Enhancing Community Resilience through Energy Efficiency

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Contents

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ACEEE is solely responsible for the content of this report.

Executive Summary

Cities and municipalities across the United States face a growing number of threats to their residents and economies. The specific threats vary depending on the local context, but may include aging infrastructure, extreme weather, and economic volatility. Many municipalities lack the resources to prepare for and respond effectively to these threats. US energy systems are particularly vulnerable due to their interactions with other systems that allow communities to function and thrive, such as transportation, housing, and business activity. A resilience perspective requires looking outside the traditional definition of the energy system to consider its interactions with other systems, including water, air, health, and the broader economic system. Energy efficiency can support community resilience by strengthening local energy systems and delivering more-reliable and affordable energy for local governments, households, and businesses.

Risk and Resilience

The level of risk to a community is a function of the hazards it faces, its vulnerability to the damaging effects of those hazards, and its capacity to cope with those effects. For our purposes we define risk with a formula that relates it to each of these components.[1]

$$\text{Risk} = \frac{\text{Hazards x Vulnerability}}{\text{Capacity to cope}}$$

We define community resilience as a community's reduction of and preparation for risk. Resilience can result from low vulnerability to hazards, high capacity to cope with hazards, or both. Resilience generally focuses more on vulnerability and capacity to cope than hazards themselves because those are the elements of risk over which the community can exercise the most control.

Resilience is not a result or static state, because communities cannot eliminate all risk. Rather, increasing resilience is a continuous process of evaluating risk and proactively taking steps to mitigate the impacts of disruptions before, during, and after their occurrence. Improved resilience means that a community is better prepared to minimize disruptions and respond to those that occur, not that it is perfectly prepared to neutralize all risks. The aim is for communities not only to survive disruptions but to emerge with increased adaptation skills and strategies afterward.

Energy Efficiency's Role in Increasing Resilience

As shown in table ES1, the myriad benefits of energy efficiency can make it an effective strategy for improving the resilience of community systems. We disaggregate those benefits here, but energy efficiency's potential effectiveness as a resilience tool is best recognized

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[1] Inter-Agency Task Force on Climate Change and Disaster Risk Reduction, "Disaster Risk Reduction Tools and Methods for Climate Change Adaptation" (Geneva: United Nations Office for Disaster Risk Reduction, undated) http://www.unisdr.org/files/5654_DRRtoolsCCAUNFCC.pdf.

when we consider them as a cohesive set. Together, they help reduce vulnerabilities to hazards while increasing communities' capacity to cope.

Table ES1. Resilience benefits of energy efficiency

Benefit type	Energy efficiency outcome	Resilience benefit
Emergency response and recovery	Reduced electric demand	Increased reliability during times of stress on electric system and increased ability to respond to system emergencies
	Backup power supply from combined heat and power (CHP) and microgrids	Ability to maintain energy supply during emergency or disruption
	Efficient buildings that maintain temperatures	Residents can shelter in place as long as buildings' structural integrity is maintained.
	Multiple modes of transportation and efficient vehicles	Several travel options that can be used during evacuations and disruptions
Social and economic	Local economic resources may stay in the community	Stronger local economy that is less susceptible to hazards and disruptions
	Reduced exposure to energy price volatility	Economy is better positioned to manage energy price increases, and households and businesses are better able to plan for future.
	Reduced spending on energy	Ability to spend income on other needs, increasing disposable income (especially important for low-income families)
	Improved indoor air quality and emission of fewer local pollutants	Fewer public health stressors
Climate mitigation and adaptation	Reduced greenhouse gas emissions from power sector	Mitigation of climate change
	Cost-effective efficiency investments	More leeway to maximize investment in resilient redundancy measures, including adaptation measures

When considering energy efficiency, there are many options and measures to draw from. Table ES2 details energy efficiency measures that reduce vulnerability and increase capacity to cope.

Table ES2. Energy efficiency measures that reduce vulnerability and increase capacity to cope

Energy efficiency measure	Resilience implications
CHP	Provides backup power, allows facilities receiving backup power to double as shelter for displaced residents, reduces overall net emissions, and potentially increases cost savings
Microgrids	May disconnect from grid during power outage, maintaining power supply; allows facilities receiving backup power to double as shelter for displaced residents; reduces overall net emissions; and potentially increases cost savings
Transportation alternatives	Multiple transportation modes that can be used during evacuations and everyday disruptions
District energy systems	Provides heating, cooling, and electricity using local energy sources and reduces peak power demand through thermal energy storage
Utility energy efficiency programs	Increases reliability and reduces utility costs
Energy-efficient buildings	Allows residents/tenants to shelter in place longer, reduces annual energy spending, and reduces overall net emissions. Can help vulnerable populations avoid dangerous and occasionally life-threatening situations in which weather and economics present a dual threat
Green infrastructure	Reduces localized flooding due to storms, reduces energy demand, and reduces urban heat island (UHI) effect in cities and electricity demand
Cool roofs and surfaces	Reduces UHI effect and electricity demand and reduces overall net emissions
Transit-oriented development	Increases economic development opportunities; provides transportation cost savings and reduces impacts of price volatility; and may improve air quality

The case studies in Appendix A show that energy efficiency has already proven its value in unanticipated events. After Hurricane Sandy hit the Northeast, CHP ensured that a critical water pollution control facility in New Jersey stayed online. This prevented untreated sewage from polluting local waterways, which would have had implications for public health. Looking forward, the Brooklyn/Queens Demand Management Program will increase the reliability of the electric system and reduce costs for Con Edison ratepayer initiatives. Other efficiency measures discussed in case studies, including transit-oriented development and energy-efficient buildings, also have implications for community resilience.

Despite growing interest in local resilience, local governments have not coalesced around a specific resilience planning process. Most resilience efforts also do not recognize the value of energy efficiency fully, if at all. The renewed attention to local resilience planning provides a significant opportunity to improve energy efficiency's integration into such plans and their implementation.

In our discussion of resilience planning, we indicate the role that energy efficiency typically has or has not played in various planning processes, including locally developed resilience plans, energy assurance plans, and hazard mitigation plans. By indicating the potential for energy efficiency to be included in resilience planning, this guide gives local governments a variety of customizable pathways toward resilience.

CONCLUSIONS

When we define resilience as a community's reduction of and better preparation for risk and separate resilience into its component parts, the value of energy efficiency as a resilience strategy becomes clear. It offers various benefits for emergency response and recovery and climate change adaptation and mitigation, as well as social and economic benefits. Although it appears that most cities and municipalities have not tapped energy efficiency as a resilience resource, the opportunity for including energy efficiency measures in resilience planning processes is significant. Energy efficiency is a clear pathway toward making communities and their residents stronger, safer, and more resilient.

As this is the first research effort to explore the broad connection between energy efficiency and resilience, it not only answers questions but raises them as well. The following are some areas we may explore in the future:

- *Water–energy nexus*. How do initiatives that save both water and energy increase community resilience, and what specific initiatives best achieve this goal?
- *Energy efficiency measures*. What synergies exist between energy efficiency and renewable energy, particularly distributed solar energy, and how could the strategic deployment of both help maximize resilience in communities? Also, are there other case studies of specific energy efficiency measures pursued for resilience purposes that could be valuable for cities looking for implementation examples from peers?
- *Resilience planning*. What are the optimal routes to include energy efficiency in resilience planning mechanisms? Technical assistance on methods to incorporate efficiency into communities' planning processes would be valuable.
- *Indicators*. What are some broad, holistic measures to quantify energy efficiency's impact on resilience?

Introduction

Cities and municipalities across the United States face a growing number of threats to their residents and economies. The specific threats vary depending on the local context, but may include aging infrastructure, extreme weather, and economic volatility. Many municipalities lack the resources to prepare for and respond effectively to these threats. US energy systems are particularly vulnerable due to their interactions with other systems that allow communities to function and thrive, such as transportation, housing, and business activity. Energy efficiency can support community resilience by strengthening local energy systems and delivering more-reliable and affordable energy for local governments, households, and businesses.

Hurricane Katrina's impacts on the Gulf Coast and Hurricane Sandy's impacts on northeastern states brought community resilience to local policymakers' attention throughout the country. But beyond bringing the issue to the forefront and serving as vivid examples of the dangers of extreme weather, they showed that community stresses and unanticipated events impact the various systems that allow communities to flourish. For example, local economies are damaged when businesses do not reopen, hurting the bottom lines of households that rely on the income from these jobs. Social circumstances can also exacerbate the impacts of severe storms or other events on certain communities, especially low-income communities, which are typically most impacted by disruptions.

Energy efficiency can be a core strategy to reduce risks and enhance the resilience of the communities that energy systems serve. Energy efficiency can reduce vulnerability to hazards, including extreme weather and climate change, and increase community capacity to cope with stresses by providing public health, safety, equity, and quality of life benefits.

The connection between resilience and energy efficiency has not been broadly acknowledged, but this report seeks to address that research gap. The case studies in the appendix also explore specific energy efficiency strategies that communities and utilities have used or will use in the future to increase resilience. This report is not the final assessment of how energy efficiency increases resilience. Rather, it is a foundation that will serve as a springboard for additional research and stakeholder outreach.

Risk and Resilience

Risk has long been a concept and an important basis for decisions in finance and management. In recent years, risk has also come to the forefront of analysis and public policy decision making for countries, states, and communities. This development is due in part to improved data, analysis, and outreach, which allow for deeper understanding of the complex interactions of community systems. Cities and municipalities are coming to a better understanding of the hazards and vulnerabilities they face, as well as their increasing magnitude.

The scale of risk to a community is a function of the hazards it faces, its vulnerability to them, and its capacity to cope with their adverse impacts (CCDRR Inter-Agency Task Force, undated). For our purposes we define risk with a formula that relates it to each of these components.

$$\text{Risk} = \frac{\text{Hazards x Vulnerability}}{\text{Capacity to cope}}$$

Source: CCDRR Inter-Agency Task Force, undated

This formula helps differentiate the components that make up risk and help us understand variations in how risk is structured and how it can be changed. The components of the formula are defined as follows:

- *Hazards*. Threats a community is facing. These can be natural (e.g., flooding, heat, fire), human-made (e.g., disruptions from human error or computer failures, or intentional disruptions), or some combination of the two.
- *Vulnerability*. The susceptibility of a community to the damaging effects of hazards.
- *Capacity to cope*. The ability of individuals or a community to respond to or bounce back from impacts in a way that decreases the negative consequence to households, businesses, or communities.

A hurricane is often used as an example of a hazard. A community's vulnerability to a hurricane would include factors such as the likelihood that it leads to loss of life and property and whether local industries see their revenues decrease in the wake of the storm. A community's capacity to cope would be determined by several factors, including the capability to evacuate impacted areas, insurance reimbursements for houses destroyed, family savings to pay for alternative shelter, and neighbors who could provide shelter or money to affected families.

The formula also shows how risks can look different in various communities. For example, high risk can result from a high level of hazards even if vulnerability is low and capacity to cope is high. An example of this might be coastal California, where the frequent occurrence of earthquakes presents a considerable risk even with seismic provisions in building codes, emergency response plans, high levels of social services, and high average income in the most vulnerable areas. Alternatively, high risk can result from high vulnerability and low capacity to cope, even if the hazards present are relatively small. An example of this could be the Mississippi Delta. The region experiences chronic flooding from the Mississippi River, and many low-income residents in the area have inadequate capacity to cope with the impacts of flooding.

