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The Important Role of Energy Codes in Achieving Resilience

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INTRODUCTION

In mid-June 2017, the American southwest experienced stifling heat, breaking or tying numerous records for high temperatures (Masters 2017). Late-January 2019 saw a polar vortex entering midwest states, delivering "prolonged, life-threatening cold" (Pydynowski 2019). The 2017 Hurricane Season brought significant devastation along the Atlantic and Gulf coasts and islands in the Caribbean, leaving millions of people without power for extended periods of time.

These events and the growing frequency and intensity of disasters (NOAA 2019) in general point to the need to think and act differently. Enhancing community resilience has been identified as a key strategy for assuring communities are prepared for such events.

Building codes are an essential strategy in achieving resilience. Building codes provide minimum requirements to protect life-safety in the built environment—every day and particularly in the face of hazards. Energy codes are no exception. Code-based strategies to enhance community resilience must be coordinated across all building codes including energy, plumbing, mechanical, electrical and fire codes. While energy codes have primarily developed to enhance energy efficiency (a resilience goal in and of itself), they also are an important contributor to individual and community resilience in other ways. Figure 1 illustrates the contributions of energy codes to resilience. This paper examines the intersection of energy and resilience (here labeled the energy/resilience nexus) and the important role of energy codes in supporting community resilience. It is a supplement to the recent report *Building Community Resilience through Modern Model Building Codes* (ANCR and ICC 2018) and the second in a series of white papers on how various codes contribute to resilience (ICC 2019).

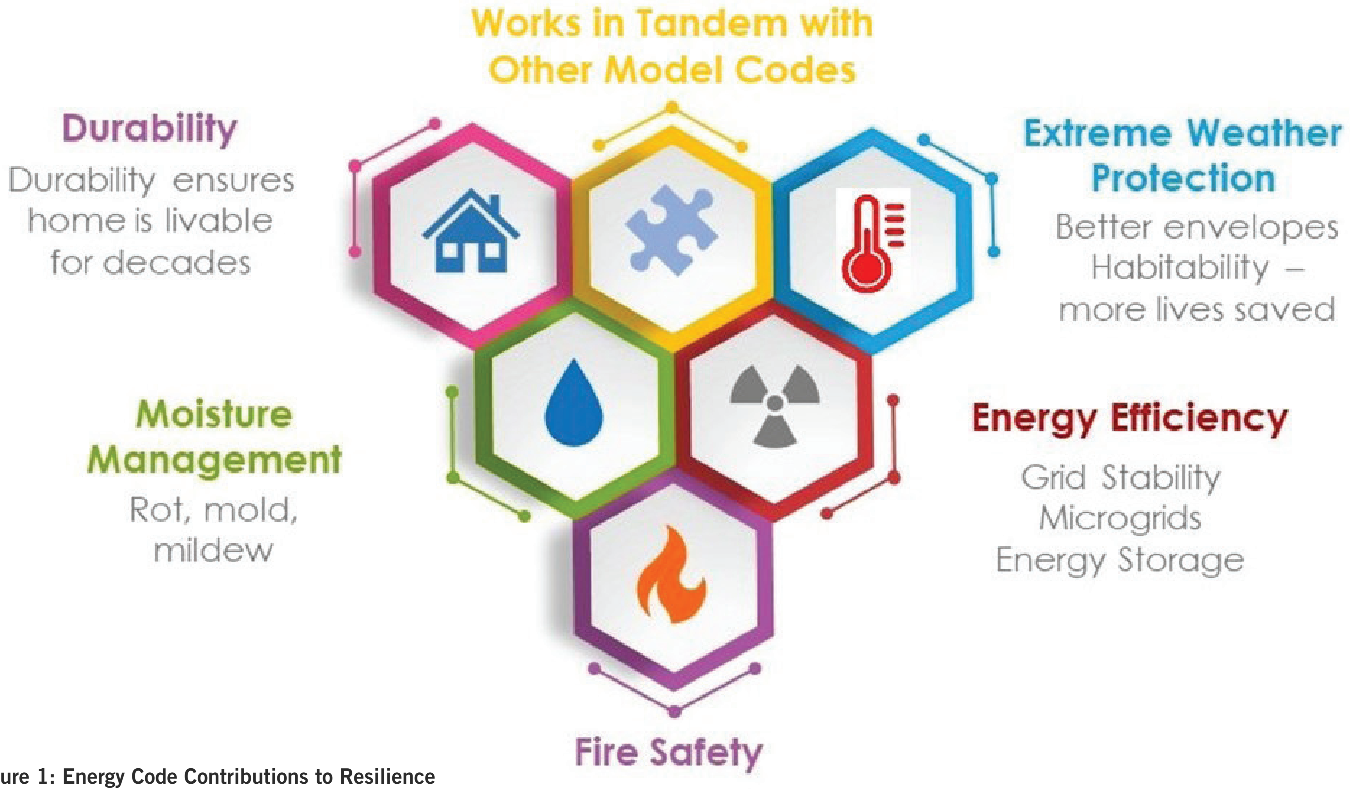


Figure 1: Energy Code Contributions to Resilience

DEFINING RESILIENCE

Nearly 50 organizations representing all aspects of the planning, design, construction, ownership, operations, management, regulation, and insurance of the built environment have signed on to an "Industry Statement on Resilience (AIA 2019)." Through the Statement the organizations have adopted a common definition for resilience based on one developed by the National Academies (2012), "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events."

The adverse events anticipated in the definition may take many forms including extreme, acute events like hurricanes, tornadoes, and earthquakes or more prolonged, chronic events like heat waves, cold snaps, and droughts. Adverse events could also include social challenges like loss of a major employer, growing poverty or homelessness, or economic downturns. Often, an initial adverse event may produce cascading impacts or secondary events that further stress a community. See Figure 3 for hazards and potential secondary hazard effects. The lack of power following a disaster (particularly in the middle of summer or winter) can lead to additional deaths as was the case in elder care facilities in Florida following Hurricane Irma (O'Matz, 2017).

