Evidence Matters

Transforming Knowledge Into Housing and Community Development Policy

SPRING 2017

The costs and characteristics of residential construction materials affect a home's affordability, energy efficiency, and durability.

In This Issue

Leveraging Building Innovations for Housing Affordability

Housing affordability is a pressing concern for both renters and homebuyers throughout the United States. In addition to factors such as land, labor, and financing, the materials used to construct residential buildings affect construction costs, energy performance, and durability and, by extension, the overall affordability of housing. The extent of this impact presents an opportunity for researchers and policymakers to create innovative materials, technologies, and processes that reduce construction and energy costs and improve long-term durability. Evidence and experience suggest that construction costs can be reduced through simplified and more efficient building materials and processes. Innovative products, from new types of insulation to programmable thermostats, can reduce energy costs, which account for a significant portion of household budgets. Finally,

Editor's Note

Building technology, the focus of this edition of *Evidence Matters*, plays a significant role in increasing housing affordability at a time when many U.S. households are experiencing high housing cost burdens. Advances in building materials and processes can not only reduce construction costs but also long-term maintenance and operation expenditures by improving the energy efficiency, durability, and resilience of housing. Ensuring that homes are durable and disaster resistant is especially vital to fostering community resilience in areas vulnerable to natural disasters. Strategies for long-term resilience should be considered not just when rebuilding after a disaster but also as part of regular regional and city planning. This issue looks at some of the innovative building materials and technologies and their potential impacts on residential construction costs, energy performance, and resilience and durability when exposed to harsh climates and natural hazards.

The lead article, "Leveraging Building Innovations for Housing Affordability," discusses how innovations in construction processes, materials, and technologies can lower costs and examines barriers to the adoption and diffusion of new materials and technologies. The Research Spotlight article, "Combining Energy Efficiency and Disaster Mitigation Efforts in Residential Properties," discusses opportunities and strategies for integrating energy-efficient and disaster-resilient technologies and materials in homes and communities. Finally, the In Practice article, "Retrofits Improve Affordability and Resilience," describes three innovative programs that offer financing and other supports for energy retrofits and home disaster mitigation efforts.

We hope this edition of *Evidence Matters* provides a helpful overview of this critical topic. Our next issue will focus on housing for an aging population. Please provide feedback on any of our issues at **www.huduser.gov/forums**.

— Rachelle Levitt, *Director of Research Utilization Division*

Highlights

- Innovations in building materials may lower construction costs by eliminating unnecessary materials, substituting less expensive materials, or streamlining processes. These savings, if passed on to buyers and renters, can make housing more affordable.
- Energy-efficient upgrades to the building envelope, appliances, systems, and controls can lower residents' energy costs, easing pressures on household budgets.
- Lack of awareness, a desire to do things the way they have always been done, concern over costs and potential defects, and limited workforce skills can prevent builders from adopting new materials and technologies, but researchers may be able to help overcome those barriers.

durable materials make for healthier and safer homes and reduce the long-term costs associated with maintenance and repairs. Despite these and other apparent benefits, several barriers prevent the wider adoption and diffusion of newer materials and technologies, including the challenges of measuring the cost savings associated with specific products, split incentives, risk aversion, and a lack of training in the installation or use of new materials. Research — and effective communication of that research, particularly when it takes a whole-home view — can play a pivotal role in leveraging construction and energy breakthroughs to make housing more affordable and durable over the long term.

Construction Costs

Builders and consumers have, to varying degrees, adopted cost-saving innovations in building materials and processes, with some in recent years becoming standards or near standards. Depending on how much of these savings in construction costs are passed on to homeowners and renters, these innovations can potentially have a significant impact on affordability, usually without sacrificing quality, energy performance, or durability.

