1) to decide which Benefits and Costs should be included in the assessment, and 2) how should the two terms be defined and determined (i.e., calculated). The California Public Utilities Commission (CPUC) was the first government agency to formulate a systematic set of Cost-Effectiveness Tests, during the 1980s (CPUC 2001). Before naming and describing these tests, it will be useful to first list some of the general principles that were adopted, and because this will serve to address the challenges listed above.

- Benefits and Costs are always positive values (i.e., a negative Benefit is a Cost, which doesn’t matter when B minus C is calculated, but does matter when B/C is calculated).

- It is not necessary to assess each individual efficiency measure and exclude those that “fail” the B/C test. The best approach is to assess the entire program and the whole portfolio, which are collections of diverse energy efficient equipment. A few measures with B/C < 1.0 can be included if customers want them; the important criterion is that the program’s B/C be greater than 1.0.

- For the utility and its various ratepayers, the main Benefit of conducting the program is the net present value (NPV) of future costs that will be avoided over the lives of the energy-efficient equipment or systems that are expected to be installed. For the utility customers who install the energy-efficient equipment or system, the benefit is the NPV of all future savings (i.e. reduced expenditures) over the life of the equipment or system, plus the NPV of program financial incentives and tax savings of this same period.

- The main Costs to be paid vary with the Test, but always include the NPV of the total cost of conducting the program; ideally the cost over multiple years so the costs of start-up and termination do not strongly bias the results. For some Tests, the NPV of all the life-cycle costs associated with purchasing, financing, owning, operating, maintaining, and eventually removing the equipment and system should be taken into account.

- The Tests must take into account the fact the some individuals who participate in the program and accept incentives would have installed the energy-efficient equipment or system even if the program did not exist. These individuals are termed “free-riders,” and the Tests should exclude both the Benefits they produce and Costs that they directly incur. However, the direct and indirect program Costs they contribute to also must be included.

- It is recognized that not all Costs and Benefits can be accurately monetized. It is desirable that at a minimum they be mentioned and taken into account if this can be done in a fair and reasonable way. Reduced emissions of polluting materials is an example of a definite Benefit, but there is a lack of consensus concerning the dollar value that each unit of reduction will produce.

States that authorize utilities to offer energy efficiency programs funded by rate-payers typically have adopted these tests, but sometimes with modifications. These often involve aspects such as specifying avoided energy and demand unit costs, stating discount rates to be used, and which non-energy benefits (if any) can be considered. The state typically will also designate which test(s) is or are the most important.

The Total Resource Cost (TRC) test is the most common primary measurement of energy efficiency. According to a national survey, 84% of the states use this test and 71% use it as their main cost-effectiveness test (Kushler, Nowak, and Witte 2012, 13-14). It compares benefits to society as a whole (e.g., avoided supply-side cost benefits and additional resource savings benefits) with the participant's cost of installing the measure plus the cost of energy efficiency program administration (non-incentive costs). It measures whether total costs of energy in the respective territory will decrease, and thus if energy efficiency is cost-effective overall (EPA 2008). Incentives are considered a transfer payment from program to participant; therefore, they are not explicitly accounted for in the TRC calculation. Also, only monetized environmental benefits are included in the TRC test. These can include greenhouse or other allowance prices in cap and trade markets (ORNL 2014). Moreover, a positive TRC result means that the program will produce a net reduction in energy costs for the utility service territory over the program's lifetime.

Closely following the TRC test, the Societal Cost Test (SCT) is commonly used to measure energy efficiency cost-effectiveness. This test is similar to the TRC, except that it explicitly quantifies external benefits, such as avoided pollutant emissions not represents in market prices and other non-energy benefits (e.g., improved health or productivity). Therefore, it measures whether society is benefiting and the overall cost-effectiveness of energy efficiency (EPA 2008). The SCT typically has the lowest discount rate of all the tests because it accounts for the reduced risk of investment being spread across society. This value is used in calculating the net present value (NPV). This test reflects the long term benefit to society.

The Ratepayer Impact Measure (RIM) test, the Participant Cost Test (PCT), and the Program Administrator Cost Test (PACT) are used to indicate how different stakeholders are affected. The RIM, PCT, and PACT determine whether the selection of measures and design of the program is balanced from the non-participant, participant, and utility perspectives (respectively) (EPA 2008).