Industry Statement on Resilience

Representing nearly 1.7 million professionals, America's design and construction industry is one of the largest sectors of this nation's economy, generating over $1 trillion in GDP. We are responsible for the design, construction, and operation of the buildings, homes, transportation systems, landscapes, and public spaces that enrich our lives and sustain America's global leadership.

We recognize that natural and manmade hazards pose an increasing threat to the safety of the public and the vitality of our nation. Aging infrastructure and disasters result in unacceptable losses of life and property, straining our nation's ability to respond in a timely and efficient manner. We further recognize that contemporary planning, building materials, and design, construction and operational techniques can make our communities more resilient to these threats.

Drawing upon the work of the National Research Council, **we define resilience as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events.**

As the leaders of this industry, we are committed to significantly improving the resilience of our nation's buildings, infrastructure, public spaces, and communities.

- **We research** materials, design techniques, construction procedures, and other methods to improve the standard of practice.
- **We educate** our profession through continuous learning. Through coordinated and continuous learning, design, construction and operations professionals can provide their clients with proven best practices and utilize the latest systems and materials to create more resilient communities.
- **We advocate** at all levels of government for effective land use policies, modern building codes, and smarter investment in the construction and maintenance of our nation's buildings and infrastructure.
- **We respond** alongside professional emergency managers when disasters do occur. Industry experts routinely work in partnership with government officials to survey damage, coordinate recovery efforts, and help communities rebuild better and stronger than before.
- **We plan** for the future, proactively envisioning and pursuing a more sustainable built environment.

The promotion of resilience will improve the economic competitiveness of the United States. Disasters are expensive to respond to, but much of the destruction can be prevented with cost-effective mitigation features and advanced planning. Our practices must continue to change, and we commit ourselves to the creation of new practices in order to break the cycle of destruction and rebuilding. Together, our organizations are committed to build a more resilient future.

CULTIVATORS

led the effort to establish and implement the Statement with their industry peers

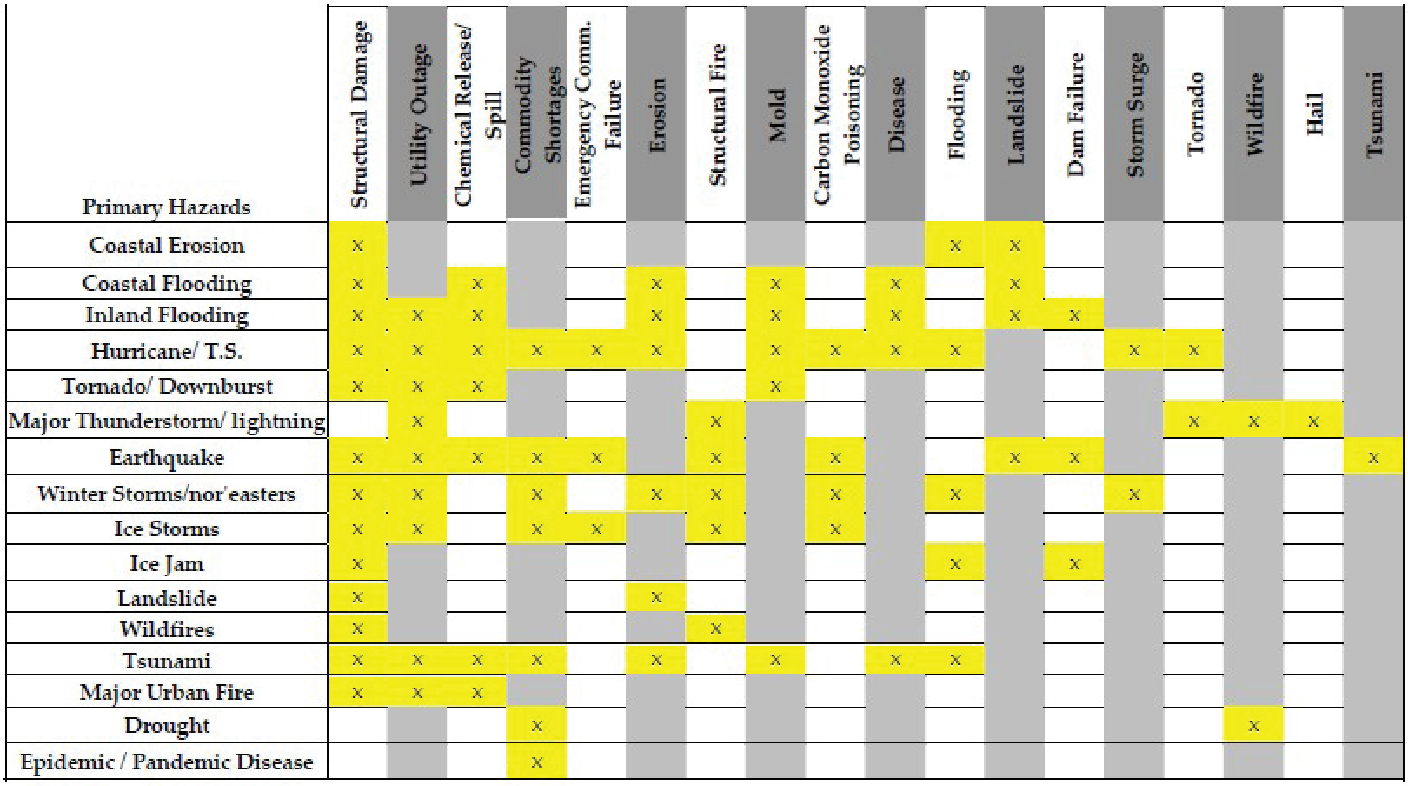
FOUNDERS

united to define the goals and objectives of a resilient built environment

AMPLIFIERS

joined the founding signatories in committing to the advancement of Statement goals