WHAT IS RESILIENCE?

We define community resilience as a community's reduction of and preparation for risk. Using the risk formula, we can conceptualize the various components of resilience and ways to increase it. Resilience can result from low vulnerability to hazards, high capacity to cope with hazards, or both. Improved resilience decreases risk because of actions to change these two components of the risk formula. Resilience generally focuses more on vulnerability and capacity to cope than hazards themselves because those are the elements of risk over which the community can exercise the most control. For example, a city may be able to plan and prepare for the impacts of a hurricane, but it cannot prevent a hurricane from affecting the city in the first place.[2]

Resilience is not a result or static state, because communities cannot eliminate all risk. Rather, increasing resilience is a continuous process of evaluating risk and proactively taking steps to mitigate the impacts of disruptions before, during, and after their occurrence. Improved resilience means that a community is better prepared to minimize disruptions and respond to those that occur, not that it is perfectly prepared to neutralize all risks. The aim is for communities to not only survive disruptions but emerge with increased adaptation skills and strategies afterward.

Although stakeholders have not coalesced around one multidisciplinary definition of resilience, most have similar approaches, focusing on readiness, responsiveness, and revitalization (Arup 2014; Island and Kresge 2015; Task Force 2014; ULI 2014). The largest difference among these approaches is the hazards covered within each approach's respective scope, with many focusing on the impacts from climate change. Our broad approach to resilience accounts for diverse hazards. Our definition of resilience accounts for emergency response and recovery, social and economic factors impacting residents' and businesses' coping capacities, and climate change concerns.

RISK AMPLIFIERS

Cities and municipalities face a number of hazards that are being further amplified by various factors. Climate change has been found to increase the magnitude of hazards already facing a community (DOD 2014). For example, more-extreme storms and higher storm surges can stress aging infrastructure and accelerate property damage. Those living in areas vulnerable to more extreme weather may have more difficulty getting insurance to cover their losses as insurance rates increase (Melillo, Richmond, and Yohe 2014). Hotter temperatures could amplify the urban heat island (UHI) effect in cities, leading to higher cooling needs during summer months and increased demand on energy systems.[3] As a result, climate risks and resilience are increasingly major issues of concern for communities. This includes both mitigation of carbon pollution and adaptation of social, environmental, and economic systems to new climate characteristics.

The potential impacts of climate change receive the most attention, but researchers and decision makers have identified other social, economic, and environmental factors that are risk amplifiers. For example, increasing urbanization may make it more difficult to keep up the pace of infrastructure upgrades, like expanded sanitation systems, to accommodate more residents, especially when systems are already aging (Rodin 2014). In the United States, urban areas accounted for 81% of the population in 2010, up from 79% in 2000 (Census 2012). Some communities also face risk due to nondiversified local economies.

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[2] An exception to this could be establishing a city policy to avoid siting new assets in places where hazards exist, thereby eliminating the danger.

[3] The UHI effect is a global phenomenon in which a predominance of dark, impermeable surfaces and concentrated human activity causes urban temperatures to be several degrees hotter than those in surrounding suburban and rural areas (Hewitt, Mackres, and Shickman 2014).

Communities that are overly reliant on one industry are more susceptible to economic downturns, as was the case with Detroit and the auto industry. Unequal income distribution, the concentration of poverty, dependence on foreign resources, shifting social relationships, and biodiversity loss can also amplify risk.

Risks and Resilience Strategies in the Energy Sector

Now that we have described resilience generally, what does it mean to focus on energy-related resilience in buildings, transportation, and industry? Approaching energy from a resilience perspective has implications for investment and decision making for the entire energy system, including procurement, generation, distribution, and end uses. A resilience perspective also requires looking outside the traditional definition of the energy system to consider its interactions with other systems, including water, air, health, and the broader economic system.

The interaction of these various systems during unanticipated disturbances can lead to cascading effects, wherein the failure of one system detrimentally impacts other systems. For example, water utilities need energy to source, treat, and transport drinking water to consumers. If a region experiences a widespread power outage and the water utility does not have a backup power source, the utility may not be able to provide water to residents who need it. In this way, a disturbance that started with the traditional energy system can lead to wider public health problems.

Energy systems face varied hazards, and energy efficiency can mitigate the impacts of some of them. Extreme heat events, which may increase in magnitude and frequency due to climate change, could increase peak electricity demand (DOE 2013). For example, electric systems may need to meet higher demand during heat waves to accommodate the high air-conditioning load from consumers. Weather events combined with an aging infrastructure could heighten the risk of power outages. The transportation system faces similar risks. Increasing intensity and frequency of flooding events may disrupt rail and barge transport of oil, petroleum products, and coal, causing supply shortages (DOE 2013). For example, after Hurricanes Gustav and Ike hit the Southeast in 2008, vehicle owners had to wait in long lines at gasoline stations and pay high prices to fill up their cars (Mufson 2008). The transportation system may also face domestic fuel supply shortages from supply-side disruptions abroad.

These risks also have social and economic impacts. For example, power outages may affect an entire city, but disproportionately affect those who cannot leave their homes, such as the elderly. In Chicago, hundreds died from heat-related factors during a 1995 heat wave; many of the dead were elderly residents who were hesitant to leave their homes (Klineberg 2002). Similarly, interruptions in public transit service could limit economic opportunity for those who depend on public transit to get to work. While these examples are meant to be illustrative, they are by no means a comprehensive assessment of potential hazards and the resulting impacts on communities. In fact, many risks are not even fully known or understood.

A combination of economic and environmental imperatives, market developments, and policy innovations is making resilient energy systems increasingly urgent, feasible, and economically beneficial for communities. Many policymakers recognize the need to integrate risk awareness into regulation (Binz et al. 2014). The improved economics of clean distributed energy and advanced energy-efficient technologies and strategies are making new energy solutions affordable and feasible (Clean Energy Group 2014). The global trend toward an urbanized future presents many new opportunities for reshaping energy use in the built environment (IEA 2013). The accelerating impacts of climate change, in large part a result of past energy practices that did not follow the resilience approach, add a time-sensitive global importance to these changes (Melillo, Richmond, and Yohe 2014; IPCC 2014). Additionally, increasing strain on water resources and more-frequent droughts mean that the myriad interactions between water systems and energy systems are more important than ever, and increasingly vulnerable (DOE 2014).

For the energy system, resilience means providing affordable energy services, minimizing disruption or volatility of those services, and providing them without adversely impacting other systems. While the first two pieces of this definition have long been the focus of efforts related to "energy assurance," the final piece has not. The new developments outlined above mean that the old understanding of energy assurance is no longer enough. A resilient energy system needs to go beyond hardening infrastructure to reduce vulnerability, and begin including measures to increase residents' and businesses' capacities to cope with stresses.

The Resilience Opportunity of Energy Efficiency

Energy efficiency can be an effective strategy for improving the resilience of community systems. In table 1, we organize energy efficiency's resilience-related benefits into three categories. First, energy efficiency benefits communities as they respond to and recover from emergencies and shocks, such as extreme storms, drought, and flooding. Second, energy efficiency has social and economic benefits that strengthen community systems, increasing households' and businesses' capacities to cope with unanticipated events. Third, energy efficiency can help communities mitigate as well as adapt to the impacts of climate change. We disaggregate energy efficiency's benefits in our discussion, but its potential effectiveness as a resilience tool is best recognized when considering these benefits as a cohesive set of gains that accrue to communities. Energy efficiency can be a particularly effective resilience strategy because these myriad co-benefits, when taken together, allow it to reduce vulnerabilities to hazards while simultaneously increasing communities' capacity to cope. We elaborate on these benefits in the following sections.

Table 1. Resilience benefits of energy efficiency

Benefit type	Energy efficiency outcome	Resilience benefit
Emergency response and recovery	Reduced electric demand	Increased reliability during times of stress on electric system and increased ability to respond to system emergencies
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EMERGENCY RESPONSE AND RECOVERY

A reliable energy supply is necessary for our way of life. For example, a reliable electricity supply powers the lights and appliances in our homes, computers and office equipment at our places of work, and phones and tablets when we are on the go. Interruptions to power supply are more than just a nuisance; they can be dangerous to human health and local economies. Power losses could mean that vulnerable populations have to endure heat waves without cooling systems or that local restaurants absorb financial losses from spoiled inventory. Energy efficiency reduces electricity demand, which is important during times of increased electricity use or stresses on the grid. Reduced demand and increased reliability can mean fewer and shorter outages and fewer adverse impacts on households and businesses.[4]

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[4] Reliability can be defined as the ability of the power system components to deliver electricity to all points of consumption, in the quantity and with the quality demanded by the customers. Reliability is often measured by outage indices, based on both the total length of each service interruption and the frequency of interruptions (Osborne and Kawann 2001).

However some grid outages are inevitable, especially during emergencies and large-scale weather disruptions like hurricanes and ice storms. When outages do occur, energy efficiency technologies like combined heat and power (CHP) and efficiency-enabling energy systems like microgrids can provide a much-needed backup supply (Chittum 2012; Bourgeois et al. 2013). This can be particularly important to critical facilities in communities, including hospitals and drinking water and wastewater treatment plants (as discussed in case study A).[5] Also, unlike traditional backup supplies, CHP and microgrids ideally operate continuously, not only during emergencies. In this way, energy efficiency technologies both serve as energy supply resources and are used to create redundancy in the energy system.

The public safety benefits of energy efficiency can also help communities withstand disruptions. For example, efficient buildings with robust building envelopes can improve the habitability of indoor environments during a multiday power outage (Leigh et al. 2014). Researchers from the Urban Green Council and Atelier Ten modeled six common New York City building types to evaluate how indoor temperature would be affected by a power outage in winter and summer, when use of heating and cooling systems is at its peak. In the winter, in all existing building types, indoor temperatures drop to the 40s (Fahrenheit) after one to three days, posing risks to health, particularly in vulnerable populations (Leigh et al. 2014). Buildings built to today's energy code standards fare better, remaining about 10°F warmer than older buildings. Buildings built to more rigorous standards fare even better than those built to minimum code. High-performance buildings relying on the best technology for insulation and air sealing were able to maintain a habitable temperature in the upper 50s during the entirety of a hypothetical weeklong power outage in the winter (figure 1). Interior space temperatures that remain below 50°F for an extended period can be a health threat (Leigh et al. 2014). Based on these models, only the high-performance buildings consistently maintain temperatures safely above that level throughout the weeklong outage scenario.

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[5] A common definition for "critical infrastructure" comes from the PATRIOT Act of 2001 § 1016(e). It refers to those assets, systems, and networks that, if incapacitated, would have a substantial negative impact on national or regional security, economic operations, or public health and safety.