Substituting less expensive materials of the same or better quality as traditional materials can provide significant savings. Examples of such substitutions that have been widely adopted include installing plastic electrical boxes instead of metal ones, using plastic plumbing instead of copper, and using alternative sheathing materials. Plastic electrical boxes are typically at least 10 percent less expensive than metal boxes, with the added benefit of being 20 percent more efficient.[1] Oriented strand board (OSB) sheathing materials are less expensive than, and are considered interchangeable with, traditional plywood materials. Advances in OSB production have reduced panel weight by changing the materials used to bind the product and the processes used to make it.[2] In some cases, insulated foam board can be substituted for OSB. Although OSB or plywood may be needed for bracing exterior wall corners as well as in the middle of long exterior walls, lighter, less expensive, and more easily cut insulated foam board can be used as exterior wall sheathing. Foam board also offers higher insulating performance than does OSB or plywood.[3] Another strategy to reduce construction costs is eliminating unnecessary materials. For example, advances in framing, sometimes referred to as optimum value engineering (OVE), can eliminate unnecessary wood materials without compromising structural integrity and often increasing insulation value. In many cases, studs can be placed at intervals of 24 inches instead of 16 inches, and two-stud corners with drywall clips can replace three-stud corners, reducing lumber costs and leaving room for more insulation.[4] A case study comparing two otherwise identical 2,000-square-foot homes found that the costs for materials and installation on the traditionally framed home were twice as high as those for the OVE-framed home. The OVE-framed home also had lower heating and cooling costs.[5]

Cost savings can also be achieved by reducing construction waste and inefficiency. On average, the construction of a single-family home produces more than two tons of construction waste. Logistical and labor costs and fees related to waste disposal can be expensive, and reductions in the amount of waste can significantly lower those costs. Reuse and recycling of waste materials — potentially onsite, such as turning wood scraps into garden mulch — reduces end waste. Planning and design can also be optimized to reduce inefficiencies and limit waste.[6] This principle also applies to prefabricated building materials such as wall panels. Using factory-built wall panels reduces waste on the construction site, and the panels can be designed and scaled to minimize waste in the factory. In a 2009 report, the National Research Council highlighted increased use of "prefabrication, preassembly, modularization, and offsite fabrication techniques and processes" as part of five core recommendations that, it concluded, could result in "breakthrough improvements" in the productivity, efficiency, and competitiveness of the construction industry.[7]

The use of prefabricated materials can simplify many onsite construction processes, with the potential to cut both labor and materials costs, although there may be an initial need for training in proper use and installation.[8] Using engineered trusses and wall panels, for example, can reduce lumber needs by 25 to 35 percent and construction time by 30 to 50 percent for an estimated net cost savings of 16 percent compared with conventional framing practices.[9] The potential exists for greater use of prefabrication in multifamily as well as single-family housing. Galante et al. examine offsite production of three- to five-story, wood-framed multifamily housing and find

Photo by Clark Mishler, courtesy of BRIDGE Housing

Marea Alta in San Leandro, California, a multifamily development built with modular construction, includes 115 rental apartments affordable to households earning 30 to 50 percent of area median income.

potential construction cost savings of up to 20 percent compared with traditional building methods. Offsite production offers savings through more efficient processes, reduced movement between and within construction sites, and fewer weather-related delays. Offsite assembly also allows for purchasing at greater scale, driving down procurement costs. The researchers estimate that the use of offsite construction can reduce project construction time by as much as 40 to 50 percent because processes can be done simultaneously; for example, foundation work that must be done onsite can take place while building materials are constructed offsite. The reductions in overall project time can translate into a host of savings, including financing costs. Galante et al. emphasize that such savings may be particularly beneficial in the construction of affordable multifamily projects, because the savings can be passed on to residents in the form of lower rents.[10] Andrew McCoy, professor of building construction at Virginia Tech, says that in addition to panels, prefabricated "cartridges" — a fully built bathroom or kitchen, for example, are beginning to appear. These cartridges can then be fitted within the structure onsite. The costs of transporting prefabricated materials from the factory to the site and, in some cases, the equipment needed to move materials onsite constitute the primary limiting factors to broader adoption.[11]

Energy Costs and Performance

Energy costs make up a significant portion of any household's expenses and may be especially burdensome for low-income households.[12] Reductions in energy costs, therefore, may be an important lever for improving overall housing affordability; a more energy-efficient home is a more affordable home. Building materials and technologies can have a significant impact on a home's energy performance and associated costs. Currently, the residential sector accounts for about one-fourth of total energy consumption in the United States.[13] That large share could be reduced through wider implementation of interventions that improve the energy performance of the building envelope (the parts of the house that separate the interior from the exterior, such as the roof, exterior walls, and subfloor), control energy usage more effectively, and increase the efficiency of household appliances. Many improvements to energy performance work hand in hand with efforts to cut construction costs. For example, in many cases, reductions in structural materials leave spaces for other materials with higher insulating value. In other cases, improving energy performance requires a higher upfront investment, but savings from reduced energy consumption accrue to residents over time.

