The Role of Electric Utility Energy Efficiency Programs in Building Community Resilience

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ABSTRACT

Local governments are increasingly focused on disaster preparedness, climate adaptation, and community resiliency. A growing number of threats, from aging infrastructure to multiple climate impacts, can stress physical and social systems. There are different dimensions to resilience planning, but an important consideration is planning for a reliable electricity supply with limited disruptions and outages. This paper is about using electric utilities to increase community resilience. Utility energy efficiency programs can benefit utilities and communities by increasing system reliability. We review selected programs that have had the largest impact on reducing peak demand, and we introduce metrics that can be used to compare their performance. We also examine programs that increase the thermal efficiency of building envelopes, which can help maintain interior thermal conditions when power outages occur.

Introduction

Our approach to resilience follows a framework established in past ACEEE research that defines resilience as a community's reduction of and preparation for risk (Ribeiro et al. 2015). Risk is a function of hazards, vulnerability, and capacity to cope (CCDRR Inter-Agency Task Force, undated). Of these factors, vulnerability to damaging effects and the capacity to cope with hazards are clear targets for community resilience planning. The hazards themselves (e.g., storms and other weather events) are beyond control.

Communities must account for a variety of hazards and stressors in their resilience planning. Energy is a vital concern because it powers modern life. Not only is a steady energy supply of the utmost importance, but using that energy efficiently is a core strategy for making energy systems—and the communities served by those systems—stronger and more resilient.

Energy utilities and related organizations provide a significant number of the energy efficiency programs in the United States, so they can have an important role in increasing community resilience. Past ACEEE research has explored energy efficiency's broader benefits (Baatz 2015; Nadel et al. 2015). This paper examines two significant resilience benefits that accrue from utilities' energy efficiency programs. First, utility programs may reduce electricity demand (power, measured in megawatts). Reduced demand, especially at times of system peak, can increase reliability by avoiding system outages. In addition, many utility programs lead to improved interior thermal conditions by improving building envelopes. Such improvements can maintain more livable conditions for occupants when electricity is unavailable. Buildings that allow residents to stay in their homes during outages are important for housing vulnerable populations—those people more sensitive to temperature extremes, hot or cold—including people with health conditions and the elderly.

This paper addresses the resilience benefits of demand reduction and improved building thermal performance. Other benefits, including economic and social benefits that accrue from utility programs, are beyond our present scope but are also likely important to communities concerned with resilience and sustainability (Baatz 2015; Russell et al. 2015).

Energy Efficiency and System Reliability

Electric system reliability is most vulnerable at times when demand is high and there are limited supply resources available to meet it. Such situations can arise for a number of reasons, including:

- Summertime heat waves
- Storms with high winds
- Snow and ice storms
- Unscheduled outages of major generation units
- Transmission and distribution constraints
- Electricity market malfunctions (inability to adequately match supply with demand)

While electric outages (blackouts) are uncommon, California and a number of other states experienced unprecedented electric system crises in 2000–2001 that resulted from a variety of market factors and system problems. In 2000 California experienced rolling blackouts and had to triage public systems. Electricity costs suddenly increased dramatically, reliability dropped, and the economy suffered severe disruptions and losses. This crisis stemmed largely from opportunistic efforts in the 1990s to restructure and deregulate electricity markets. Ongoing investments in necessary electric system infrastructure stalled due to uncertainties associated with this attempted transformation from a fully regulated market to a type of deregulated market. Institutional and market problems also contributed to the crisis, including control of choke points in the transmission system and manipulation of the markets to drive up profits (Leopold 2002).

During this crisis in California, energy efficiency and demand management played key roles in addressing the reliability challenges posed to the system. They literally helped keep the lights on. Research by ACEEE (Kushler et al. 2002) on reliability-focused energy efficiency programs found that a set of efficiency and conservation programs and related efforts reduced demand by nearly 3,700 MW, an average of about 10% peak demand reduction. They also reduced total energy use by nearly 7%. Such savings were meaningful; they yielded much needed system relief on reserve margins that were stretched very thin. Without such reductions, additional rolling outages likely would have occurred. With the reductions, California made it through the entire summer and remainder of 2001 without a single rolling outage. Immense economic losses could have resulted from such additional outages.