Figure 2. Industry Statement on Resilience



Primary Hazards	Structural Damage	Utility Outage	Chemical Release/ Spill	Commodity Shortages	Emergency Comm. Failure	Erosion	Structural Fire	Mold	Carbon Monoxide Poisoning	Disease	Flooding	Landslide	Dam Failure	Storm Surge	Tornado	Wildfire	Hail	Tsunami
Coastal Erosion	x										x	x						
Coastal Flooding	x		x			x		x		x		x						
Inland Flooding	x	x	x			x		x		x		x	x					
Hurricane/ T.S.	x	x	x	x	x	x		x	x	x	x			x	x			
Tornado/ Downburst	x	x	x					x										
Major Thunderstorm/ lightning		x					x								x	x	x	
Earthquake	x	x	x	x	x		x		x			x	x					x
Winter Storms/nor'easters	x	x		x		x	x		x		x			x				
Ice Storms	x	x		x	x		x		x									
Ice Jam	x										x		x					
Landslide	x					x												
Wildfires	x						x											
Tsunami	x	x	x	x		x		x		x	x							
Major Urban Fire	x	x	x															
Drought				x												x		
Epidemic / Pandemic Disease				x														

Figure 3. Secondary Hazard Effects Matrix (Linnean 2013)

Source: MA Hazard Mitigation Plan (2010) p. 117 Table 14

In many cases, adverse events may have a particularly strong impact on vulnerable populations. Vulnerable populations are "any individual, group, or community whose circumstances create barriers to obtaining or understanding information, or the ability to react as the general population. Circumstances that may create barriers include, but are not limited to age; physical, mental, emotional, or cognitive status; culture; ethnicity; religion; language; citizenship; geography; or socioeconomic status (Iowa 2008)." These vulnerabilities may be particularly pronounced during chronic events where access to financial resources could serve to limit an event's impact. For example, residents living paycheck to paycheck may need to make tough choices around whether to forgo other necessities to heat their home during a cold snap.

Resilience is not a strategy to be deployed in isolation. As recognized in the Energy Independence and Security Act of 2007, a high-performance building is one that, "integrates and optimizes on a life cycle basis all major high-performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations (EISA 2007)." High-performance communities should also take a holistic approach recognizing the need for integration and optimization.

Communities act as systems. A community is only as resilient as its weakest link (ANCR 2018). The Alliance for National & Community Resilience (ANCR) has identified 19 functions that contribute to a community and its resilience (See Figure 4). Identifying strategies that support the resilience of multiple community functions or help address other community priorities including energy efficiency can help reduce the overall cost of implementation and satisfy diverse stakeholder groups. Such an approach recognizes the potential for co-benefits and leverages potential synergies.

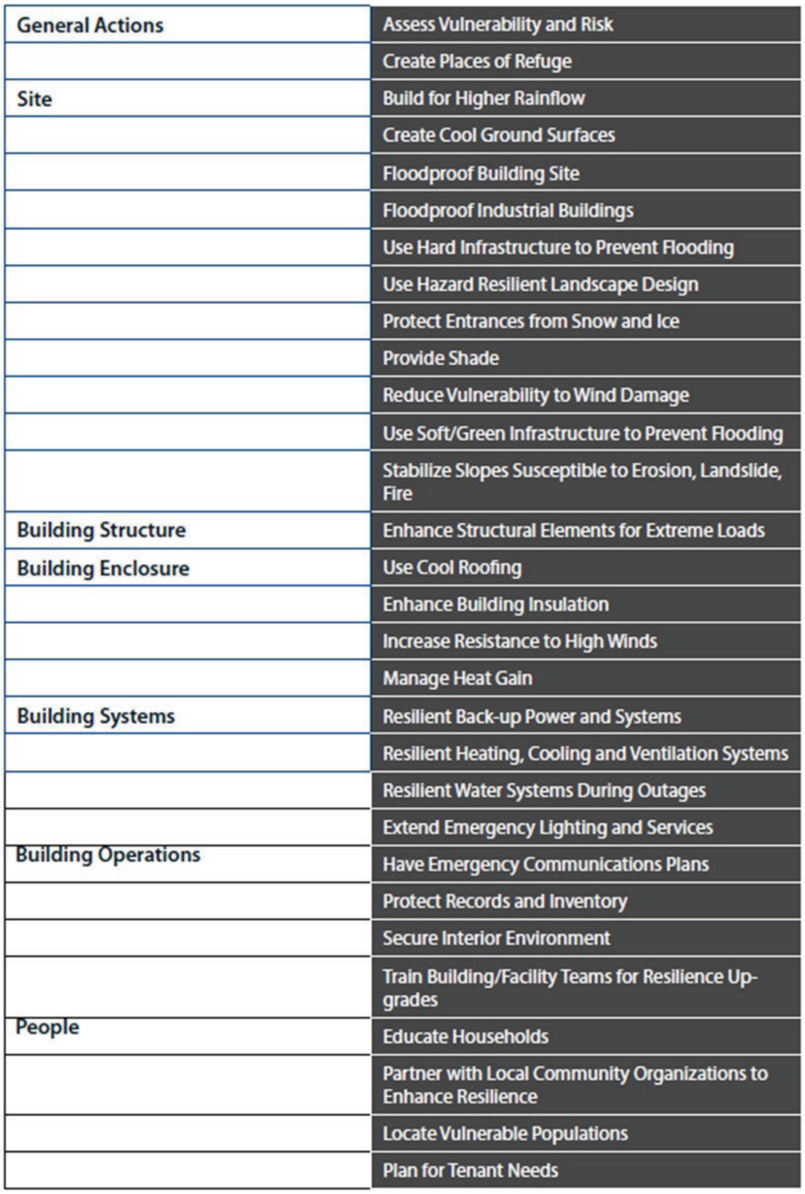
Figure 4. Functions that Define Community Resilience

THE ENERGY/RESILIENCE NEXUS

While significant attention is being paid to community resilience, the literature exploring linkages between resilience and energy, the "energy/resilience nexus," have been limited. This is even more pronounced when considering how building energy codes contribute to resilience. After discussing the broad energy/resilience nexus literature to date, this white paper will focus on energy codes as a resilience strategy.