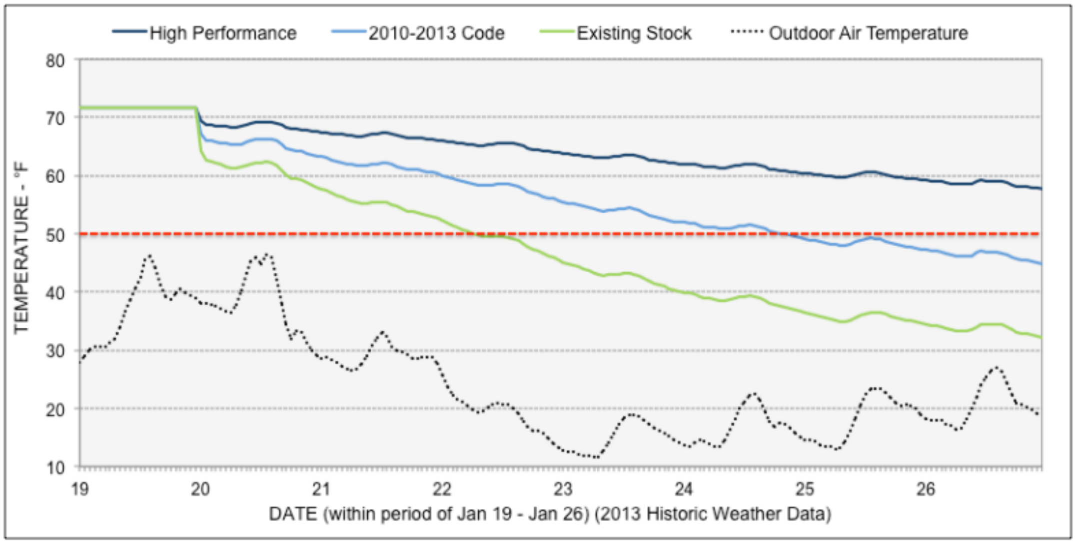

Figure 1. Temperature drift during weeklong outage in early high-rise masonry residence, existing and improved envelopes. ***Source:*** **Leigh et al. 2014.**

Communities that have integrated energy efficiency into their regional transportation systems are also better suited to respond to emergencies. Public transit is inherently energy efficient because it uses less energy than it would take to move the same number of people in private vehicles. Well-connected multimodal transit networks reduce the need to rely on single-occupant vehicles. This can be vital during emergencies that require residents to evacuate. During Hurricane Rita in 2005, Houston's primary transit provider coordinated bus transport for those without access to vehicles or those who chose not to use them. In all, 500 buses and 500 other vehicles transported 20,000 individuals in 4,500 trips (TRB 2008). On the other hand, 1 to 1.2 million residents evacuated by car from the New Orleans metro region in the aftermath of Hurricane Katrina. Seventy thousand residents, some of the most vulnerable, were left behind, partly because transit drivers did not report to work and transit equipment was inadequate (TRB 2008; HUD 2015).

Transit systems themselves, however, may fail or be vulnerable to hazards. For example, the New York City subway system was closed prior to Hurricane Sandy's arrival, and many of the system's tunnels flooded during the storm. Some jurisdictions are taking much-needed steps to ensure that transit systems stay online through emergencies. For example, New Jersey Transit has announced a plan to make a microgrid in its New York–New Jersey corridor to help keep trains running if the central grid goes out (NJ Transit 2014). However, when public transit is unavailable, cities must rely on vehicles. A prevalence of highly fuel-efficient vehicles can mean less strain on petroleum and diesel during times of constraint and fuel supply disruptions.

SOCIAL AND ECONOMIC

When considering the concept of resilience, some may focus on the response to and recovery from emergencies or disasters. However it is also important to recognize the underlying social and economic conditions that make communities more susceptible to emergencies and less able to cope with their impacts in the first place. These may include a weak local economy or the concentration of poverty, which can heighten vulnerability and make investing in resilience measures more difficult (Thomalla et al. 2006). By taking steps to address these conditions, communities improve their residents' capacity to cope with various disruptions, both those they can anticipate and those they cannot. Energy efficiency addresses these issues by improving the everyday resilience of households.

Energy efficiency enables communities to spend more income on needs that directly benefit the local economy, rather than on fuels derived from natural resources that are generally extracted elsewhere. Most communities and cities consume electricity imported from central power sources located outside their communities' boundaries. This is common due to the legacy of centralized power generation in the United States. Similarly, the oil and other resources manufactured into fuel and consumed by vehicles are generally drilled, mined, or collected from locations outside of communities' boundaries. As a result, the dollars spent on electricity and fuel imports represent a leakage from the local economy, while efficiency helps retain those dollars for local development. In general, households spend a large share of their income on goods and services that are procured from their local communities.[6] Therefore, residents who spend less on electricity and other energy imports can contribute more to the economic activity in their own communities. Energy efficiency efforts allow residents and businesses to export less of their money and keep it within the community, where it can help grow the local economy and invest in local businesses. A strong and diverse local economy may be less vulnerable to a variety of hazards and disruptions.

Energy efficiency increases overall productivity, which, broadly speaking, helps promote economic growth. By reducing energy intensity, efficiency makes individuals and businesses less dependent on energy and less vulnerable to the impacts of energy shortages and price volatility. When energy prices spike, more efficient economies are less susceptible to economic downturns than they otherwise would be. At the same time, by increasing overall productivity, energy efficiency helps create and maintain a healthy and prosperous economic environment that makes investment in resilience efforts possible.[7]

Energy prices, specifically gasoline, fuel oil, natural gas, and wholesale electricity prices, have historically been volatile, and customers continue to face economic risks from fuel price volatility (Harrison and Popke 2011). Energy efficiency works to reduce consumer vulnerability to volatility, allowing households and businesses to better plan for the future. For example, efficient vehicles that allow residents to fill up at the pump less often make it easier to cope with gasoline price increases. Previous research at ACEEE has demonstrated not only that energy efficiency is often less expensive than the energy it obviates, but that

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[6] See, for example, residential consumption pattern data and local purchase coefficients in regional economic modeling data available from IMPLAN (IMPLAN Group, LLC, IMPLAN System [data and software], 16740 Birkdale Commons Parkway, Suite 206, Huntersville, NC 28078; www.IMPLAN.com) or similar models.

[7] A case study detailing the economic benefits of a residential energy efficiency program in Babylon, New York, including local economic reinvestment and increased energy cost certainty, can be found here: http://www1.eere.energy.gov/wip/solutioncenter/pdfs/clean_energy_investment_cases.pdf

the cost of deploying efficiency tends to be much less volatile than energy prices. In this way, energy efficiency can provide a hedge against energy price increases due to market forces, supply disruptions, or regulatory changes, even if energy prices have been low for a number of years.[8]

Communities that embrace energy efficiency are more resource efficient. Energy efficiency leads to lower energy intensity, meaning that the natural resources used to generate energy are used more efficiently. This reduces a community's energy demand because fewer energy inputs (whether they be gallons of gasoline, short tons of coal, gallons of water, or cubic feet of natural gas) are needed to produce goods and services. Less spending on energy enables families in communities to spend income on other needs, simultaneously increasing disposable income and decreasing spending volatility. This is especially important for low-income families, who are most susceptible to the impacts of unanticipated events and whose energy burden (the ratio of energy spending to household income) is high. For example, an analysis of 2009 Residential Energy Consumption Survey (RECS) data demonstrates that the average household energy burden for households at or below 150% of the federal poverty guideline was 13.5%. The burden for households above 150% of the poverty guideline was 3.7% (J. Howat, senior policy analyst, National Consumer Law Center, pers. comm., July 13, 2015).[9]

Energy efficiency can also lead to public health improvements. For example, installing some energy efficiency measures in homes may improve indoor air quality. Properly sealing air ducts, installing weather stripping, and adding insulation are among the well-documented energy savings strategies for homes that can also yield considerable health benefits by mitigating asthma triggers and reducing thermal stress associated with lack of proper indoor temperatures, particularly for low-income households (Tonn, Rose, and Hawkins 2015; Morgan 2015). Meeting basic health, safety, and ventilation requirements is an integral part of the work done by quality contractors performing energy efficiency upgrades, which can also contribute to improvements in indoor air quality.[10] Lowering the amount of energy that communities waste also reduces the need to burn fossil fuels to generate electricity. As ACEEE's State and Utility Policy Reduction (SUPR) calculator shows, energy efficiency can reduce the emission of local pollutants like SO_X and NO_X.[11] These reductions can lead to improved health outcomes, given that pollutants from fossil fuel combustion contribute to

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[8] An example of this can be found in ACEEE analysis comparing the average cost of a therm of saved natural gas from utility efficiency programs implemented over eight recent years to the historical average US price of a therm of natural gas supply. More detail can be found in Mackres 2014.

[9] This analysis does not normalize by weather. Filtering the data by geographic area and heating fuel would provide results that vary considerably from this analysis of national data.

[10] The Building Performance Standard, a nationally recognized standard for energy efficiency and weatherization retrofit work, specifies minimum health, safety, and ventilation requirements that must be met for all jobs. More information can be found here: http://www.bpi.org/Web%20Download/BPI%20Standards/Building_Analyst_Professional_1_4_12.pdf.

[11] The SUPR calculator provides a rough estimate of the costs and benefits of policies and technologies that could help a state meet its air quality goals under the Clean Power Plan (Young and Hayes 2015). Users can select from a list of 19 different policies and technologies, including several energy efficiency policies. This tool calculates the impact that energy efficiency can have in reducing local air pollution, including NO_x and SO_2 emissions.

four of the leading causes of death in the United States: cancer, chronic respiratory disease, heart disease, and stroke (ACEEE and PSR, forthcoming).

CLIMATE CHANGE MITIGATION AND ADAPTATION

Climate strategies are generally categorized as either mitigation or adaptation strategies. Mitigation strategies focus on decreasing carbon pollution to decrease vulnerability to hazards amplified by climate change. Climate adaptation strategies are those that are primarily about increasing social, economic, or physical capacity to cope with the impacts resulting from climate change. In reality, however, many climate resilience strategies include aspects of both mitigation and adaptation, both vulnerability reduction and improvements in capacity to cope.

ACEEE analysis shows that energy efficiency can cost effectively reduce greenhouse gas emissions from the power sector (Hayes et al. 2014). If each state in the United States adopted four energy efficiency policies (implementing an energy efficiency savings target, enacting national model building codes, constructing CHP systems, and adopting efficiency standards for products and equipment), by 2030 carbon emissions from the power sector would decrease by 26% relative to 2012 emissions (Hayes et al. 2014). This would avoid 600 million tons of carbon dioxide emissions and eliminate the need for 494 power plants in 2030 (Hayes et al. 2014). It would also cost less than if each state conducted business as usual, since energy efficiency simultaneously meets electric demand and reduces pollution.

Some of energy efficiency's other climate resilience properties, such as an improved ability to respond to more-frequent weather events and the strengthening of community systems, have been discussed in previous sections. Communities may also be faced with redoing existing or building new infrastructure, because their aging infrastructure was not built to respond to the demands of a changing climate. In other situations, communities may need redundant systems to serve as backups for catastrophic infrastructure failures. However redundancy is not at odds with energy efficiency as a resilience strategy. Rather, communities that integrate efficiency into their resilience planning can maximize its cost effectiveness, particularly with respect to capital project planning for resilience. This allows communities more leeway to make any needed infrastructure and redundancy investments. Energy efficiency also helps defer the construction of unnecessary power plants and transmission and distribution infrastructure. This can help communities focus on those infrastructure investments they actually need to make.

The New York City Department of Environmental Protection (DEP)'s Water for the Future program shows the value of using resources efficiently. DEP is building a new tunnel to replace a leaking section of an aqueduct and will need to shut down the aqueduct as the new tunnel is connected, eliminating a source of drinking water. DEP plans to use a water conservation program as one of its strategies to reduce drinking water demand and maintain a continuous supply of drinking water during the shutdown (DEP 2015).