California’s experience shows the reliability benefits of energy efficiency. California was able to achieve such a dramatic result because it already had a set of utility energy efficiency programs in place. The state was able to build on this existing infrastructure of utility programs, increasing program activity to serve more customers and achieve correspondingly high savings. In some cases California’s utilities boosted budgets for existing programs to increase their impact; in other cases the utilities introduced new programs and initiatives. Statewide the total funding for the full set of utility and related programs reached $971 million, almost doubling the pre-crisis program funding of about $400 million.

A number of other states and regions also faced electricity crises in 2001 and ramped up their energy efficiency efforts to reduce both overall energy use and peak demand. On a national basis, weather-related outages are estimated to cost $40–75 billion annually, and much more in years with severe storms like Superstorm Sandy or Hurricane Ike (President's Council of Economic Advisors et al. 2012). Costs include lost output and wages, spoiled inventory, delayed production, inconvenience, and damage to the electric grid. A single outage can easily result in an economic loss of billions of dollars.

Community Resilience, Grid Resilience and Utility Energy Efficiency Programs

Reliability of the electricity grid is fundamental to community resilience. Our homes, businesses, institutions, and industries all rely on electricity to provide essential needs and an ever-expanding array of amenities. As the California electricity crisis so dramatically illustrates, the peak-demand savings capabilities of energy efficiency improvements can yield significant reliability benefits. Reducing peak demand helps avoid spikes in demand that can be difficult to meet if supplies are constrained for any reason. Outages will occur if demand exceeds supply.

Over three decades of experience with utility demand-side management (DSM) has clearly demonstrated that a variety of program mechanisms and services can affect customer demand. There are two primary types of DSM programs: (1) energy efficiency and (2) load management. ("Demand response" has recently emerged as a primary load management program model.) Energy efficiency programs generally seek to reduce customer energy use (kilowatt-hours) on a long-term basis through improvements in energy efficiency. Load management programs seek to curtail or shift power demand (kilowatts) away from high-cost peak demands. The relative costs and benefits of each type of program vary from utility to utility.

Despite the clear relationship between saving energy through improved energy efficiency and reducing peak demand, research by ACEEE (York et al. 2007) found that most program evaluations historically have focused on estimating energy savings impacts. Often the peak demand impacts are simply derived from standardized assumptions about load profiles of typical customer end-uses of electricity. True estimates of energy savings impacts draw on a variety of specific customer data sources, including metering and onsite measurements.

This picture is changing rapidly, though, as a rapidly growing number of utilities upgrade distribution systems to use advanced metering infrastructure (AMI). AMI greatly expands capabilities for measuring, reporting, and responding to customer energy use and power demand. It involves real-time metering of energy use, which provides much more detailed data for customers and utilities. These data can be used to optimize customer energy use, improve system reliability, and create new pricing and service options. AMI enables a variety of technologies and services that customers can use to change their energy use in response to real-time data. For maximum impact, it needs to be coupled with communications, pricing, and controls.

Metrics for Energy Efficiency and Community Resilience

Community resilience adds a dimension to the analysis, selection, and implementation of utility energy efficiency programs. To explore this dimension, we examined a set of efficiency programs provided to electric utility customers in Wisconsin and Arkansas. We selected these states because one has a cold climate and the other, a warm one.

Differences in climates are important for a discussion of resilience benefits. The dangers of winter outages in a cold climate are different than those of summertime outages in a hot one. Various types of energy efficiency programs may have different demand impacts in summer than in winter. For example, a program that promotes energy-efficient residential air conditioners clearly would have an impact on summer peak demand, but likely little to no impact on winter peak demand in cold climates.

Our analysis focuses on the peak demand savings capabilities of programs relative to their energy savings. Most databases of energy efficiency measures, such as those used for technical reference manuals, include deemed savings estimates or algorithms for both energy savings (kWh) and demand savings (kW). These data make it possible to scrutinize individual measures for peak demand impacts and rank them accordingly. However the scale of demand reductions necessary to achieve electric system reliability benefits is that of entire programs, not individual measures. Therefore our analysis is at the program level.