Energy plays a significant and varying role in modern life. It facilitates activities across the economy from transportation to buildings to manufacturing. Critical lifelines, water and wastewater systems, communications, emergency response and transportation networks all require energy to function. To date, the literature on resilience has either focused on addressing energy-related resilience needs broadly with buildings as a subset or building-related resilience literature has only touched on energy-related aspects.

The City of Boston undertook an effort to identify best practices for climate change adaptation and resilience in its existing building stock. The resultant study looked at the building stock in Boston and the potential vulnerabilities that would need to be addressed now and into the future. Floods and winter storms were identified as the most frequent potential events with hurricanes, severe storms, tornadoes and brush fires following. Based on these risks, the study identified specific strategies to address these risks. About one-third of the 30 recommendations related to building systems, building enclosures and other energy-related aspects of buildings (Linnean 2013). See Figure 5.

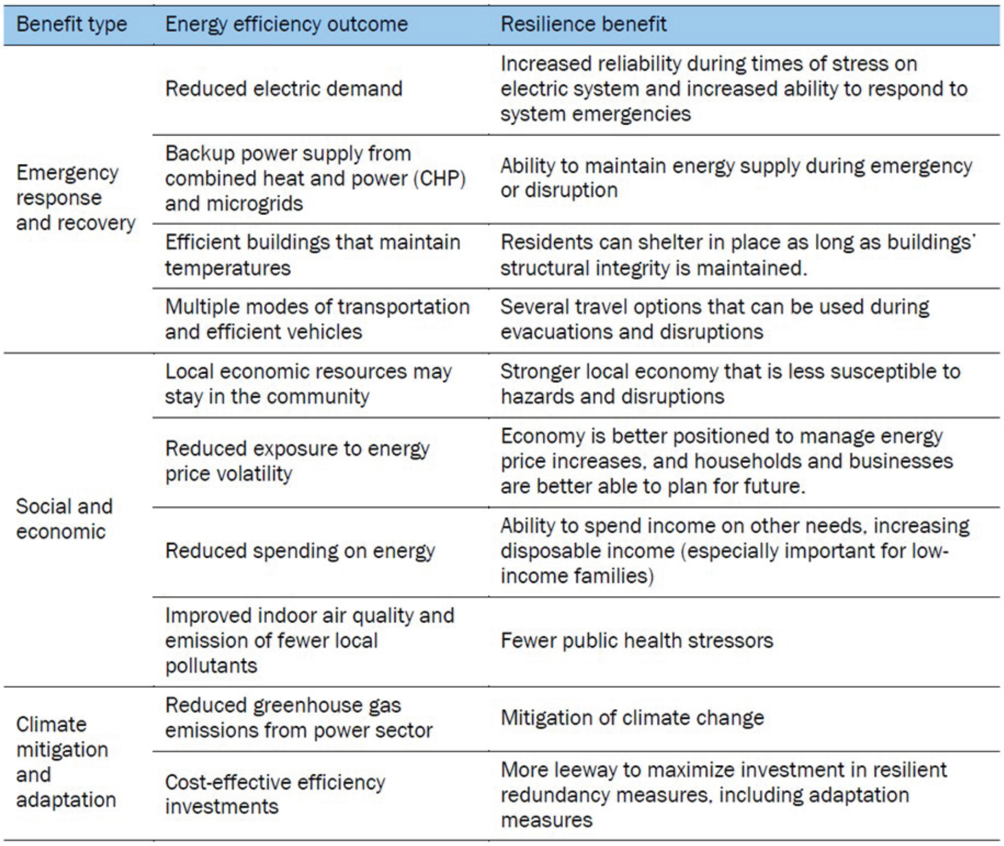


General Actions	Assess Vulnerability and Risk
	Create Places of Refuge
Site	Build for Higher Rainflow
	Create Cool Ground Surfaces
	Floodproof Building Site
	Floodproof Industrial Buildings
	Use Hard Infrastructure to Prevent Flooding
	Use Hazard Resilient Landscape Design
	Protect Entrances from Snow and Ice
	Provide Shade
	Reduce Vulnerability to Wind Damage
	Use Soft/Green Infrastructure to Prevent Flooding
	Stabilize Slopes Susceptible to Erosion, Landslide, Fire
Building Structure	Enhance Structural Elements for Extreme Loads
Building Enclosure	Use Cool Roofing
	Enhance Building Insulation
	Increase Resistance to High Winds
	Manage Heat Gain
Building Systems	Resilient Back-up Power and Systems
	Resilient Heating, Cooling and Ventilation Systems
	Resilient Water Systems During Outages
	Extend Emergency Lighting and Services
Building Operations	Have Emergency Communications Plans
	Protect Records and Inventory
	Secure Interior Environment
	Train Building/Facility Teams for Resilience Upgrades
People	Educate Households
	Partner with Local Community Organizations to Enhance Resilience
	Locate Vulnerable Populations
	Plan for Tenant Needs

Figure 5. Boston's Resilience Strategies for Existing Buildings (Linnean et. al. 2013)

The American Council for an Energy-Efficient Economy (ACEEE) has developed multiple papers looking at the energy/resilience nexus. Its 2015 paper on *Enhancing Community Resilience through Energy Efficiency* takes a very comprehensive look at the resilience benefits of energy efficiency (see Figure 6) and the energy efficiency measures that reduce vulnerability and increase capacity to cope (Figure 7). Building-related strategies feature prominently, but the paper does not delve into specifics around how building energy codes relate (Ribeiro et. al. 2015). In follow-on work ACEEE looked at potential metrics that could be used to understand the energy-resilience of a community. This 2017 paper did include discussion on multiple building-related and energy affordability strategies and potential metrics (Ribiero and Bailey 2017).