The RIM test compares the utility's avoided cost benefits with the cost of administering energy efficiency programs plus lost revenue from reductions in customer energy consumption. It measures whether the utility rates will increase; thus evaluating the program from the non-participant perspective. The PCT compares the participant benefits (incentives plus bill savings) with participant costs (incremental or capital costs, installation, O&M, etc.). It measures whether the participant will benefit over the measure life. Finally, the PACT, sometimes referred to as the utility cost test, compares the utility's avoided cost benefits with energy efficiency program expenditures (incentives plus administrative costs). It evaluates cost-effectiveness from the utility or implementer's perspective; therefore, it measures whether utility bills will increase (EPA 2008).

B/C Assessment of CHP Programs

Applying cost-effectiveness at the program level for a CHP program may result in the need for exceptions and forbearance by regulators. Because customers typically are not familiar with CHP, programs ramp up slowly over time because of the need to make both utility customers and CHP developers located locally and in surrounding states aware that the program exists, and to familiarize customers with the benefits and costs of the technology. Then, CHP developers need to meet with customers, prepare and present proposals, obtain signed contracts, and secure all needed permits and agreements. For example, in the Pepco and Delmarva Power Commercial and Industrial Energy Savings Programs in Maryland, it took three years to reach the point where CHP projects were actually being built. Therefore, a CHP program may not show cost-effectiveness in the early years of a multi-year program because promotional costs are being incurred but no savings are as yet being recorded.

In addition to being patient and allowing time for CHP projects to develop and be built, another problem is that the projects may not pass the B/C test because Benefits are relatively low and Costs are relatively high:

- In the usual formulation the Benefit term is a linear function of avoided costs. Most other efficiency measures tend to have a high percentage of annual operating hours at times when marginal avoided costs are highest. Because CHP systems operate around the clock and nearly equally during all seasons, a large fraction of the annual operating hours occur at times when marginal fuel costs are lowest. Future avoided energy and capacity costs are expected to remain relatively low for a number of years because load growth is low and natural gas is expected to remain plentiful.

- The Cost term tends to be high for two reasons: the first cost is high and operating (i.e., fuel) and maintenance costs must be included, unlike the case with most other efficiency measures.

This brings us to the main point of this paper: the B/C tests should include the unique characteristics of CHP systems the fall into the non-energy benefits category.

Non-Energy Benefits

Non-Energy Benefits (NEB) are the additional benefits of an energy efficiency project beyond energy savings, such as comfort, productivity, health, convenience, aesthetics, and increased property value. None of the five cost-effectiveness tests explicitly recognizes changes in NEBs. From the customer perspective, NEBs include increased comfort, air quality and convenience (EPA 2008). CHP can also improve business competitiveness by increasing energy efficiency and managing costs (EESI 2013). For the utility, NEBs may include a reduced number of shut-off notice issues or bill complaints (EPA 2008). With regards to the societal perspective, efficiency measures can provide regional benefits such as increased community health due to lower air pollutant emissions, decreased water consumption at power plants, and reduced land use for new power generation, transmission, and distribution infrastructure (ORNL 2014).

Studies have shown that NEBs can be more important for the customers than the energy savings. For example, in a study on NEBs as they pertain to commercial and industrial customers participating in Wisconsin's Focus, researchers found that interviewed participants value NEBs of installed program measures two and a half times greater than the energy savings (Hall and Roth 2004, 10). Additionally, in an EPA and Lawrence Berkeley National Laboratory study, researchers found that over 52 case-studies of industrial customers who had installed energy efficient technologies, the associated productivity gains were valued higher than the value of the energy savings (Hall and Roth 2004, 12).