ACEEE's earlier research (York et al. 2007) used an approach to compare various types of customer energy efficiency programs in terms of their peak demand savings capabilities. The study classified programs according to how much peak demand savings they achieved in conjunction with energy savings and program costs.

Two metrics are readily derived from typical energy efficiency program evaluations:

- Megawatt saved per program dollar (annual program cost)
- Megawatt saved per gigawatt-hour saved (first-year savings)

These simple metrics can identify the types of energy efficiency programs that yield significant peak demand reductions. Energy savings (gigawatt-hours) are the primary objective for energy efficiency programs. Assessing how much peak demand can be reduced per program dollar can help planners and program administrators prioritize programs with the highest impact.

Tables 1 and 2 present data for energy efficiency programs in Arkansas and Wisconsin (Entergy Arkansas, Inc. 2015; Cadmus 2015). Budgets are in nominal (reporting year) dollars, and energy savings are net first year, ex-post evaluation results. We include budgets and total savings as indicators of program magnitude. The programs are arranged from highest to lowest values.

Table 1. Budgets and impacts for selected Arkansas energy efficiency programs

Program	Budget ($million)	Energy savings (GWh)	Demand savings (MW)	MW/ GWh	MW/ $million
Entergy Arkansas Programs					
Efficient Cooling Solutions	3.1	10.0	4.5	0.45	1.45
Home Energy Solutions	11.2	16.6	5.6	0.33	0.50
Energy Star New Homes	0.4	0.0	0.0	0.24	0.03
Lighting and Appliances	4.4	42.9	7.7	0.18	1.75
Energy Solutions for Multifamily	0.5	1.1	0.2	0.17	0.38
Small Business	3.2	12.2	2.1	0.17	0.66
Agricultural Energy Solutions	0.4	2.6	0.4	0.14	0.95
C&I Solutions	23.8	97.7	13.9	0.14	0.58
Energy Solutions for Manufactured Homes	0.8	0.7	0.1	0.13	0.11
City Smart	2.8	14.7	1.5	0.10	0.54

Program	Budget ($million)	Energy savings (GWh)	Demand savings (MW)	MW/ GWh	MW/ $million
Oklahoma Gas & Electric Programs					
OG&E – AOG Weatherization	2.23	3.68	1.09	0.30	0.49
C&I Standard Offer	0.95	1.61	0.43	0.27	0.45
Commercial Lighting	0.96	6.53	1.12	0.17	1.16
Multifamily Direct Install	0.23	1.67	0.21	0.13	0.90
Student Energy Education	0.09	0.31	0.04	0.13	0.44

Table 2. Budgets and impacts for selected Wisconsin Focus on Energy programs

Program	Budget ($million)	Energy savings (GWh)	Demand savings (MW)	MW/ GWh	MW/ $million
Enhanced Rewards	2.2	0.76	0.33	0.44	0.15
Residential Rewards	9.7	8.01	3.26	0.41	0.34
Assisted Home Performance with ENERGY STAR®	1.6	0.43	0.15	0.35	0.09
Home Performance with ENERGY STAR	3.6	1.91	0.64	0.33	0.17
New Homes	1.9	2.56	0.81	0.32	0.42
Small Business	7.5	30.10	5.79	0.19	0.77
Business Incentive	18.4	103.93	16.23	0.16	0.88
Chain Stores and Franchises	4.4	27.09	3.95	0.15	0.89
Appliance Recycling	3.0	9.48	1.26	0.13	0.42
Large Energy Users	16.2	112.93	14.73	0.13	0.91
Design Assistance	4.6	10.43	1.29	0.12	0.28
Express Energy Efficiency	2.9	8.12	0.92	0.11	0.32
Residential Lighting and Appliance	11.5	198.24	22.14	0.11	1.93
Multifamily Programs	3.2	9.64	1.00	0.10	0.31

Implications for Community Resilience

These data and the derived metrics illustrate the wide variation among programs in their peak demand reduction relative to energy savings. Values range from 0.10 to 0.45 MW/GWh and from 0.03 to 1.93 MW/million dollars. For consistency across programs, the energy savings values in our data sets are for first-year savings. Programs also typically will estimate and report lifetime savings, but this require assumptions about measure life and persistence that may vary from one program to another.