The National Association of State Energy Officials (NASEO) looked at the role of state energy offices in contributing to community resilience with a specific focus on residential structures. NASEO identified numerous challenges to integrating energy efficiency and resiliency into residential rebuilding including motivating property owners and developers to value energy efficiency and disaster resilience during the rebuilding process, identifying and understanding the various sources of rebuilding funding and assistance, and working with property insurance providers to allow upgrades above the value of the pre-existing structure. Despite these challenges, they identified six helpful strategies including leveraging existing programs and relationships, ongoing coordination and planning in advance of an event, and conducting evaluations to see what worked (NASEO 2015).



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

Figure 6. Resilience Benefits of Energy Efficiency (Ribiero et.al. 2015)

Following Hurricane Sandy, the Urban Green Council undertook an effort to look specifically at how the temperatures inside buildings without power are impacted during both summer and winter. Details on this work are provided in the discussion below on passive survivability (Urban Green 2015).

The most specific paper looking at energy codes and resilience was published in 2013 and focused on individual residential code provisions and their impacts on resilience. The content remains relevant and is captured in the discussion below (Meres and Makela 2013).

INTRODUCTION TO ENERGY CODES

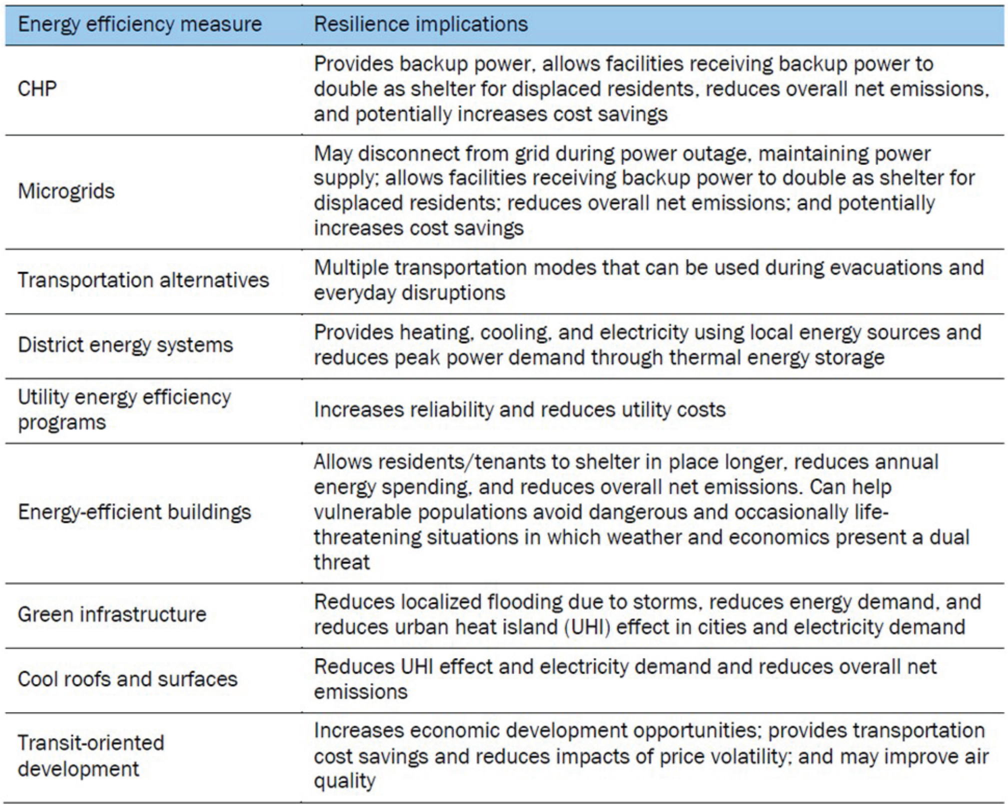
Energy codes were born out of a national crisis. The oil embargo and following energy crisis in the 1970s brought national attention to the need for criteria focused on building energy use. However, energy efficiency in homes caught the attention of the federal Housing and Home Finance Agency (a precursor to the U.S. Department of Housing and Urban Development) in 1950. HHFA developed requirements for residential energy efficiency following defaults on federally backed mortgages due to high energy bills. Development of standards for commercial building energy efficiency were triggered by a blackout in New York in 1970 (ASE 2013).

Today, those early efforts manifest themselves in model energy codes and standards intended for adoption by federal, state and local governments and as the basis for incentive and other programs. ASHRAE first published Standard 90: Energy Conservation in New Building Design in 1975. The standard has been regularly updated since then and is now known as ANSI/ASHRAE/IES Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential. Predecessor organizations to the International Code Council published energy efficiency codes, but the International Energy Conservation Code (IECC) was released in 1998 as a national model code. The IECC and ASHRAE Standard 90.1 are updated on a three-year cycle.

In the Energy Policy Act of 1992 (EPAct 1992), Congress explicitly recognized the importance of national model energy codes in meeting national priorities. EPAct 1992 required states to report on their adoption of energy codes and whether they meet the currently published model codes. Similar requirements remain in law to this day.

Congress reaffirmed the importance of energy codes as it dealt with a national crisis of another form—recession. The American Recovery and Reinvestment Act of 2009 (ARRA) required states to commit to adopting the latest energy codes as a requirement of receiving certain energy stimulus funding. Plans to achieve high levels of code compliance were also required.