Widespread adoption of materials that improve energy performance could have a substantial impact. Research by Kneifel and O'Rear estimates that national adoption of the 2012 International Energy Conservation Code, which requires a range of energy-efficient materials and technologies, for a select sample of building types would lead to a 15.2 percent reduction in energy costs over a 10-year period as well as a 19.2 percent reduction in energy consumption, indicating

Energy-efficient construction lowers residents' utility bills, making housing more affordable over the long term.

higher energy performance compared with existing building codes. Savings for residences vary geographically based on baseline code comparison and climate zone as well as on unit-specific characteristics such as size.[14]

A considerable amount of heat can transfer through the building envelope, making it more difficult to keep the home cool when outdoor temperatures rise and to keep the home warm in cold weather. Various materials used to construct the parts of the building envelope — the walls, roof, subfloor, doors, and windows — can reduce this heat transfer, resulting in a more efficient, cost-effective, and comfortable home. Different wall assemblies such as double-stud walls, truss walls, OVE walls, and walls with exterior insulating sheathing, for example, offer varying R-values (a measure of thermal performance) and airtightness. Although the cost effectiveness of a particular assembly depends on the local climate and the cost of labor and materials, several researchers point to conventional wall frames with exterior insulating sheathing as the easiest to construct while offering a relatively inexpensive and high-performing wall assembly.[15]

A second way to improve residential energy performance is through more effective energy controls. Programmable thermostats, for example, can offer significant consumption reductions and associated savings without compromising comfort, if settings are optimized. Approximately 10 percent of the energy consumed in the United States is controlled by a thermostat, and an increasing portion of households now have programmable thermostats, suggesting the high potential savings that could be leveraged.[16] This potential, however, tends to be unrealized, as users often fail to set thermostats effectively and savings fall well short of projected gains.[17] Self-programming thermostats have attempted to overcome these problems. For example, a program called ThermoCoach uses sensors to track and model occupancy patterns against heating and cooling needs and then emails residents suggesting three thermostat configurations — high comfort, energy saving, or balanced — that the user can select with one click. In a randomized controlled trial, researchers found that ThermoCoach saved 4.7 percent more energy than a manually programmable thermostat and 12.4 percent more energy than a self-programming or "learning" thermostat alone.[18]

In addition, more energy-efficient appliances and products can reduce energy costs. For example, water heating accounts for an average of 14 to 18 percent of residential energy use. Installing an energy-efficient water heater, improving insulation around the heater and pipes, and lowering the temperature setting can reduce energy usage and costs.[19] A wide range of high-efficiency appliances such as refrigerators, clothes washers and dryers, and dishwashers are available. Another cost-cutting strategy is to exchange traditional incandescent light bulbs for longer-lasting and more efficient compact fluorescent lamps and light emitting diodes (LEDs). Although more efficient lights tend to be more expensive to buy, they are 3 to 25 times longer lasting and use 25 to 80 percent less energy, ultimately saving consumer dollars.[20]

> Energy costs make up a significant portion of any household's expenses and may be especially burdensome for low-income households.

Durability and Resilience

New building materials and technologies, including energy-efficient ones, may affect a building's durability and resilience. Durability refers to the ability of a building and its materials to maintain their functionality over their expected lifespans, and resilience refers specifically to durability in the face of natural hazards.[21] Improved durability benefits both builders and consumers through reduced maintenance and repairs and enhanced long-term functionality, and it can frequently be added without incurring extra costs.[22] Wall systems, for example, which are critical to controlling heat transfer in the building envelope and constitute a substantial portion of the material construction costs, can be vulnerable to natural hazards such as wind. Alternatives to the widely used traditional wood-framed construction may offer better hazard resistance for homes, particularly against hurricanes and tornadoes (although wood-framed construction does perform comparatively well in earthquakes). For example, walls made of insulated concrete forms, precast concrete panels, autoclaved aerated concrete, and concrete masonry units (CMUs) all perform better against winds associated with hurricanes and tornadoes and flood than do wood or steel framing (although CMUs do not perform comparatively well in earthquakes).[23] Tests by Texas Tech University researchers found that buildings with insulated concrete form walls can withstand winds of up to 250 miles per hour, with the added benefit of reduced susceptibility to fire.[24] Autoclaved aerated concrete panels are much lighter than conventional concrete, are one-sixth or less thermally conductive, and can withstand winds of up to 150 miles per hour.[25] Construction costs with alternative wall assemblies are likely to be higher compared with traditional wood framing, but the energy costs are likely to be up to 25 percent lower.[26] Concrete-based panels represent a small but growing portion of the single-family residential construction market.[27]