The programs that achieve the highest peak demand reductions relative to energy savings are:

Entergy Arkansas

- Efficient Cooling Solution
- Home Energy Solutions
- ENERGY STAR New Homes

Oklahoma Gas & Electric – Arkansas

- AOG Weatherization
- C&I Standard Offer
- Commercial Lighting

Focus on Energy – Wisconsin

- Residential: Enhanced Rewards
- Residential Rewards
- Assisted Home Performance with ENERGY STAR

Planners and program managers trying to improve community resilience would prefer to have such programs in their program portfolios, taking into account climate and the need to reduce seasonal or time-of-use peak demands to improve grid reliability.

The other derived metric, MW/$million, can help guide planners and administrators who seek to maximize this value or who simply want an alternative lens through which to view program alternatives. For example, portfolios with small budgets that seek to achieve greater peak demand savings may prioritize and allocate more funds to programs that yield high peak demand savings relative to costs.

The above results are similar to ACEEE's earlier research on the peak demand impacts of energy efficiency programs (York et al. 2007). Table 3 below presents selected results from this study.

Table 3. Selected reliability-focused energy efficiency programs

State	Program Name	Annual energy savings (GWh)	Peak demand savings (MW)	MW/GWh
TX	Air Conditioner Installer and Information Program	20.4	15.7	0.77
CA	Comprehensive Hard-to Reach Mobile Home Energy Saving Local Program	7.7	3.7	0.48
CA	Northern California Power Agency SB5x Programs	37.3	15.9	0.44
MA	Small Business Lighting Retrofit Programs	35.8	9.7	0.27
MA	National Grid Energy Initiative Program—Lighting Fixture Impacts	36.0	6.5	0.18
CA	San Francisco Peak Energy Program	56.8	9.1	0.16
MA	National Grid 2004 Compressed Air Prescriptive Rebate Program	673	0.1	0.15

It is not surprising that energy efficiency programs that affect air conditioning loads rank highly in terms of their impact on peak demand relative to energy savings. The great majority of electric utilities are summer peaking, driven primarily by air conditioning loads. The primary strategy to reduce such loads is upgrading air conditioning units to high efficiency models. Air conditioning loads also can be reduced by improvements to building envelopes, such as increased insulation, air sealing, and shading of windows to reduce solar gain—all measures typically done as part of home performance programs.

The programs we have analyzed show that energy efficiency programs can yield measurable, meaningful peak demand savings. They also illustrate the variability among programs in terms of the relationship between peak demand savings and energy savings. The derived metric, MW/GWh, varies by a factor of about 5 for the set of programs examined in ACEEE's 2007 research on reliability-focused programs. Some energy efficiency programs have negligible impact on peak demand savings (for example, a program promoting high-efficiency outdoor lighting). A robust portfolio likely will and should include highly cost-effective programs even if they yield little or no peak demand reductions.

Planning Mechanisms to Target High Peak Demand Savings

Utilities in many states and regions have long recognized the value of demand savings. Their planning and investments in energy efficiency reflect this benefit to their systems. In terms of communities and resilience, such programs can provide similar reliability and demand reduction benefits. Communities that are planning and implementing programs to increase resilience can use two primary mechanisms to target energy efficiency programs that also provide significant peak demand savings.

The first is simply to direct available program dollars to those programs that deliver high peak demand savings relative to energy savings as measured by watt/kilowatt-hour. If a desired outcome of a program portfolio is a large amount of peak demand reduction, the portfolio should contain a higher proportion of programs that yield higher peak demand reductions relative to energy saved. For summer-peaking utilities, programs that reduce air conditioning load as shown in our results above would generally be a top priority. Commercial lighting programs also can provide significant peak demand reductions.

The second mechanism is to incorporate a resilience value into the determination of avoided capacity costs in analyzing the cost effectiveness of energy-efficiency measures and programs. Avoided capacity costs (including avoided transmission and distribution costs) already are used in such screening, but these values reflect market prices and marginal generation costs. (The latter are the value of power at peak production, whether purchased through markets or generated by a company's own units.) Such costs generally do not add values for resilience benefits, i.e., the cost offset that is produced by avoiding or reducing outages.