Energy codes have become an important component of building codes and support achievement of national and local priorities—including providing social, economic and infrastructural resilience as outlined in the sections that follow. Provisions from the IECC are directly incorporated into the International Building Code (IBC)(Chapter 13) and the International Residential Code (IRC)(Chapter 11). The IBC and IRC are adopted nationwide (all 50 states and 49 states respectively) and serve as the basis for federal, state and local incentive programs focused on advancing resilience. The IECC and Standard 90.1 are also widely adopted nationally—in 48 states for residential buildings and 41 states for commercial buildings.



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

Figure 7. Energy Efficiency Measures that Reduce Vulnerability and Increase Capacity to Cope (Ribiero et.al. 2015)

ENERGY CODES AS A COMPONENT OF RESILIENCE POLICY

Community resilience focuses on deploying strategies that provide benefits before, during, and after disasters. The most commonly identified building-related strategies at the energy/resilience nexus have focused on passive survivability and reducing the urban heat island effect. While these approaches are a critical piece of the energy resilience nexus, they are not the only piece.

PRE-DISASTER/MITIGATION

SOCIAL RESILIENCE

Whole community resilience requires a focus on social, infrastructural and economic issues. Energy (and water) related policies and practices squarely fall within all three realms. Effective energy policies and practices contribute to the social resilience of a community and can help avoid significant burdens on vulnerable populations. Energy efficiency in particular supports local economies and local businesses by allowing funds otherwise spent on utility costs to remain in the community (Ribiero et. al. 2015).

Economically vulnerable populations must regularly balance energy costs with other important needs. The median energy burden for low-income households is more than twice that of average households (Drehobl and Ross 2016). High-energy burdens can mean that households have limited capacity to prepare for and respond to adverse events. They may also stress low-income residents, impacting their long-term health and well-being (in addition to the physical effects of inadequate housing).

In addition to the energy burden, volatility in energy prices may cause residents to become increasingly vulnerable and may hinder a business's ability to operate or expand. Overall energy costs may also fluctuate as extreme heat or cold require elevated use of heating or cooling. Again, energy efficiency provides a limit to the exposure level a homeowner or business owner may have to pricing volatility.

Reducing the energy burden through energy efficiency measures provided in energy codes can help reduce one potential source of vulnerability.

COMMUNITY HEALTH THROUGH REDUCED AIR POLLUTION

Energy generation produces multiple air pollutants including particulate matter (PM). Such pollutants can create or enhance health-related vulnerabilities in the form of asthma and other breathing issues. Such health impacts can influence the resilience of a community both pre- and post-disaster. An increased number of residents needing health care resources post-disaster can add unnecessary strain to the recovery effort. Such effects may even be further compounded when disasters have direct influence on health—extreme heat or cold for example.

Energy efficiency measures reduce energy generation and thus the pollutants associated with such generation. A reduction in health stressors can also reduce a potential source of vulnerability.

According to ACEEE, reducing electricity use by 15 percent for one year would result in saving six lives each day, up to $20 billion in avoided health harms and nearly 3,000 fewer asthma episodes (Hayes and Kubes 2018).

URBAN HEAT ISLANDS

Urban environments tend to be several degrees warmer than the surrounding suburbs. This is due to a variety of factors, but certainly building energy efficiency measures including roofing material choices can help reduce these effects. Such measures could influence the severity of extreme heat events at a community level while also supporting passive survivability in individual buildings during such events.

DISASTER/LIFE-SAFETY

EXTREME TEMPERATURES

During extreme heat or cold events, energy infrastructure can be significantly stressed (DOE 2013). The polar vortex in 2014 caused increases in natural gas demand which could not be met by many utility systems. A 2016 Southern California heat wave ended up leaving 5,300 households without power for several hours as Los Angeles saw peak demand reach 50% higher than average (Ribeiro and Bailey 2017). Buildings constructed to be energy efficient maintain temperatures longer and require less energy to provide heating or cooling, resulting in less stress on the grid. This may allow the grid to remain functional during such an event, resulting in decreased overall impact to the entire community. A natural gas utility in Michigan recently experienced distribution challenges when a compressor station failed due to a fire. Residents were asked to lower their thermostats during freezing weather to allow continued service (Wisely and Hall 2019). Without energy efficiency measures like those contained in the energy code, the required use reductions would have been significantly higher, causing further reductions in service.

In conjunction with the decreased impact during extreme events, energy efficiency contributes to reductions in peak demand. During times of peak demand, the grid can also be significantly stressed. Smoother peaks can support resilience by lessoning the extent of extreme conditions and allowing investments to be made to support everyday operations and reduced vulnerabilities (AEE 2015).

REDUCED IMPACTS FROM PRIMARY HAZARD EVENTS

In the midst of other hazard events including hurricanes and tornadoes, wind-borne debris can cause property damage or result in injuries. In earthquake and wind events, the structural stability of buildings is important. Wildfires or chemical release incidents can spread contaminants that may enter facilities causing health risks. During droughts, potable water use becomes a critical issue. In some cases, energy efficiency-focused measures can also contribute to the ability to withstand and remain operational during such events.

Highly-efficient windows can reduce the impact of projectiles either through the application of films or by nature of its multiple panes. Some insulation applications can also enhance building strength and stiffness. Controlled ventilation strategies can reduce the infiltration of outdoor contaminants. Pipe insulation can reduce the need to run water to achieve the desired temperature, thus resulting in less waste during drought.

POST-DISASTER/RECOVERY

The recovery process post-disaster is often a stressful time. Many residents and businesses may have suffered extensive damage to their homes and businesses. Often, the community is looking to “get back to normal.” If energy-related concerns (like those discussed below) are minimized, employees, business owners, first responders, and community leaders have one less challenge to address as the community recovers.

EXTENDING ON-SITE GENERATION AFTER LOSS OF POWER

Disaster events typically trigger loss of power for significant parts of the impacted community. This loss of power may linger for a significant time following the disaster, contributing to delays in recovery. Critical facilities would be particularly vulnerable to power outages, so many have deployed on-site generation and storage strategies to support continued operations. Non-critical facilities including businesses and homes also have installed generators to avoid the potential long-term challenges associated with power loss.