Even though NEBs are valued so highly, they are difficult to quantify. Moreover, they are rarely incorporated into the TRC or even under the SCT. In some states, they are treated as a simple adder (ORNL 2014). However, there is an increasing interest in valuing energy efficiency's effect on reducing GHG emissions (EPA 2008). To do so in cost effectiveness tests, the quantity of avoided CO_2 emissions from the efficiency program is determined. Then, its economic value is calculated and added to the net benefits of the energy efficiency measures used to achieve the reductions. Some areas, including California and the Northeast, GHG emission are a monetized avoided cost and may be included as a Benefit, and sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions may also be monetized (ORNL 2014). Although more states are trying to incorporate CO_2 emissions, it is difficult to achieve a consensus on a specific dollar per ton price for the electricity sector. Nevertheless, to further promote beneficial energy efficiency programs, it is important to try to value these NEBs and include them in cost-effectiveness calculations.

Because most CHP systems burn fuel, their GHG and air pollution reduction characteristics are marginally small at best, and may be slightly negative if a sizeable fraction of electricity from the grid is produced in hydro-electric or nuclear power plants. However, energy resiliency and the extended life of HVAC equipment are other NEBs and defining attributes of CHP systems. This paper makes the case for regulators to authorize their inclusion in B/C tests.

Energy Resiliency

Events over the past few years have demonstrated the challenges with energy distribution and the importance of reliable energy. For example, in 2012 during Superstorm Sandy, South Oaks Hospital in Amityville, New York remained in operation while the rest of the Long Island Power Authority (LIPA) grid was down (ORNL 2013). While more than 8.5 million customers lost power for over a week, South Oaks Hospital had five 250 kW CHP units, which enabled them to stay operational and disconnected from the grid for about fifteen days (Willis and Loa 2015; ORNL 2013). Lights stayed on, patients from other sites were admitted, and refrigeration units for vital medicines for those that lost power remained operational (ORNL 2013).

Another example of CHP's energy resiliency is Louisiana State University (LSU). In 2008, during the Hurricane Gustav in Baton Rouge, Louisiana, most of the university remained online while severe weather impacted the rest of the Entergy power grid (ORNL 2013). LSU had two CHP units, a 3.7-MW unit and a 20-MW unit, which enabled most of the campus to produce on-site power during and after the hurricane (ORNL 2013). This was the second natural disaster that tested the system; the first of which was Hurricane Katrina in 2005, during which, LSU continued to operate and provide safety for displaced employees (ORNL 2013).

There is a relatively easy way to quantify the Resiliency Benefit when the CHP system is designed to continue to operate during a grid outage: use the avoided cost of not needing to install a stand-up generator of the same capacity.

Extended Life of HVAC Equipment

By economically providing both a source of electricity and a source of thermal energy, CHP systems reduce the run-hours of HVAC equipment, such as the host facilities' boilers and domestic hot water (DHW) heaters. As a result, the life of these equipment items and the time before the owner needs to invest in their replacement is extended. The numerical Benefit is simply the NPV of the replacement deferral.

Future Research

Measurements surrounding NEBs, such as energy resilience and beyond, are important to add into cost-effective tests, as they are so essential to the justification of the unit installation. Currently, there are 154 different metrics, such as the amount of electricity delivered, gallons of fuel shipped, or economic output generated by energy during a disruption, that are used to measure resilience (Willis and Loa 2015). Unfortunately, there are no standardized metrics for NEBs. There should be more research into effective means of measuring NEBs in order to create a standardized evaluation method. This way, cost-effectiveness tests can include NEBs, such as resilience, that aim to make communities safer and more productive.

Conclusion

CHP simultaneously delivers reliability and numerous efficiencies, which has led the technology to become one of the hottest technologies in the evolving distributed energy resource (DER) market. However, cost-effectiveness tests should be modified in order to properly account for all of the benefits that differentiate this technology from facility efficiency upgrades, such as LED lamps, a more efficient air conditioner, or a variable frequency drive.

The non-energy benefits of CHP systems are real and should not be overlooked. The increased reliability that CHP provides to buildings that can serve as emergency shelters for extended periods following hurricanes, tornadoes, earthquakes, etc., has saved lives in the past and will continue to do so in the future. At a more mundane level, delaying the need for a hospital to invest in a new boiler for 5 to 10 years has an unquestionable economic value.

It is also our recommendation that utilities or states evaluating CHP programs follow the footsteps of California and Maryland who specifically apply the cost-effectiveness tests at the portfolio level to promote programs for emerging technologies such as CHP for utilities to meet policy goal but do not necessarily pass the TRC or PCT tests (EPA 2008).

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