SYSTEM STRATEGIES

The risk formula discussed earlier shows the value of simultaneously reducing vulnerability and increasing capacity to cope to reduce overall community exposure to risk. Some resilience strategies are focused on reducing vulnerabilities to specific hazards (e.g., building a seawall to protect against storm surges). Others are focused on making communities more resilient in general and better able to respond to a variety of hazards (e.g., green infrastructure strategies that have benefits related to health and water quality in addition to mitigating storm surges). The strategies that take a more holistic approach to resilience can be considered "system strategies" because they impact various systems in cities, from energy to healthcare to social well-being. While hazard-specific strategies tend to focus on vulnerability reduction, system resilience strategies generally focus on increasing capacity to cope while reducing vulnerability. These latter strategies often have benefits beyond addressing specific hazards because they usually entail a variety of co-benefits beyond their primary benefit. Energy efficiency, with the various co-benefits outlined above, is a system strategy for increasing resilience.

As a result of these various co-benefits, system strategies often also have higher benefit–cost ratios than hazard-specific strategies (although accounting for their full benefits can often be challenging). For example, energy efficiency improvements in homes make communities more resilient in several ways: spending on efficiency creates more economic activity and jobs; buildings gain economic value, durability, and safety in case of disaster; energy savings from improvements mean fewer emissions of greenhouse gases and other pollutants, improving public health; and smaller and less volatile energy bills allow households to spend their money in more beneficial ways.

Energy Efficiency Measures and Their Resilience Benefits

Cities and municipalities can encourage increased energy efficiency throughout their local economies, including in energy and water utilities, transportation systems, and their own municipal operations (Ribeiro et al. 2015). While the previous section broadly discussed the resilience benefits of energy efficiency, this section details the resilience features of particular measures that reduce vulnerability to hazards and increase the capacity of communities to cope with hazards. We summarize these measures in table 2. This is merely a selection of measures rather than an exhaustive list.

Table 2. Energy efficiency measures that reduce vulnerability and increase capacity to cope

Energy efficiency measure	Resilience implications
CHP	Provides backup power, allows facilities receiving backup power to double as shelter for displaced residents, reduces overall net emissions, and potentially increases cost savings
Microgrids	May disconnect from grid during power outage, maintaining power supply; allows facilities receiving backup power to double as shelter for displaced residents; reduces overall net emissions; and potentially increases cost savings
Transportation alternatives	Multiple transportation modes that can be used during evacuations and everyday disruptions
District energy systems	Provides heating, cooling, and electricity using local energy sources and reduces peak power demand through thermal energy storage
Utility energy efficiency programs	Increases reliability and reduces utility costs

Energy efficiency measure	Resilience implications
Energy-efficient buildings	Allows residents/tenants to shelter in place longer, reduces annual energy spending, and reduces overall net emissions. Can help vulnerable populations avoid dangerous and occasionally life-threatening situations in which weather and economics present a dual threat
Green infrastructure	Reduces localized flooding due to storms, reduces energy demand, and reduces UHI effect in cities and electricity demand
Cool roofs and surfaces	Reduces UHI effect and electricity demand and reduces overall net emissions
Transit-oriented development	Increases economic development opportunities; provides transportation cost savings and reduces impacts of price volatility; and may improve air quality

COMBINED HEAT AND POWER (CHP)

CHP is a suite of efficient technologies that generate electricity and thermal energy in an integrated system. CHP is more energy efficient than separate generation of electricity and thermal energy because heat that is normally wasted in conventional power generation is recovered as useful fuel. The primary resilience benefit of CHP is its ability to serve power and thermal needs even when the grid is down. Its value has been proven time and again in the wake of extreme weather events. After Hurricane Sandy, CHP kept the heat and lights running in some multifamily buildings, kept Long Island's South Oaks Hospital in operation, and allowed for the continuous treatment of wastewater at some wastewater treatment plants (as is further discussed in case study A) (Chittum 2012). The ability to keep these vital services online after a disruption reduces vulnerability to the impacts of the disruption. Facilities with backup power can also double as places to house displaced residents from the community, leading to increased social resilience and capacity to cope.

Unlike traditional backup generators, which only operate during outage events, CHP systems typically operate continuously and can use a variety of fuels to efficiently serve local energy demands. Most CHP systems are fueled by natural gas, which can increase resilience because natural gas–fueled CHP can operate as long as pipelines are working, even during power outages (UGC 2013). Some CHP installations can use biomass or biogas, which can be equally reliable in times of disaster (Chittum 2012). In addition to providing emergency power, CHP systems can also save customers money and reduce overall net emissions (Gilleo et al. 2014).

MICROGRIDS

Microgrids are not inherently energy efficiency measures; rather, they enable the use of energy efficiency measures in a system by allowing a segment of buildings to supply their own energy needs. Microgrids are local power grids that connect selected buildings and facilities to distributed energy supplies, such as CHP, district heating and cooling, solar photovoltaic systems, and energy storage devices. The energy efficiency measures integrated into microgrids lower supply needs, reducing the demand on the microgrid and therefore reducing the amount of supply needed to power the microgrid overall. The more efficient the buildings and facilities connected to the microgrid are, the less supply is needed for the system.

Microgrids are generally connected to the larger electric grid, but they can also disconnect and supply customers even when the macrogrid is incapacitated (Bourgeois et al. 2013). This ability to maintain a reliable supply of power is the reason microgrids are an important resilience technology. As noted of CHP earlier, if microgrids supply critical infrastructure, such as hospitals treating the injured and police stations servicing officers that maintain public safety, they also increase communities' capacities to cope with disruptive events.

Microgrids also have several co-benefits that increase economic resilience. They reduce demand on the larger grid during times of stress, potentially allowing utilities to defer or avoid costly system upgrades (Bourgeois et al. 2013). Their intelligent management systems can also lead to cost savings by using microgrid-supplied power when it is abundant or when energy from the larger grid is more expensive. The same systems allow microgrids to participate in demand response programs and the ancillary services market to further reduce costs. Furthermore, because microgrids hedge against power outages, they may attract businesses that value an uninterrupted energy supply (Bourgeois et al. 2013).

TRANSPORTATION ALTERNATIVES

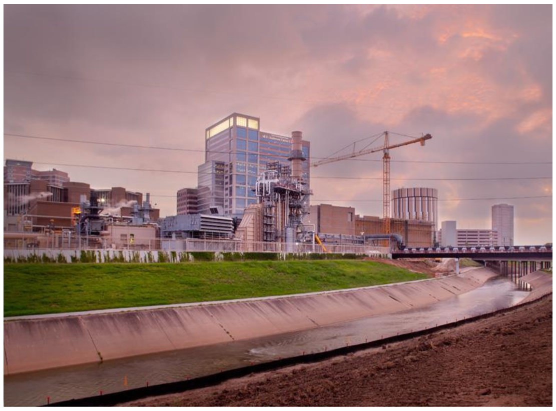
Cities and municipalities with multiple modes of transportation, such as public transit and shared-use mobility, provide their residents and commuters with options for getting around and leaving if need be. Well-connected public transit networks reduce residents' need to drive and therefore the number of vehicle miles traveled in metropolitan areas. These options can be important during emergencies that require residents to evacuate or during everyday life when one travel mode is disrupted. Earlier we covered the role these transit systems have played during natural disasters, but they have also proven effective during human-made emergencies. For example, after the World Trade Center attacks in 2001, New York City relied on public transit to move passengers out of Lower Manhattan and rush in employees and equipment to support emergency responders (TRB 2008). Furthermore, even if some of these modes fail or are inoperable during emergencies, high fuel economy vehicles can reduce strain on limited petroleum and diesel supplies.

DISTRICT ENERGY

District energy systems supply hot water or steam and chilled water to buildings for space heating, domestic hot water, air conditioning, and industrial-process energy. These systems pool thermal users to accommodate larger, more cost-effective CHP units. District cooling systems reduce dependence on the electric system by shifting power use from peak demand to off-peak through thermal energy storage systems, and by using waste heat to produce chilled water (through absorption or steam turbine chillers) instead of using grid power.

Beyond allowing for increased penetration of CHP, district energy systems also use other local fuel sources. For example, most of the buildings in downtown St. Paul, Minnesota, are heated and cooled using biomass, mostly tree trimmings and other urban waste wood (Saint Paul 2015). This community waste material is converted to supply heating, cooling, and electricity.

CHP at Texas Medical Center, Houston



The addition of a CHP unit to the district energy system at Texas Medical Center (TMC) has improved the resilience of the campus, which is the largest medical center in the world.

With the capacity to meet 100% of the campus's summer peak power requirements and still export excess power to the grid, the CHP system protects the campus from grid outages and relieves grid congestion in the state's Electric Reliability Council of Texas (ERCOT) region, which has recently experienced constraints, especially in the Houston area. By avoiding peak power prices and dispatching CHP generation based on real-time pricing, the system saves between $6 and $12 million annually (Clark 2015).

The Thermal Energy Corporation (TECO) added the CHP system in order to be able to meet expected growth in its operations, but also to improve efficiency, reduce emissions, and strengthen overall system reliability and emergency operating capacity, especially during natural disasters and other crises (EPA 2015b).

UTILITY ENERGY EFFICIENCY PROGRAMS AND STRATEGIES

As discussed earlier, energy efficiency plays a key role in the reliability of the electric grid. The energy utility sector is critical to energy efficiency efforts, as utilities deliver a large share of efficiency programs. In fact, electric and natural gas utilities invested over $7 billion in efficiency in 2013 through ratepayer-funded programs (Gilleo et al. 2014). Of all programs and measures, those that reduce demand have the highest value for increasing the reliability of the system.[12] This is because demand growth and reserve margin levels are the primary factors influencing reliability.[13] Demand reduction can occur in both

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[12] Electric demand is defined as the rate at which electric energy or natural gas is delivered to or by a system at a given instant or averaged over a designated period, expressed in kilowatts (kW) or megawatts (MW) (Duke 2004, 29).

[13] Reserve margin levels describe how much excess generation capacity a utility has to meet demand. Reserve margins are used to provide backup generation in the event that another generator is inoperable. North American Electric Reliability Corporation (NERC) recommends that utilities maintain 115% of projected peak

energy efficiency and demand response programs.[14] The difference between energy efficiency and demand response is that demand response typically shifts demand from peak to off-peak times, when the cost to produce electricity is lower, while energy efficiency can reduce demand but cannot shift it to another time of day.

Utilities have created energy efficiency programs to specifically address threats to reliability, and increasingly as locational or geo-targeted distributed resources (Kushler, Vine, and York 2002; Neme and Grevatt 2015). The programs most useful for increasing reliability are those that reduce system peaks, whether on the entire system or in specific locations that are particularly strained. The following are examples of reliability-focused programs offered by utilities:

- *Geographically targeted energy efficiency*. Reduces peak demand in a specific geographically targeted area using energy efficiency measures (see case study C for an example).
- *Direct load control programs*. Allow a utility to remotely control the operation and energy consumption of certain appliances (such as air conditioners) during peak hours (Fadlullah and Kato 2013). The utility and its customers agree upon direct load control programs in a contract.

Electric utilities can also use conservation voltage reduction (CVR) to reduce power demand, allowing the system to respond to high-demand scenarios. CVR involves measuring and analyzing voltages on distribution feeders to find ways to reduce voltages, while maintaining service at levels that allow equipment to operate without problems (York et al. 2015). Lower voltages can improve end-use equipment efficiency and reduce line losses for both the customer and the utility (York et al. 2015).