The roof is the section of the building envelope most susceptible to damage from wind-related natural hazards. Because these hazards often include rain, wind damage can be compounded by moisture threats to a compromised roof. Most residential buildings in the United States have roofs covered with asphalt shingles.[28] Research has shown that higher-performance shingles such as styrene-butadiene-styrene (SBS) polymer-modified asphalt shingles to be durable and impact resistant to wind and hail. SBS shingles have greater flexibility than traditional shingles. Wind tests conducted by the Insurance Institute for Business & Home Safety show that polymer-modified asphalt shingles consistently outperform traditional oxidized shingles. A secure adhesion of the sealant strip is important for durability and wind resistance. Research shows that the polymer-modified shingles are also better able to reseal and self-heal compared with traditional shingles.[29]

Foundations are also susceptible to natural hazards, including water damage and earthquakes. Engineers at Stanford University have developed home construction modifications designed to be more resistant to earthquakes even more severe than the Loma Prieta disaster that struck the San Francisco Bay area in 1989. Instead of affixing the house to its foundation, the upper structure rests on "steel-and-plastic sliders" over plates or bowl-shaped dishes that function as seismic isolators, meaning that they isolate the structure of the home from an earthquake's vibrations. The engineers sought to use inexpensive materials to make the design financially feasible. In addition, they incorporated processes and materials that strengthen the house in what they termed a "unibody" design. A thicker-than-average drywall is glued as well as screwed to the studs of the interior walls, and wire mesh stucco stiffens the exterior. The engineers tested the design on the Large High Performance Outdoor Shake Table at the University of California, San Diego. The home sustained no significant damage after a simulation of a quake of three times the intensity of Loma Prieta.[30]

Ideally, innovations or modifications that reduce construction costs or enhance energy performance will also be more durable, and vice versa. However, in practice, these goals may be in tension. For example, spacing studs at 24-inch intervals reduces the cost of materials and nets more space for insulation, thereby improving energy efficiency; however, such walls may be less resilient to wind and seismic hazards.[31] In other cases, energy performance upgrades such as double-paned windows and concrete wall assemblies do, in fact, make a structure more resilient to hazards.[32] In Greensburg, Kansas, a town devastated by a tornado in 2007, builders executed an innovative design to explore and exemplify the potential of materials and techniques to combine energy efficiency and wind resistance. The home features an airtight building envelope, high-performance insulation, a sun-reflecting metal roof, and efficient appliances as well as a prefabricated wood block system to resist high winds. (See "Combining Energy Efficiency and Disaster Mitigation Efforts in Residential Properties," p. 9.)[33]

Paul Norton, National Renewable Energy Laboratory

Double-stud walls allow space for additional and continuous insulation to improve the efficiency of the building envelope.

Barriers to Adoption of New Technologies

For many reasons, the construction industry tends to be slow to adopt new technologies and materials. Builders are concerned about the costs of adopting new materials — not only the costs of the materials themselves, but also the potential costs involved in training workers, paying for more highly skilled labor, increased construction time, and callbacks related to new materials and innovations that may impact the builders' bottom line. McCoy says that for builders of multifamily affordable housing, the direct costs of more energy-efficient "green" building are more or less even with traditional building at this point, but green building has more "soft costs," mostly paying consultants, to ensure the long-term durability of green attributes.[34] Along with skepticism of new technologies and practices, builders may also exhibit inertia, a simple tendency to continue doing things as they have always been done.[35] Builders are also risk averse, and, as University of Minnesota professor Patrick Huelman points out, many "have been burned a time or two" after being convinced to try something new. Whether because of a defect in the material or a failure to install it

Photo courtesy of Eduardo Miranda and Gregory Deierlein, Stanford University

Stanford University engineers developed construction modifications such as a unibody design and seismic isolators that make homes more resilient to earthquakes.

properly, an experience involving costly callbacks for repairs would not easily be forgotten.[36] Builders who work on a large scale — the scale at which many innovations can be adopted most efficiently — may be especially reluctant to try a new material without a track record of effectiveness and durability. Persuading builders to try something new requires reducing risk as much as possible and showing that adoption can be both beneficial and profitable. Such calculations of cost and risk exist in a context in which builders are already concerned about what they consider excessive fees and regulations, high labor costs, and high land costs.[37]