Coupled with on-site generation, energy efficiency measures deployed during design and construction and maintained in operations support both community and facility level resilience. Energy efficiency extends the supply of on-site power generation by reducing the overall energy needs to provide essential functions. This could result in either a reduction in on-site fuel storage needs and generator capacity or allow for longer operations without grid-provided electricity. Extended operating time reduces the burden on emergency shelters and emergency planners to implement contingency plans. Resources can be focused on more pressing community needs.

Further, if renewable energy generation (or CHP) is available on-site (with islanding capabilities) the facility may also continue to function post-disaster. Again, effective energy efficiency measures can reduce the burden placed on such systems (or allow the systems to cover the necessary loads). The renewable system may also fulfill a portion of a facility’s electricity needs when the grid is under pressure (during an extreme heat event for instance).

PASSIVE SURVIVABILITY

Passive survivability is the ability for a building to remain habitable in the face of an event or crisis resulting in the loss of energy, water or sewage services. The need for passive survivability may surface during extreme heat or cold events when the grid is severely taxed or secondary to other hazard events. Temperature extremes can stress the grid, resulting in blackouts.

Incorporating measures related to passive survivability can help support resilience on two ends--reducing energy demands through increased efficiency thus reducing grid strain and keeping buildings occupiable for longer periods reducing shelter or other emergency services needs. Urban Green Council and Atelier Ten looked at passive survivability potential in New York City's existing building stock (Urban Green 2014, Leigh et. al. 2014). The study found that during a winter blackout a typical high-rise apartment would drop to 45°F within three days and continue to fall. Buildings that met building codes in place at that time (ASHRAE 90.1-2007 and 2009 IECC) remained about 10°F warmer than older buildings. Subsequent improvements in the code likely lead to even greater improvements in performance relative to the existing building stock. In a summer blackout, a typical high-rise apartment would reach 95°F by the fourth day and peak at over 100°F. Code compliant buildings provided a few additional degrees of relief.

Extreme temperatures can lead to hypothermia and hyperthermia and other significant health risks. Impacts can begin at 61ºF where respiratory resistance may be compromised. At 54ºF blood pressure rises leading to increased heart attack or stroke risk. Environments below 41ºF can lead to hyperthermia (Baker 2013). Hypothermia and heat stroke can set in when the internal body temperature reaches 104ºF (NIH 2012). The heat index, a combination of temperature and relative humidity, determines risk for hyperthermia. A heat index of 105ºF is considered dangerous and can occur when the dry bulb temperature exceeds 98ºF and relative humidity is at 40 percent (Leigh et.al. 2014).

Power outages and extreme temperatures present particular challenges to vulnerable populations. The elderly and infirm are most susceptible to temperature extremes and may be unwilling or unable to leave their homes. The 1995 heat wave in Chicago saw hundreds of deaths—many elderly residents who were unwilling to leave their homes (Klineberg 2002). Economically vulnerable populations also may suffer as they make hard choices on whether to increase their energy spend in the face of extreme heat or cold.

Multiple provisions within the energy code contribute to conditions that support passive survivability. Enclosure criteria around insulation, air barriers, solar heat gain, glazing and fenestration support temperature-related aspects. While the building enclosure performance garners most of the attention around passive survivability, other code provisions are also relevant. Pipe insulation can prevent the freezing of pipes during extreme cold events. Daylighting can support continued use of spaces when emergency lighting is insufficient or when back-up power runs out. Access to daylight may also support occupant mental health during an otherwise stressful time.

Using energy codes to provide enhanced passive survivability provides significant co-benefits. Community and individual resilience is enhanced while building owners and tenants reap energy efficiency related rewards everyday in the form of lower energy bills and greater cost certainty.

ROT, MOLD AND MILDEW

In addition to power outages, communities may see secondary impacts affecting residents. Following extreme temperature and some water-related events (e.g., flooding, hurricanes, severe storms) incidents of mold, mildew and other indoor environmental quality issues may arise. Rot and durability issues are also of concern. To prevent rot, mold, and mildew, the energy code dives deep into the field of building science—controlling heat, air, and moisture transfer in building enclosures (Brinker 2017).

Warm air that comes in contact with a cooler surface can condense water onto that surface. Throughout different seasons and climate zones, houses are full of areas where warmer air and surfaces come in contact with cooler air and surfaces. Preventing that condensation through proper sealing, insulation materials, and construction techniques is what keeps the rot, mold, and mildew from running rampant. Energy code provisions that control moisture include:

- Air barriers. Air barriers prevent air—which carries moisture—from carrying and depositing that moisture right into the wall cavities.
- Slab-on-grade insulation. Take a cold slab in the winter and add warm conditioned air above it: you get condensation. Slab-edge insulation, if done properly according to code, reduces the risk of condensation.

- Sealing at rim joists. Rim joists are often easy to insulate but difficult to properly air seal. So, in colder climates, air (and moisture) passes through the insulation and condenses on the rim joists, keeping those rim joists moist for months on end. First the mold sets in, and then the rim joists get rotted out, making the building unsafe. Air sealing the rim joists according to code protects against this.
- Window U-factors and thermal barriers. Warm conditioned air that comes in contact with the cold surface of windows in winter months can condense, damaging nearby wall, ceiling, and floor materials over time. Better-quality windows specified by climate zone in the code significantly reduce this condensation.
- Insulation and sealing to avoid ice dams. Ice dams are thick ridges of ice that build up along the eaves. These can tear off shingles and cause water to build up and leak into the house. Ice dams form when warm air seeps through cracks and crevices into an unconditioned attic, causing snow to melt on the roof but refreeze at the cold eaves. Properly insulating and sealing the ceiling assembly, as specified in the energy code, is the solution.