Utility programs that aim to increase reliability using energy efficiency help communities become more resilient. While this discussion has focused primarily on electrical reliability and resilience of the electrical grid, these concepts could also be applied to natural gas or water utilities. Reducing demand on the system has the potential to increase reliability as it alleviates the strain on the system. Increased reliability means that communities are at lower risk of outages that impact their citizens and economies. Implementing reliability-focused demand reduction programs is one way in which utilities play an important role in increasing community resilience.

ENERGY-EFFICIENT BUILDINGS

All modern buildings use energy to function, providing comfort to occupants and shelter from exterior conditions. Increasing the energy efficiency of buildings by significantly

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demand requirements to ensure a 15% reserve margin (Osborne and Kawann 2001). In a sense, capacity margins are system-redundant capabilities allowing a utility to maintain reliable service in the event of a disruption. Energy efficiency does not reduce the redundancy, but instead reduces the cost to maintain the reserve margin by reducing peak demand requirements.

[14] Demand response refers to programs or actions taken by retail customers to reduce demands during peak time in exchange for compensation.

improving building envelopes is a core strategy to increase a community's ability to mitigate and respond to economic risks, as well as climate risks. As discussed earlier, improving building envelopes through better insulation and air sealing can maintain more livable conditions for occupants when electricity from the grid is unavailable or unreliable. Buildings that allow residents to stay in their homes during power outages are of particular importance for housing-vulnerable populations that are more sensitive to temperature changes, including people with health conditions and the elderly. A building that is able to maintain comfortable indoor conditions can also reduce the need to relocate large numbers of people during an extreme weather event.

Periods of outage in the summer are also a concern for habitability, as temperatures can rise to unsafe conditions, particularly in south-facing spaces. During summer outages, high-performance buildings (both single-family and multifamily housing) offer big performance gains compared to existing buildings, as well as buildings built to current code (Leigh et al. 2014).[15] Using the Urban Green Council analysis described earlier, researchers found that a typical all-glass high-rise apartment or a single-family house would heat to almost 90°F on the first day of a blackout during a summer heat wave. However a high-performing brick high-rise building would keep temperatures below 85°F for a week (UGC 2014). Strategies such as external shading and improved window coatings, which are used in high-performance building efforts, are key measures in slowing indoor air temperature rise. Importantly, the impacts of extreme temperatures are often accompanied by price spikes for electricity (for cooling) and oil and gas (for heat). This compounds livability issues for low-income and other vulnerable households, as the cost of maintaining indoor air temperatures spikes just as the need for it increases. Increasing energy efficiency across the economy produces benefits for all consumers in the form of reduced prices (Baatz 2015), and efficiency targeted at vulnerable populations can help avoid dangerous and occasionally life-threatening situations in which weather and economics present a dual threat to those least able to deal with either.

Energy efficiency improvements in buildings also have other resilience benefits. Buildings with very low heating and cooling loads can lower annual energy use expenditures for households in both single-family and multifamily buildings. This can improve local economic resilience by increasing households' disposable income and their opportunities to contribute to the local economy. Efficient buildings also have increased economic value, durability, and safety in case of disaster, and the energy savings from improvements translate to fewer emissions of greenhouse gases and other pollutants, improving public health.

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[15] Improvement in indoor air temperature from the existing building stock to a building built to current code is modest because added insulation reduces the ability of the building to get rid of heat due to solar gain. A high-performance building lowers solar gain through external shading and improved window coatings, resulting in a slower indoor temperature rise.

GREEN INFRASTRUCTURE AND WATER EFFICIENCY

Green infrastructure refers to stormwater management measures that capture rain where it falls or cause it to run directly into the ground, reducing stormwater runoff into pipes in sewer systems. This can prevent combined sewer systems from being overwhelmed during storms due to increased stormwater and reduce the incidence of combined sewer overflows (CSOs) into nearby water bodies (CNT 2010).[16] Green infrastructure can also prevent localized flooding from rainstorms, making households less vulnerable to potential property damage and adverse public health effects that can result from floods, including sewer backups into homes and mold issues (Rowe and Bakacs 2012).[17] Common examples of green infrastructure include green roofs, rain gardens that capture stormwater runoff from impervious surfaces, permeable surfaces on sidewalks and roadways that allow rainwater to run directly into the ground, and rainwater harvesting systems such as rain barrels and cisterns.

Green infrastructure installations can also be energy efficiency measures. In combined sewer systems, they reduce the energy consumption required for water treatment by reducing the amount of stormwater that needs to be processed at treatment plants (CNT 2010). In urban areas, evaporative cooling from vegetated forms of green infrastructure can lead to cooler surface temperatures and reduced cooling demand (CNT 2010). They also provide better quality of life by improving the aesthetics in the community and reducing noise pollution levels (CNT 2010).

MEASURES TO MITIGATE THE URBAN HEAT ISLAND EFFECT

The UHI effect causes urban temperatures to be several degrees warmer than temperatures in surrounding suburban and rural locations. Cities have warmer surface temperatures because they have more dark, impermeable surfaces and more-concentrated human activities than surrounding jurisdictions. Urban heat islands have several impacts on public health, air quality, energy consumption, climate adaptation, quality of life, and stormwater management. For example, in cities with severe urban heat islands, more people may get sick or die during heat waves. By reducing urban heat islands, cities reduce their vulnerability to stress on the electric grid, especially during periods of particularly high temperatures. Cool roofs and surfaces can mitigate the UHI effect because they reflect solar energy. This means that they stay cooler themselves, release less heat into the air, and allow for nighttime cooling, and, in the process, reduce electricity demand for cooling. Darkly colored roofs store heat rather than reflecting it, which means that they transfer more stored

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[16] Combined sewer systems, typically found in communities in the Northeast and Midwest, collect stormwater runoff and sewage in the same pipes. These systems generally transport all their contents to wastewater treatment plants for processing. During storms or events producing high volumes of precipitation, the stormwater in the system can exceed the capacity of the sewer pipes. In these situations, combined sewer overflows (CSOs) containing untreated human waste and toxic materials flow into nearby water bodies (EPA 2015a).

[17] It is unlikely that green infrastructure could mitigate catastrophic flooding caused by hurricanes and other extreme storms, throughout a community.

heat into buildings during heat events, making residents more vulnerable (Hewitt, Mackres, and Shickman 2014).

Measures to mitigate the UHI also have other resilience benefits. For example, cool roofs can reduce the incidence of ozone and smog formation in cities, and cool pavements last longer than traditionally colored pavements due to decreased heat stresses (Hewitt, Mackres, and Shickman 2014).

TRANSIT-ORIENTED DEVELOPMENT

Transit-oriented development (TOD) is an approach to development and land use planning that involves mixing housing, retail, and other amenities in walkable areas within a half mile of public transit facilities or hubs (MPC 2015). By doing so, communities become more location efficient, thereby reducing their transportation-related energy use. Transit-oriented development encourages the use not only of transit but also of nonmotorized modes of transport. Typical TOD communities include road networks that are well connected and accommodate both bicycling and pedestrian activity. Parking management programs are also integral to creating these sustainable communities (VTPI 2014). ACEEE estimates that zoning for TOD could reduce fuel consumption by 10% nationally in 2045 when coupled with eliminating parking requirements and giving developers incentives to build around transit hubs (Vaidyanathan and Mackres 2012). Cities that focus on TOD can provide several resilience benefits for communities. TOD can help residents reduce their overall fuel consumption, withstand changes in economic conditions, and protect against fluctuating energy prices.

Transportation expenditures make up a significant proportion of spending for the average American household. According to the US Department of Transportation, transportation costs account for approximately 20% of household income, second only to housing costs at 32% (DOT 2015). For low-income communities, this proportion increases to almost 30% (Roberto 2008). Much of this cost results from the fact that Americans have relied on the automobile as a primary means of transport since the 1950s. Transit-oriented development helps households become more economically resilient by reducing the cost burden associated with driving on a daily basis. The Department of Transportation estimates that in the United States, living in a location-efficient environment with access to transit centers could reduce transportation costs to 9% of total income for the average American household. Meanwhile, in automobile-dependent suburbs, households spend 25% of their income on transportation costs (DOT 2015). Transit-oriented development can be especially beneficial for low-income communities, which generally have a reduced capacity to cope with disruptions. For example, analysis by the Center for Neighborhood Technology (CNT) indicated that extremely low-income California communities located within a quarter mile of transit may reduce their vehicle miles traveled by 50%, compared to those in non-TOD areas (CHPC and Transform 2015).

Properties located near transit generally hold their property values better than those not located near transit (CNT 2013a), which can add another layer of economic resilience to transit-oriented development. Transit systems can also remove barriers to social equity by providing better access to jobs, opening up portions of communities that were largely unavailable to those without cars (CNT 2013a).

An additional benefit of TOD may be the social relationships it produces. There is some research linking social capital to livable, walkable neighborhoods. Communities that are more walkable may have higher social capital, defined as the social networks and interactions that ensure trust and reciprocity among citizens (Leyden 2003). Residents in communities with higher social capital are more likely to know their neighbors and engage other community members. This is important because neighbors are often the first ones to respond to acute disruptions, even before public safety officials (Rodin 2014; Aldrich 2012).

Integrating Energy Efficiency into Resilience Planning

Local governments are taking steps to make their municipalities more resilient and ensure that their citizens and economies are prepared to handle an assortment of stresses, including severe weather and climate change. Despite the growing interest in local resilience, local governments have not coalesced around a specific resilience planning process.

Most resilience efforts do not recognize the value of energy efficiency fully, if at all. Some local resilience plans incorporate energy efficiency as a key strategy; others treat it as a secondary strategy to help achieve other resilience goals, and some exclude it. The renewed interest in local resilience planning provides a significant opportunity to improve energy efficiency’s integration into local resilience planning and implementation programs.

Below we describe several approaches taken by local governments, both large and small, in their resilience planning. This is not an exhaustive list, but highlights some of the processes local governments use to increase resilience. In our discussion of these, we indicate the role that energy efficiency typically has or has not played in these planning processes. By indicating the potential for energy efficiency to be included in resilience planning, this guide gives local governments a variety of customizable pathways toward resilience.

LOCAL GOVERNMENT-DRIVEN RESILIENCE PLANNING

Some cities, regions, and even individual neighborhoods are leading the way in resilience planning by creating and implementing local strategies that plan for hazards. This can include local or regional planning efforts that emphasize community resilience, or the development of resilient-specific plans. Coastal cities like Boston, San Francisco, and New York City are examples of cities that have initiated their own planning processes to become more resilient.

Boston’s Green Ribbon Commission Climate Preparedness Working Group partnered with several organizations to develop a set of best practices for resilience, viewed by the city as the ability to recover from or adjust to misfortune or change (Linnean Solutions et al. 2013). In its 2013 report, *Building Resilience in Boston*, the working group recommended using energy efficiency strategies as a way to increase resilience in Boston’s building stock, which is the oldest building stock of any major US city (Linnean Solutions et al. 2013). It sees building energy efficiency as a resilience strategy because the design and location of a majority of Boston’s residential buildings puts inhabitants at risk of the most common threats the city faces: flooding, severe storms, and extreme temperatures (Linnean Solutions et al. 2013). As noted earlier, energy efficiency measures in buildings reduce the amount of electricity needed for building operations, which can be especially important during emergency situations such as these (PTI 2011).