Furthermore, builders may not even be aware of new materials and technologies, or research supporting the usefulness or effectiveness of those materials. Huelman says that the onus is on researchers to more effectively communicate their findings to builders to help them understand the benefits of adoption.[38] In addition, the workforce training necessary to properly install and maintain these new materials and technologies is lacking, and both the performance and cost savings promised by innovation depend on correct installation. It may also be unclear how — or even if — new products or processes meet code requirements.[39]

One challenge to the widespread adoption of technologies and materials that improve energy performance is the issue of split incentives. In many cases, the upfront costs associated with an energy performance investment are borne by the builder, but the energy cost savings accrue to the homebuyer over many years after purchase. Theoretically, the cost of the energy-efficient upgrades could be passed on to the buyer in the sale price of the home. This would require that the buyers value the upgrades and, because most home purchases are financed, that appraisers and lenders also value them.[40] Builders may need to actively market the durable and energy-efficient attributes to the homebuyer.[41] Similarly, in rental housing in which tenants pay for utilities, the owner may have fewer incentives to invest in energy improvements because the benefits from any energy savings would go to their tenants.[42] A related challenge is that the costs and potential savings associated with particular innovations may cut across processes that are traditionally spread among several contractors and subcontractors, making it difficult to convince all those involved to adopt something new.[43]

Another route to wider diffusion of higher-performing energy products, but in a different package, is for builders to "sell" comfort. Builders may find that buyers can be sold on a home's "comfort" features more readily than its energy performance, and the builders themselves may be more interested in durability than energy efficiency. Yet both goals ultimately could achieve improved energy performance.[44]

Despite the many challenges, McCoy notes that the diffusion of innovations related to energy efficiency has accelerated in recent years. He says that the chance of a product being widely adopted is highest when it complements another or if it is similar to other products that meet the same energy goal. For example, the popularity of energy-efficient windows complements improvements in heating, ventilation, and air conditioning systems, because upgrades to the latter would largely be lost without also reducing thermal loss through windows. Interest in energy-efficient innovations tends to correspond with energy prices; when prices go up, consumers become more concerned about the energy performance of their homes.[45]

Looking Forward

Innovations in building materials, technologies, and processes have tremendous potential to affect housing affordability through reduced construction and energy costs and improved durability. Realizing that potential, however, depends on several factors, including the diffusion and adoption of effective innovations, proper installation and implementation, and careful attention to how they interact with one another. Research — and effective dissemination of that research — can play an important role. Huelman notes that currently little funding is being devoted to research on building materials, and much of it is very narrow in scope and often sponsored by the manufacturers. Such narrow research may be able to show that one material is better than another, but it fails to examine whole systems and the interactions of materials therein. Although funding was historically available, McCoy agrees that since the Great Recession, funding has been lacking for national studies, and he notes that the fragmentation of research reflects the fragmentation of the industry. It is rare, he says, to see research that scales up to support universal and marketable conclusions.[46] Further, says Huelman, just having the research is not enough; it also needs to be communicated effectively throughout the industry in a way that gives builders the confidence to adopt new materials and methods.[47]

With the United States facing a growing housing affordability crisis — nearly 40 million households spent more than 30 percent of their income on housing in 2014 — multifaceted solutions are required.[48] Reductions in construction and energy costs may be an important aspect of broader efforts to make housing more affordable. Supported by robust research and evaluation, innovations in building materials, technologies, and processes hold great potential to help achieve those reductions, making housing not only more affordable but also safer and more comfortable, durable, and resilient. EM

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Combining Energy Efficiency and Disaster Mitigation Efforts in Residential Properties

Highlights

- In many cases, materials and technologies that enhance a building's energy efficiency can also make the building more durable and resilient to threats posed by natural disasters.
- Interventions such as the use of cogeneration systems and microgrids can help communities better withstand and recover from natural disasters that threaten their electricity supply.
- Increasing public awareness directly influences the adoption and implementation of energy-efficient and resilient design in postdisaster rebuilding.

Natural disasters are devastating to communities and homes, yet they can also offer an opportunity to integrate energy-efficient and disaster-resilient technologies and materials during the reconstruction process. Understanding how stakeholders make decisions following a disaster can help us learn how to encourage collaboration and eliminate potential barriers to integrating efficiency and mitigation efforts. Although these efforts may incur additional costs or slow construction or rebuilding, high-performance buildings generate significant long-term savings in energy costs, increase the structures' durability, and reduce the waste produced from damaged or destroyed buildings.