ADDITIONAL BENEFITS

Energy codes may also help avoid additional cascading effects following a disaster. This is particularly true for provisions concerning the building envelope and ventilation. Wildfires and other disasters that generate airborne particulates could present health concerns for citizens still in the area. Controlled ventilation practices may reduce the level of air pollutants indoors, allowing for extended occupancy and reducing the potential incidents of illness like asthma in a health system already under stress.

Selected Code Topic	Relevant Sections (2018 IECC)	Supported Resilience Strategy	Relevant Hazards
Insulation	C402.2, R402.2	▪ Passive survivability ▪ Reduced energy burden ▪ Reduced grid impact ▪ Reduced ice-dams ▪ Reduced condensation, limiting mold and mildew	▪ Extreme heat ▪ Extreme cold ▪ Snow storms ▪ Social resilience ▪ Secondary impacts to all hazards
Walk-In Coolers and Freezers	C403.10	▪ Food safety/preservation	▪ Extreme heat ▪ Secondary impacts to all hazards
Daylighting	C402.4.1	▪ Passive survivability ▪ Reduced grid impact	▪ Extreme heat ▪ Secondary impacts to all hazards
Window-to-Wall Ratios	C402.4.1, R402.3	▪ Passive survivability ▪ Impact vulnerabilities	▪ Extreme heat ▪ Extreme cold ▪ Hurricanes ▪ Tornadoes
Solar Heat Gain Coefficient	C402.4.3, R402.3.2	▪ Passive survivability ▪ Reduced grid impacts	▪ Extreme heat ▪ Secondary impacts to all hazards
Solar Reflectance of Roof	C402.3	▪ Urban heat island ▪ Passive survivability	▪ Extreme heat ▪ Secondary impacts to all hazards
Air Leakage	C402.5, R402.4	▪ Contaminants (secondary to wildfire, earthquake, etc.) ▪ Mold and mildew (secondary to flooding, hurricane, extreme cold, etc.)	▪ Secondary impacts to all hazards
Pipe Insulation	C404.4, R403.4	▪ Passive survivability ▪ Reduced energy burden	▪ Extreme cold ▪ Drought ▪ Social resilience
On-Site Renewable Energy	C406.5, Appendix CA, Appendix RA	▪ Contribute to distributed generation ▪ Facilitates islandability	▪ Secondary impacts to all hazards

Table 1. Select Energy Code Provisions Contributing to Resilience

POTENTIAL FUTURE CODE-BASED SOLUTIONS, RESEARCH NEEDS AND POLICY PLANNING

While today's energy codes clearly contribute to community resilience, opportunities remain to further enhance these provisions and leverage future research to support increased linkages.

Discussion is emerging around the development of immediate occupancy codes or functional recovery standards that focus on keeping buildings occupiable and operational following a hazard event (rather than just immediate life-safety). As the conversation advances, participants should be cognizant of the important role energy plays in the functionality of buildings. As outlined above, energy efficiency and strategies contained in energy codes can contribute to keeping a building functional.

While today's energy codes contribute significantly to the achievement of passive survivability, they have not specifically been developed with such a result in mind. Such strategies should examine the role of operable windows, passive ventilation and other technologies. Targeted research along with the development of metrics focused specifically on human needs (not just comfort) and methodologies for testing the performance and achievement of passive survivability strategies will allow development of criteria that actively support the long-term occupation of buildings post-disaster.

Existing technology incorporated into energy codes can be further leveraged to enhance resilience. Occupancy and other sensors that help control things like lighting or ventilation could be enhanced to include features that help locate victims following a disaster event. The flexibility provided by solid-state lighting technology and the internet of things (IOT) could support enhanced communication methods before, during and after a disaster event.

The evolving electrical grid with the addition of distributed generation resources and smart meters can enhance community resilience. This evolution will certainly impact and be impacted by how buildings interact with the grid. Effectively managing distributed generation and capitalizing on the resilience such generation could provide requires increased focus on the connections between buildings and the grid. Buildings will need to be able to synthesize information they receive from the grid and respond. Building professionals will need education and training to understand these new dynamics. Codes and standards will need updating to address these changes (ASHRAE 2018).

Microgrids and islanding of facilities with on-site generation present a significant opportunity to enhance resilience that is not yet widely applied. As their use increases, codes and standards must develop to ensure that they effectively address resilience, energy efficiency and safety concerns and opportunities.

Expanding on the role energy efficiency serves in extending the supply or productivity of on-site power generation, the use of direct current (DC) from renewable generation may avoid energy losses associated with inverters. This allows more generated energy to be put to its intended use, allowing more essential needs to be filled when the grid goes down. To capture this benefit, DC-native products must be available. Again, codes and standards have an important role in this transition.

As federal, state and local governments look to advance resilience, strong, regularly adopted and properly administered building codes are fundamental (ANCR and ICC 2018). Energy codes are a key component of building codes and firmly contribute to individual and community-level resilience as demonstrated by the discussion above. Therefore, ICC makes the following recommendations to assure that these benefits are effectively captured:

- Any policies, guidance or criteria that includes building codes as a strategy should explicitly incorporate energy codes as a fundamental resilience strategy. This is particularly relevant as FEMA develops criteria in support of implementation of the Disaster Recovery and Reform Act (DRRA).
- Grant programs funding mitigation should look to include energy-related measures and where possible reward mitigation projects that include co-benefits of reduced energy use and enhanced resilience. These include high-performance building enclosures, combined heat and power, microgrids, energy storage, and islandable renewables.
- All federal agencies engaged in code-related initiatives should coordinate their activities and messaging to support a holistic approach on the importance of building codes.

CONCLUSION

From their initial creation through today, building energy codes have played a major role in reducing the impacts of adverse events. Before, during and after disasters building energy codes influence both individual and community capacity to withstand and bounce back from such events. As policymakers consider approaches that enhance resilience, energy codes should be a cornerstone.

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