San Francisco has been at the forefront of resilience planning efforts for decades. The city's original planning efforts were precipitated by the 1989 Loma Prieta earthquake in Northern California and focused on earthquake response and recovery. Community resilience continues to be a priority for city leadership. For example, with support from the 100 Resilient Cities grant program, the city hired a chief resilience officer to develop and implement a resilience strategy.[18] San Francisco's leadership also worked with individual neighborhoods to develop localized resilience plans. For example, San Francisco's Bayview neighborhood and others in the Bay Area built on San Francisco's existing resilience initiatives and established Resilient Bayview, a group of local nonprofits, small businesses, faith-based organizations, residents, and city agency stakeholders. The group is working to create Bayview-specific resilience policies (Neighborhood Empowerment Network 2013). It is unclear whether the city is including energy efficiency measures in its planning, although energy concerns are a component of the *City Resilience Framework* used by the 100 Resilient Cities program (San Francisco 2015).

New York City released *A Stronger, More Resilient New York*, a resilience plan using lessons learned from Hurricane Sandy, in 2013. The report called for the city to expand existing energy efficiency programs, as well as work with the New York City Energy Efficiency Corporation (NYCEEC), the New York State Energy Research and Development Authority (NYSERDA), and private lenders to identify and finance energy efficiency projects in the city. The city's main goals for these programs are to save utility customers money, reduce carbon emissions, and reduce the likelihood of power outages, allowing longer habitability for residents in buildings during emergency situations when outages do occur (New York 2013). While the plan mentions energy efficiency, it does not appear to integrate energy efficiency as a core strategy throughout.

LEVERAGING FEDERAL PROGRAMS

Leveraging programs and models originating from the federal government, when they are available, can also help communities plan for increased resilience. One model encouraging a regional approach to local resilience planning was introduced by a federal effort, the Partnership for Sustainable Communities (PSC) between HUD, DOT, and EPA. As part of the PSC, HUD led the Sustainable Communities Initiative (SCI) grant program to give communities or regional authorities funding to develop local plans to promote vibrant neighborhoods and address regional issues. SCI recognized that cities are most resilient when they are able to grow stronger in light of the challenges they face, and when they consistently revise their goals and visions for the future. SCI created several principles in support of resilience planning, including the promotion of energy-efficient housing throughout the community (Bent et al. 2015).[19]

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[18] The 100 Resilient Cities grant program provides resources that allow cities to develop tailored resilience roadmaps. The program's goal is to help cities become more resilient to physical, social, and economic challenges.

[19] More information on the SCI principles can be found from the Institute for Sustainable Communities at http://betterplansbetterplaces.iscvt.org/.

Several communities and regions have successfully used the SCI model to incorporate energy efficiency into their resilience planning. Chittenden County, Vermont, included an energy goal in its ECOS Plan to improve the efficiency and reliability of the energy production, transmission, and distribution system (Chittenden County 2013). Similarly, the Pioneer Valley region of Massachusetts used the SCI model to create its regional sustainability compact. This regional agreement's "Climate Action and Clean Energy" section incorporates a goal to adopt energy efficiency improvements, including building insulation, fuel-efficient vehicles, and LED lights (PVPC 2014).

While the SCI grant program is no longer in effect, it continues to serve as a model for a comprehensive approach to resilience that incorporates energy efficiency. SCI sees its legacy as displaying a shift of federal priorities to increase focus on local initiatives. Locally driven policies like the ones SCI helped develop allow communities to use these newly established strategies to improve their social, physical, and economic health (Bent et al. 2015).[20]

The Rebuild by Design Initiative was another federally driven effort to increase community resilience. The Hurricane Sandy Rebuilding Task Force launched the initiative as a competition to, first, foster innovative resilience designs, and second, implement those designs in the portions of the northeastern United States that were damaged by the storm. In 2014, HUD announced awards of $930 million to seven winning ideas, whose first phases will be implemented in Connecticut, New Jersey, and New York over the next five years. Some of the accepted ideas incorporate elements of energy efficiency, but few include efficiency as a key tenet of their plans.[21] Using a model similar to that of Rebuild by Design, in 2014 HUD launched the $1 billion National Disaster Resilience Competition for states and communities that have recently experienced natural disasters.

ENERGY ASSURANCE PLANS

Energy assurance plans (EAPs) are strategies to prepare for and respond to events that impact the flow of energy.[22] However, by focusing solely on reducing vulnerability to power outages, these plans can overlook the importance and benefits of increasing community capacity to cope as part of increasing resilience. Although states have historically taken the lead in developing and implementing EAPs, cities are now creating their own plans, too. Local governments must engage and partner with stakeholders during the design and implementation stages to facilitate a successful plan. Public–private partnerships that include utilities, emergency management agencies, state governments, and citizen groups, as well as various other partners, provide the necessary resources for local EAPs (PTI 2011).

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[20] For reviews of the implementation process for SCI programs, please see the Institute for Sustainable Communities' *Better Plans for Better Places*, available at http://betterplansbetterplaces.iscvt.org/wp-content/uploads/2015/06/BetterPlans4BetterPlaces.pdf.

[21] For example, the Hunts Point Lifelines project calls for the use of CHP. More information on the winning proposals in the Rebuild by Design competition can be found here: http://www.rebuildbydesign.org/winners-and-finalists/.

[22] For more information on EAPs see Public Technology Institute's *Local Government Energy Assurance Guidelines*, available at https://dl.dropboxusercontent.com/u/14265518/leap/PTI_Energy_Guidelines.correx.v2.pdf.

EAP guidelines recognize energy efficiency as a key strategy for reducing reliance on supplied energy, helping to lower energy consumption and reducing the likelihood of an electrical outage. Energy efficiency measures in buildings, like LED lighting and efficient heating and air conditioning, reduce the amount of electricity buildings need to operate. This is important during emergency situations, as energy-efficient buildings require less backup power and can continue to operate longer during outages (PTI 2011). EAP guidelines note that energy efficiency is one of the most cost-effective strategies to create local energy assurance, as it reduces the capital costs for energy assurance investments while also decreasing ongoing operational costs by reducing demand for energy (PTI 2011).

Several cities — including Denver; Portland, Oregon; and Washington, DC — have created local EAPs. Washington's EAP, created in 2012, focuses heavily on energy efficiency as a strategy for resilience. The District of Columbia created several electricity energy efficiency programs, reduction goals for market-rate and low-income properties, and an energy efficiency education program in city schools to get students and their families to engage in more energy-efficient behavior. These programs aim to help the District reduce overall energy consumption by 1% each year and better position it to respond to energy emergencies (Paige et al. 2012).[23]

HAZARD MITIGATION PLANS

Hazard mitigation plans (HMPs) are long-term strategies developed by local governments to reduce the risks posed by disasters to citizens' health, safety, and welfare (FEMA 2011). They are intended to help cities transition from disaster-driven approaches to proactive mitigation approaches. Because local governments are required to develop these plans as a condition for receiving certain types of non-emergency disaster assistance, HMPs are widely developed throughout communities in the United States (Lyles, Berke, and Smith 2012).

The *Local Mitigation Planning Handbook*, released in 2013 by the Federal Emergency Management Agency (FEMA), assists local governments in developing HMPs (FEMA 2013). The handbook does not include guidelines for incorporating energy efficiency measures, but it states that creating a resilient community is a main goal of hazard mitigation planning. FEMA defines a resilient community as one that has the ability to adapt to changing conditions and prepare for, withstand, and rapidly recover from disruption (FEMA 2013). Energy efficiency measures should also be recognized in HMPs as measures to mitigate the adverse impact of hazards, but it is unclear whether FEMA considers energy efficiency measures allowable components of HMPs.

LOCAL GOVERNMENT–UTILITY PARTNERSHIPS AND UTILITY PLANNING

Local governments can work with energy utilities to increase cities' and municipalities' resilience by increasing levels of energy efficiency. As previously discussed, increased levels of energy efficiency in a community can increase electricity reliability and community resilience. Local government involvement in utility-sponsored efficiency programs can

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[23] More examples of local government energy assurance planning and best practices can be found here: http://www.energyassurance.us/best-practices.

range from very limited engagement, such as providing comments in an ongoing regulatory proceeding, to active partnerships in delivering programs. Below we highlight a few examples of how local governments can engage utilities in program design and implementation to increase penetration of energy efficiency.

Engagement in utility program planning. Local governments can submit written comments in ongoing utility proceedings related to energy efficiency program design and implementation. Written comments in such proceedings carry the benefit of drawing attention to community needs for specific programs. In some cases local governments can collaborate with utilities to develop energy plans for their communities. For example, communities within Xcel's service areas can leverage the Partners in Energy program to receive support in crafting local energy plans.

Promotion of utility energy efficiency programs. Community groups can help market utility energy efficiency programs in their neighborhoods in order to increase program participation. Local governments can engage utility efficiency marketing representatives to ensure that residents in the community have a proper education on program offerings. Proper education can boost customer participation rates and increase energy savings. For example, the City of Boston partners with its energy utilities through the Renew Boston program. Renew Boston promotes efficiency actions and connects Boston residents and small businesses with utility energy efficiency services.

Direct partnerships in delivering programs. Local governments can engage utilities directly to jointly deliver programs. In the past these have most often been low-income weatherization programs, but direct partnerships can also involve utilities working with cities to install measures in the municipal building stock.

Indicators for the Intersection of Efficiency and Resilience

Because the field of resilience indicators is still developing, communities may have difficulty determining the extent of their resilience. Indicators for tracking energy efficiency's role in resilience have yet to be explored. Policy indicators for energy efficiency–related resilience could relate to the adoption and implementation of the specific efficiency measures discussed earlier, including utility programs that target reliability and vulnerable customers, green stormwater infrastructure, and enforcement of building standards. Below, we discuss metrics communities can use that relate energy efficiency to various forms of resilience, including energy and economic resilience.

Reliability of electric system. As discussed earlier, reliability can be defined as the ability of the power system components to deliver electricity to all points of consumption, in the quantity and with the quality demanded by the customer. Reliability is often measured by outage indices, based on both the total length of each service interruption and the frequency of interruptions (Osborn and Kawann 2001).

Presence of utility programs that reduce system peak. Utility programs that reduce peak demand have the highest value for increasing the reliability of the system.

Percentage of critical facilities served by distributed energy and microgrids. Communities with a high penetration of microgrids and distributed energy, including CHP and district energy, are less vulnerable to the impacts of power disruptions.

Community-wide energy saving goal. Such a goal involves portfolio-wide reductions in the energy used throughout a city or municipality. Timetables and target dates allow a city to measure its progress toward increasing energy efficiency.

Volatility in energy costs. Volatile energy costs, especially costs for heating oil or propane, which can have localized impacts, can make it more difficult for families and businesses to plan for the future financially. This reduces community capacity to cope.

Access to public transit. Availability of transit is important to community resilience. CNT's Transit Connectivity Index measures the availability of transit service by estimating the number of rides available per week on transit located within walking distance of the average household.[24]

Energy-efficient stormwater management. Green infrastructure can be an energy-efficient way to prevent localized flooding and prevent combined sewer systems from being overwhelmed during rainstorms. The establishment of a green infrastructure program is a starting point. The reduction of peak flow into combined sewer systems' wastewater treatment plans during storms may serve as a proxy for the overall performance of green infrastructure.