Quantifying such benefits is challenging and subject to wide uncertainty. One way would be to apply an adder to the avoided capacity cost. Or it could be possible to derive a value of an avoided outage and apply a corresponding benefit value into the cost-effectiveness screening of measures and programs. In this way, one could develop a portfolio from the ground up that places a higher value on peak demand reduction. The resulting measures and program portfolios would thus have a higher proportion of energy savings programs that yield high peak demand impacts.

A few utilities do account for the risk reduction benefit of energy efficiency, part of which is attributable to increased system reliability and grid resilience. The Regulatory Assistance Project reports that the Northwest Power and Conservation Council added approximately $20/MWh for the value of risk reduction due to energy efficiency programs (Lazar and Colburn 2013). Vermont includes $2.27/MWh for risk. Again, such values reflect a wide set of risk reduction factors; improved reliability due to peak demand reduction is just one of them. These examples illustrate how such benefits can be incorporated into the program screening and selection process.

Other policies and programs besides energy efficiency programs should be pursued in planning for the resilience of electric systems. Demand response and other types of load management directly address reducing peak demand. In addition, utility investments in AMI are often justified largely on the reliability benefits of such technologies. AMI investments are part of a much larger effort to modernize the grid through a variety of smart technologies. These technologies can detect, communicate, control, respond to, and resolve system problems in near real time, which can help avoid systemwide outages (President's Council of Economic Advisors 2013). Distributed generation, whether from fossil fuels or renewable energy sources, also can greatly improve community resilience. Such systems can serve local loads when larger systemwide outages occur.

Scale is a factor in achieving the resilience benefits of energy efficiency. Sufficient total MW savings would be needed to have an impact on system load at a time when reliability is threatened. For example, California's programs in 2001 are estimated to have delivered 15–20% peak demand savings during critical times. This level of savings is not necessarily needed in other situations. It would seem that demand reductions of single-digit percentages would be needed as a minimum threshold to provide systemwide benefits. From a utility perspective, the scale of impact needs to be at the system scale of need. From a local government perspective, the city needs to protect itself and key services, for example, police, jails, fire, water, medical, sanitation, vehicle fleet, central administration, and communications.

Program-level savings are the key. In some cases these may also be targeted geographically. For example, targeted energy efficiency programs have been used to defer or avoid high-cost transmission and distribution upgrades in New York City and in Vermont.

Maintenance of Interior Thermal Conditions and Energy Storage

A primary function of our built environments is to maintain safe, comfortable indoor temperatures. During times of extreme heat or cold, we depend on our buildings to provide livable conditions. Power outages often occur at times of such extremes. Ice storms and blizzards can cause widespread outages when outside temperatures are well below freezing—even below 0° F. Summer storms can knock down power lines and trigger outages in conjunction with hot, humid conditions. Heat waves themselves can lead to outages if peak demands exceed available generation resources, or if transmission lines are overloaded from high demand.

Very few homes, especially in urban areas, have backup heating systems capable of operating without grid electricity (gas furnaces have electric ignition and fans). For dangerously hot summertime conditions, there are essentially no backup systems to air conditioners other than such passive features as shading, natural ventilation, and high insulation levels.

Most of our buildings, including our homes, rely on electricity to operate heating and cooling systems. When outages occur, such systems will cease operating. As they do, inside temperatures become a function of the building envelope. Poorly insulated, drafty buildings will quickly lose heat in cold conditions—or gain heat in hot conditions. Well-insulated, tightly sealed buildings can maintain existing temperatures for long periods. This well-known design principle is exemplified in passive homes and super-insulated homes that may not even require an active central heating system in cold climates. For example, the Rocky Mountain Institute's original office and director's residence, located high in the Colorado mountains, can maintain warm, comfortable indoor temperatures in the depths of winter with no active building heating system. Similarly, planners and developers in Brooklyn are researching and promoting passive houses in conjunction with sustainability plans (Gregormarch 2015)

Home performance programs specifically address improvements to building envelopes to reduce heat loss in winter and minimize heat gains in summer. Improving the thermal performance of building envelopes increases the capacity to cope with electric system outages during hot or cold weather. Health and safety benefits result from the ability of such buildings to avoid becoming too cold or too hot.