Location quotients. Location quotients are indicators of how concentrated a particular industry is within a local economy. They can be used to determine which industries in a local economy define the economic identity of the area. Communities that depend too heavily on one particular industry may be more susceptible to economic downturns or have more difficulty managing increases in energy costs.

Conclusions

We define resilience as a community's reduction of and better preparation for risk. Using prior thinking around risk, we can disaggregate the components of risk, and hence resilience, into hazards, vulnerability, and capacity to cope. This conceptual framework provides a systematic way to think through the ways in which energy efficiency can reduce communities' exposure to risk and increase resilience.

Energy efficiency offers various benefits for emergency response and recovery and climate change adaptation and mitigation, as well as social and economic benefits. For example, it can reduce demand and strain on the energy system, provide backup energy supplies, reduce exposure to energy cost volatility, and provide public health, safety, equity, and quality of life benefits. Taken together, these benefits make energy efficiency a core

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[24] The Transit Connectivity Index of a community can be found in the H+T Affordability Index, available at http://htaindex.cnt.org/map/.

resilience strategy, reducing a community's vulnerability to an array of hazards and increasing its capacity to cope.

The case studies in the appendix show that energy efficiency has already proven its value in unanticipated events. After Hurricane Sandy hit the Northeast, CHP ensured that a critical water pollution control facility in New Jersey stayed online. In the process, this prevented untreated sewage from polluting local waterways, which would have had implications for public health. Looking forward, the Brooklyn/Queens Demand Management Program will increase the reliability of the electrical system and reduce costs for Con Edison ratepayers.

Other efficiency measures discussed in the case studies, including transit-oriented development and energy-efficient buildings, also have implications for community resilience. Transit-oriented development in Chicago will lead to numerous resilience-related benefits, including the availability of multiple travel options, reduced exposure to major fluctuations in oil prices, and lower costs associated with less everyday driving. The case study on the Passive Housing Standard for buildings details its ability to maintain a habitable indoor environment during power outages and reduce household spending on utility bills.

Although it appears that cities and municipalities have largely not tapped energy efficiency as a resilience resource, the opportunity for including energy efficiency measures in resilience planning processes is significant. Energy efficiency is a clear pathway toward making communities and their residents stronger, safer, and more resilient.

FUTURE RESEARCH AND STAKEHOLDER OUTREACH

As this is the first report to explore the broad connection between energy efficiency and resilience, this research not only answers questions but also raises new ones. The following are areas we may explore in the future.

Water–energy nexus. In several instances, we acknowledged interactions between the energy system and water systems. For example, we discussed green infrastructure and its potential for resilience and energy efficiency. However we did not deeply explore the water–energy nexus and its implications for community resilience. Future research could explore not only how initiatives to save both water and energy could increase community resilience, but also what specific initiatives best achieve this goal.

Energy efficiency measures. We provide a list of energy efficiency measures and their resilience benefits in this report. We largely do not explore the potential for energy efficiency to leverage other energy technologies to increase community resilience. One potential area of investigation would be research on synergies between energy efficiency and renewable energy, particularly distributed solar energy, to identify how strategic deployment of both could help maximize resilience in communities. More case studies discussing specific measures could also be valuable for cities looking for implementation examples from their peers.

Resilience planning. As stated earlier, communities have not adopted a standard approach or planning methodology to plan for resilience. Future research could potentially take a deeper dive into the optimal routes for including energy efficiency in these planning mechanisms, rather than mostly acknowledging whether past uses of these mechanisms have recognized the value of efficiency. For example, it would be useful to research best practices and develop case studies for how cities and state governments can best coordinate, so that states can support the resilience planning activities of their communities. Technical assistance on methods to incorporate efficiency into community planning processes, and on how to use those experiences to formulate best practices applicable to other communities, would be valuable.

Indicators. We present several potential indicators regarding the role energy efficiency can play in resilience. However these indicators are generally measure specific. The development of more-holistic measures of energy efficiency's impact on resilience would be a valuable step. For example, it would be useful to be able to quantify the risk a community can avoid per dollar it invests in energy efficiency.

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Appendix A. Case Studies

This report focused on making the connection between community resilience and energy efficiency. To do so, the report articulated energy efficiency's resilience benefits, discussed specific energy measures that reduce vulnerability to hazards and increase capacity to cope, and provided examples of local implementation of the strategies discussed. The case studies that follow provide more detail on specific instances in which local governments and utilities have leveraged or plan to leverage energy efficiency to increase resilience.

CASE STUDY A. WATER UTILITY USES CHP TO SAFELY PROCESS SEWAGE DURING OUTAGE

Overview

The continued operation of critical facilities, such as hospitals, police stations, water and wastewater treatment plants, and other public facilities, plays an important role in a community's ability to keep residents safe during an electric grid outage. A large power outage occurred in October 2012 when flooding and storm damage from Hurricane Sandy cut power to 8.2 million people in 20 states (Mansfield and Linzey 2013). Certain places proved more resilient than others, and some were able to continue operations using CHP systems to maintain power, heat, and critical equipment (ICF 2013; Chittum 2012). One such facility, the Little Ferry Water Pollution Control Facility (WPCF) in Little Ferry, New Jersey, used backup generators and its biogas-powered CHP system to safely process all the sewage from its 47 municipalities during and after Sandy.

President Obama's Hurricane Sandy Rebuilding Task Force described the facility, operated by the Bergen County Utilities Authority (BCUA), as a model for the region and the nation because of its ability to use CHP to keep its sewage treatment facilities working during and after the storm in the face of a prolonged power outage (NJBPU and NJEDA 2014). Incorporating CHP into state and local resilience planning efforts can help protect communities in the face of extreme weather events or other human-made disasters and outages.

Details of the Project

The 2.8 MW CHP plant at BCUA was placed into service in May 2008 and uses two biogas-fueled reciprocating engine generator sets and a heat recovery boiler (figure A1). The system generates electricity that is consumed onsite to power the WPCF and to produce hot water, which is used to preheat the anaerobic sludge digester process and to heat the building in winter. The system meets 80% of the average electrical needs of the WPCF and operates in parallel with the Public Service Electric and Gas Company (PSE&G) electrical distribution system (BCUA 2015).

Figure A1. Cogeneration facility at BCUA's Little Ferry Water Pollution Control Facility. *Source:* BCUA 2015.

After PSE&G service went down during Hurricane Sandy, the facility's kerosene-powered emergency generators helped keep the system running, and the plant operated seamlessly for 24 hours without PSE&G (ICF 2013).[25] While other cities told residents to reduce water consumption as water treatment plants failed and raw sewage entered local watersheds for days, the 550,000 customers served by the BCUA system were able to safely use water as usual (Schwirtz 2012; Chittum 2012).

Impact on Resilience

Wastewater treatment facilities are critical for maintaining public sanitation and a healthy environment, and must be able to operate in the event of a natural or human-made disaster or a utility power outage (EPA 2015b). The BCUA facility was one of a small number of similar facilities that did not suffer failures during the storm. According to the state's Action Plan Amendment for disaster recovery, a majority of New Jersey's wastewater treatment facilities — 94 plants in its 21 counties — suffered a range of failures, ultimately causing more than 3 billion gallons of raw, untreated sewage to spill into local waterways. As a result, the state faces $2.6 billion in estimated needs, including emergency repair, recovery, mitigation, and resiliency (NJDCA 2014).

BCUA's WPCF and other facilities equipped with CHP to maintain operations improve the resilience of communities they serve by decreasing the impact of grid outages on public health and safety, the local economy, and the environment. Avoiding damage to homes and other property from flooding with sewage-contaminated water can help prevent injury and save households and business owners money, time, and distress.

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[25] Some CHP systems are equipped with black start capability, which allows systems to start up independently of the grid. According to ICF's report, BCUA plans to retire the existing backup power system, which currently operates separately from the CHP system, within the next 10 years and will then integrate black start capabilities.

BCUA's CHP system also provides significant benefits during normal operations, when grid service is fully functioning. The system improves the financial viability of BCUA by reducing the overall costs of operating the facility and reducing demand from the regional grid. According to BCUA, the system results in annual energy cost savings of more than $3 million, which has helped the utility save more than $10 million as of 2013. The CHP project also earned more than $40,000 in additional revenue by reducing demand through PJM Interconnection's Demand Response Program. Moreover, the CHP system reduces greenhouse gas emissions and provides air quality benefits to society as a whole. The system has also generated $100,000 in renewable energy credits (RECS) that contribute to New Jersey's Renewable Portfolio Standard (ICF 2013).

CASE STUDY B. TRANSIT-ORIENTED DEVELOPMENT (TOD) IN THE CHICAGO METRO REGION

Chicago is making some of the most significant strides toward fully incorporating transit into future development plans. The city has a long history of centering development on transit hubs. Since the late 1800s, much of Chicago has been constructed along the city's "L" passenger rail line, one of the primary modes of transportation among Chicago residents. The post–World War II focus on the personal automobile shifted development toward suburb-based construction (CNT 2013b), but in recent years the city has returned its attention to creating sustainable, mixed-use communities serviced by multiple modes of transportation.

Much of the city's focus on transit-oriented development has come about due to the following demographic changes. First of all, while transportation costs in Chicago's transit shed (the catchment area that generates ridership around transit nodes) are low compared to other suburban regions, they are still on the rise. TOD could reduce the continuing rise in transportation costs and could effectively be a way for people to find cheaper travel alternatives. Second, the rate of growth in the number of households was greater in the entire Chicago region than in Chicago's transit shed, which only serves to increase transportation costs. Finally, the growth of jobs within the transit shed has decreased in recent years, making it necessary for some residents to seek employment outside the transit shed, despite the longer and more expensive commute (CNT 2013b).

The concept of TOD was officially codified in the city of Chicago in 2013 with the introduction of the city's TOD ordinance. This ordinance specifies zoning regulations for developments between 600 and 1,200 feet away from Chicago Transit Authority's L and Metra stations and also includes special incentives and dispensations for construction around key transit stops. These incentives include:

- Reductions in minimum parking requirements to as little as 50% of the otherwise applicable requirements
- Reductions in minimum lot area per unit to increase density of units
- Increases in floor area ratios (FAR)
- Increases in maximum building height for buildings with reduced commercial and noncommercial parking (Metropolitan Planning Council 2015).

The Chicago City Council is currently discussing an expansion to this ordinance that will extend its reach to developments within a quarter mile from transit stops and eliminate parking requirements altogether, in addition to increasing floor area ratios and maximum building height allowances if low-income unit requirements are met (K. Smith, manager of transit-oriented development, CNT, pers. comm., September 3, 2015).

These codified incentives serve to create dense communities around transit stops by reducing the cost of developing in these areas. For instance, lower parking requirements can mean substantial cost savings, given that the construction costs associated with one urban parking space can range from $2,000 to $22,000, depending on its type and location (VTPI 2011). Spaces in high-value urban markets can cost as much as $60,000 (EPA 2010). In Chicago, the cost of each of these high-value urban parking spots is approximately $37,000 once adjusted for inflation, and underground parking spots go through additional regulatory approvals that incur costs above and beyond the basic construction costs (K. Smith, manager of transit-oriented development, CNT, pers. comm., September 3, 2015). Reducing the minimum number of parking spaces required for housing and commercial developments saves developers money and helps to manage vehicle ownership at the same time.

In addition to the work occurring at the city level, the Regional Transportation Authority (RTA), which serves the greater Chicago area, has taken a number of steps to create an enabling environment for TOD. The RTA created a regional TOD working group in 2008 as a way to encourage communication and coordination between the numerous players and stakeholders involved in TOD. Through its Community Planning Program, the RTA also plays an integral role in helping communities update zoning codes to support TOD and improve the overall regulatory environment. Finally, through its Access to Transit Improvement Program, the RTA has accelerated several transit projects by bundling them together to meet congestion mitigation and air quality improvement requirements and goals.

Impact on Resilience

Chicago's policy and program investment around transit-oriented development will create a number of resilience-related benefits in the near future. Proximity to businesses such as drug and hardware stores can increase a community's capacity to cope with unexpected natural events. Having multiple travel options for a given trip supports resilience in the face of changing or severe weather patterns by reducing the likelihood and severity of disruption to both routine and emergency functions. Access to a variety of alternative transportation options that are more efficient than the personal automobile also lessens a community's dependence on oil and minimizes the impacts of major fluctuations in oil prices. Furthermore, TOD helps households achieve economic resilience by reducing the cost burden associated with driving every day. Finally, the Chicago area has seen growth in a number of smaller job centers outside of the downtown/Loop area that are not easily accessible by transit, effectively restricting employment to those who own personal vehicles (CNT 2013b). TOD improves connectivity between job centers and residential neighborhoods, improving the ability of all residents to easily access opportunities for employment.

CASE STUDY C. INCREASING RELIABILITY THROUGH THE BROOKLYN/QUEENS DEMAND MANAGEMENT PROGRAM

Overview

In December 2014, the New York Public Service Commission (NYPSC) approved Consolidated Edison of New York (Con Edison)'s Brooklyn/Queens Demand Management (BQDM) Program. The BQDM Program is a proposal to use demand-side solutions such as energy efficiency to meet growing electricity demand instead of undertaking a costly construction project to upgrade distribution infrastructure in the Brooklyn and Queens areas of New York (NYPSC 2014) (figure A2).

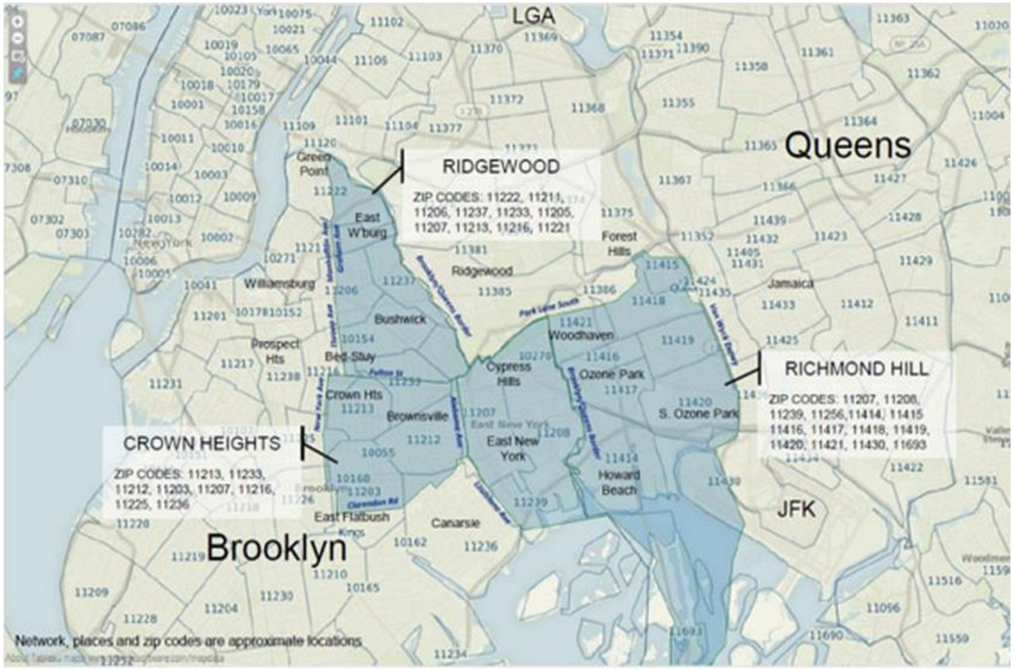

Figure A2. Brooklyn/Queens Demand Management Program area. *Source*: Con Edison 2014.

Con Edison expects the project to provide substantial cost savings. By relying on demand-side solutions instead of traditional utility infrastructure investments, Con Edison anticipates that its ratepayers will save approximately $800 million.

The BQDM project is part of a larger effort from Con Edison called the targeted demand side management program. This program will target specific neighborhoods for demand-side solutions to defer the need for expensive equipment upgrades (Con Edison 2015a). Targeting specific neighborhoods will maximize the efficiency of the limited resources available to Con Edison to reduce the cost of future electric service. It will also provide immediate benefits, including reduced pollution, economic development opportunities, and lower customer bills for program participants.

The NYPSC praised the initiative, stating, "By this Order, the Commission is making a significant step forward toward a regulatory paradigm where utilities incorporate alternatives to traditional infrastructure investment when considering how to meet their planning and reliability needs" (NYPSC 2014, 2). The initiative is also a first-of-its-kind project in New York, representing a utility's response with innovative demand-side solutions instead of traditional utility investment to address potential reliability concerns.

Details of Project

The BQDM project consists of three components to reduce demand by 69 MW by the summer of 2018. Traditional utility infrastructure investment will meet the first 17 MW, while a combination of utility-owned and customer-owned demand-side solutions will meet the remaining 52 MW. The demand-side projects will consist of energy efficiency, energy management, energy storage, customer engagement, distributed generation, and demand response. While the total number of MW to be met with customer-sited solutions is not yet fully known, Con Edison anticipated 41 MW at the time of the original filing in the summer of 2014 (Con Edison 2015b). The company has annual goals for the total amount of MW to reduce via demand-side solutions.

Con Edison's nontraditional solutions will meet approximately 11 MW of demand. These 11 MW will be met through the combination of an energy storage facility planned at the Brownsville substations 1 and 2 area, the development of microgrids at apartment complexes in the local area, and the deployment of voltage and reactive power optimization to effect a 2.25% reduction in voltage (resulting in a demand reduction of 2 MW) (NYPSC 2014, 6).

Con Edison also plans to use $25 million of already-approved funds to bolster existing energy efficiency programs. These programs include Small Business Direct Install and Multi-Family Energy Efficiency, as both of these programs were identified for their strong potential to produce early results. The Small Business Direct Install program was able to enlist more than 1,900 customers in under five months, between August 2014 and January 2015. The projected load reduction from these 1,900 customers is 5.9 MW. The Multi-Family Energy Efficiency program is also a direct-install program, focused on multifamily dwellings with 5 to 75 units. The projected load reduction from this program is 1 MW. Con Edison is also working with the New York State Energy Research and Development Authority (NYSERDA) and National Grid (the gas utility in the area) to increase the deployment of new CHP facilities and increase the efficiency of existing CHP installations.

Con Edison is also focusing on partnerships with local agencies to identify opportunities to reduce demand. Publicly administered housing buildings account for over 46 MW of demand in the target area for the BQDM project. This includes 60 complexes and over 29,000 housing units. Con Edison is currently reviewing specific measure opportunities for these dwellings to determine the best approach to implementing these programs with the New York City Housing Authority (NYCHA) (Con Edison 2015c).

The BQDM project is currently under way. As noted, Con Edison received approval from the NYPSC in late 2014. The company is now evaluating proposals to meet the customer-side portion of the demand reduction. The project will provide not only significant benefits for Con Edison customers, but also valuable insight to other states and utilities considering a similar approach.

Impact on Resilience

The BQDM project will provide the local community with multiple resilience benefits. First, the project increases electric reliability by reducing the demand on the existing system. The introduction of technologies such as conservation voltage reduction and energy storage, as well as increased funding for CHP projects, also increases electric reliability. These all increase electric reliability by reducing outages and shortening outage durations. Second, the project reduces electric costs for Con Edison ratepayers. Instead of investing over $1 billion in traditional utility infrastructure, the BQDM project will only cost ratepayers a projected $200 million. The cost savings are substantial and may provide the local community, especially low-income residents, with greater economic resilience from reduced electric bills, allowing them to save more money and increase their capacity to cope.

Increased funding for multifamily energy efficiency programs is also noteworthy because it will increase opportunities in the traditionally underserved multifamily housing segment. In addition, collaboration between Con Edison and NYCHA could potentially bring the social and economic benefits of energy efficiency to public housing, another traditionally underserved segment.

CASE STUDY D. USING PASSIVE HOUSE TO IMPROVE RESILIENCE

A number of stakeholders are recognizing high-performance building renovations as a key strategy to improve the habitability of buildings during periods of unreliable power. There are several ways that buildings can be renovated or designed to improve habitability in these situations. One of the building standards now used is Passive House, a standard for new buildings and renovation of existing buildings, developed and maintained by the Passive House Institute US and the Passive House Alliance US. The Passive House approach relies on minimizing home heating and cooling loads through passive measures such as insulation, building orientation, and passive solar gain and solar shading. Buildings that meet the performance requirements of the Passive House standard are expected to use 60–80% less energy than standard buildings (PHIUS 2015). These buildings are designed to require limited active space conditioning, thereby limiting energy use and maintaining indoor temperatures.

In New York City, a social services organization, the Hellenic American Neighborhood Action Committee (HANAC), is constructing a 68-unit senior housing development to Passive House building standards. The organization cites improvement of building habitability during blackouts as a key driver of its choice to build a high-performance building. The ability to keep senior citizens in their homes during a period with no power is important to the mission of the organization. HANAC expects to be able to maintain thermal control in the units for a period of at least five days (Gregor 2015).

Low-energy passive houses contribute to improved economic conditions as well. Interest in the Passive House standard for single-family buildings in the United States has been growing since the 1970s. More recently, the standard has been applied to affordable multifamily housing projects because the buildings offer dramatically lower operating costs for both tenants and building owners, high indoor air quality and comfort, and durable structures (PHIUS 2015). An affordable multifamily building was recently completed in Hillsboro, Oregon, providing homes for 57 households. Project developers estimated that this project cost an additional $20 per square foot for construction to Passive House standards over current code standards, representing about a 15% increase in construction costs. However the average annual utility cost per unit in this building is expected to be 20–30% of the average annual utility cost in a rented multifamily building unit (Lamar and Boetzel 2012; EIA 2011).

Washington, DC will soon be home to the mid-Atlantic region's first passive multifamily housing project. Passive to Positive, a passive housing consulting firm, and Zavos Architecture and Design collaborated to conduct a retrofit of the Weinberg Commons affordable multifamily housing community. The community consists of 3 buildings containing 37 two-bedroom units. The tenants who will occupy these units in the near future will be making 30–60% or less of the area median income (Passive to Positive 2015). The reduced energy costs will allow the tenants to considerably reduce the amount of their income that they spend on utility bills.

Reducing spending on utilities, particularly in affordable multifamily buildings, where households spend a higher percentage of their income on energy costs than single-family households, can keep more money in the local economy and improve economic resilience. Money spent on local goods and services is more likely to stay in the local economy than money spent on utilities (Stone 2011). Lower utility bills free up income that can be spent in the local economy on food, childcare, haircuts, and so on (Stone 2011). REACH Community Development, the nonprofit affordable housing development and management company responsible for the project in Hillsboro, Oregon, recognizes that low-energy buildings are an integral part of its mission to provide healthy, affordable spaces that help tenants build long-term financial success and stability.