Research by the Urban Green Council (2014; also Leigh et al, 2014) examined the thermal responses of a set of typical building configurations to outages during both hot and cold weather. They modeled six representative building categories:

- Single-family house
- Row-house apartment
- Brick low-rise apartment
- Pre-2000 brick high-rise
- Post-2000 brick high-rise
- All-glass high-rise

This research found that during an extended winter outage, the temperature inside a typical single-family house would be 35° F after three days. A typical high-rise apartment would drop to 45° F after three days and continue dropping. By contrast, a high-performance single family home (well-insulated and sealed) would maintain an indoor temperature above 60°, and a high performance high-rise building would stay well above 50° for a week. In hot summer conditions, temperatures in a typical all-glass apartment building would jump to 90°, eventually rising above 100°. A high-performance glass high-rise would keep interior temperatures below 85° for a week.

A rapidly emerging home technology that also can increase resilience is home electrical storage. While being developed primarily to integrate with home renewable energy systems, such storage could provide emergency backup power to critical home systems.

In summary, high-performance residential buildings, whether single-family detached houses or multifamily structures, are better able to cope with power outages and maintain livable interior conditions for their residents. This should factor into planning for community resilience. Having a significant percentage of residential buildings that meet high-performance criteria would increase the ability of a community to withstand an extended power outage without adverse impacts on the health and safety of residents.

Implications for Community Resilience from Improved Thermal Performance of Residential Buildings

The key measures for single-family and multifamily residential energy efficiency programs relative to resilience are:

- Retrofitting existing buildings to achieve high performance of building envelopes
- Promoting construction of new buildings that achieve performance above existing building codes

An important metric for community planners and energy efficiency program administrators is the number of existing buildings that are retrofitted and the percentage of them that are high performance. The more buildings that are high performance, the higher the resilience. Market-based single-family home performance programs with some rebates have had difficulty attracting program participants for a variety of reasons. Low participation rates mean that a small percentage of residences are high performance. As a result, communities striving to increase resilience may want to direct additional resources to home programs to increase participation and reach a greater share of the market.

Multifamily buildings constitute a significant share of residential markets in many areas. Programs serving these buildings and households face a variety of barriers that result in this market being underserved. Communities seeking to improve resilience should ensure that there are robust, well-funded programs able to serve this market. Such programs are expanding nationally, and many good examples are available (Johnson 2013).

Addressing existing buildings is clearly a top priority for improving resilience. It is also important that all new residential buildings—both single-family houses and multifamily buildings—are built to high performance standards. Communities should ensure that the highest applicable building codes are in effect to address the energy efficiency of new construction both for residential and commercial buildings. There should also be programs that promote and reward the performance of buildings beyond code. This helps drive superior performance and innovation in building design and construction. The earlier example of promoting passive homes in Brooklyn is one such model.

Conclusions and Recommendations

Resilience has not been adequately valued and considered as a benefit of utility energy efficiency programs. Most of the effort to improve the resilience of communities relative to electric system outages is directed to developing system capabilities to detect, respond to, and repair electric networks quickly in order to restore electric service to customers. Less emphasis is placed on improving system reliability by reducing system load through cost-effective energy efficiency.

Experience during the California electricity crisis of 2001 shows the ability of energy efficiency programs to yield significant reliability impacts. Reducing system demand can increase reserve margins, especially at times of peak demand when electric power systems are under the greatest stress.

When outages do occur, homes that are highly energy efficient can best maintain comfortable, even livable indoor temperatures, whether in cold winter or hot summer conditions.

Community planners and utilities can work together to increase the role and value of energy efficiency programs in increasing community resilience. Those programs and measures within programs that provide high levels of peak demand reduction relative to energy savings can be prioritized within program portfolios and associated budgets. Giving more emphasis to such programs can improve the reliability of the electric power systems that serve communities.

Energy efficiency programs that improve thermal performance of individual homes and buildings also should be prioritized to increase their ability to maintain healthy, livable indoor temperatures in the event of winter or summer outages. Home performance programs, building codes, and new construction programs can address these elements of performance and should be integral to community resilience planning.

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