At a 2014 U.S. Department of Energy seminar on disaster recovery, nearly 70 percent of participants indicated that the "lack of a clear response plan or protocol" and the "lack of awareness about energy efficiency" were the biggest barriers to coordinating energy efficiency and disaster recovery in their communities.[1] Research, however, tells us that engaging experts in combining these efforts can yield tremendous value, providing long-term benefits to single-family homeowners and communities and contributing to the broader goal of creating strong, sustainable cities.

Combining Energy Efficiency and Disaster Resilience

U.S. families spend, on average, $114 each month on their electric bill.[2] Advanced energy-efficient technologies and practices improve home energy performance by making homes more comfortable and increasing their long-term durability. Optimizing energy efficiency when building a new home or extensively remodeling an existing home requires a whole-house systems approach. A whole-system approach to energy efficiency considers all the variables, details, and interactions that affect energy in homes, including appliances and home electronics; insulation and air sealing; lighting and daylighting; space heating and cooling; water heating; and windows, doors, and skylights.

Policies and programs from federal, state, and local governments can reduce energy consumption and help homeowners save money on their energy bills. Energy rebate programs and financing options encourage homeowners to implement energy-efficient technologies and help reduce the cost of making energy efficiency improvements in new or existing homes.

In terms of disaster risk and mitigation, RealtyTrac, a real estate research firm, found that 43 percent of U.S. homes and condominiums — a total of 35.8 million homes — are at a high or very high risk of at least one type of natural disaster, such as a wildfire, hurricane, flood, tornado, or earthquake.[3] Natural disasters threaten to displace families from residential properties, but resilient housing can accommodate the stresses of a severe weather event. Resilience refers to "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events."[4] Put another way, resilience is "the ability not only to bounce back [after a disaster] but also to 'bounce forward' — to recover and at the same time to enhance the capacities of the community or organization to better withstand future stresses."[5] Characteristics of resilient homes include the ability to absorb shocks, the use of light-colored materials in sections that are prone to hot temperatures, and the flexibility to expand and adapt when needed. Resilient homes are part of an extensive support system to create and maintain resilient people and communities.[6]

The initial period after a natural disaster serves as a ripe opportunity for communities to use recovery and rebuilding to enhance resiliency. Many resiliency measures in the built environment overlap with energy-efficiency measures that can further benefit the community through lower operating costs and energy savings that reduce stress on energy infrastructure. Homeowners, architects, and builders can find ways to incorporate energy-efficient elements into their designs while achieving performance goals, including resistance to natural hazards. Sustainable design and construction constitute a cornerstone for developing resilient communities.

A lack of collaboration between those interested in increasing energy efficiency and those seeking improved disaster resilience is a potential source of inefficiency because both groups strive to

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Green Infrastructure: Revisiting Natural Systems Technology To Meet Present and Future Resilience Needs

Energy efficiency is critical to household resiliency before, during, and after an extreme weather event, and it is integral to a long-term energy strategy. As advancements in building technology and structural development improve energy efficiency, the incorporation of green infrastructure (GI) is becoming increasingly popular because it offers considerable benefits with minimal impact on development. GI addresses two concerns that most American households are likely to experience: excess precipitation and high temperatures. GI not only reduces energy consumption but also offers an added layer of protection from weather events.

GI is the incorporation of green, or natural, elements into the built environment to enhance the management of water sources by gray infrastructure systems. Examples include urban tree canopies, rain gardens, planter boxes, bioswales, buffer strips, constructed wetlands, riparian zones, and green roofs. GI largely helps reduce the volume of excess stormwater because vegetation expels 3.2 percent of surface runoff from incoming precipitation, whereas impervious surfaces expel 12 percent.[1] Reducing stormwater runoff also prevents untreated water from carrying pollutants, such as pathogens and heavy metals, into area water systems.[2] Impervious surfaces often cause flooding because they are unable to absorb excess water into surrounding surface areas. Impervious surfaces also increase temperatures in urban areas, a phenomenon known as the urban heat island effect. Impervious surfaces alone are 3.4°F ±–1.08°F warmer than surrounding surfaces during summer.[3] The urban heat island effect results in temperatures that are 1.8°F to 5.4°F higher than surrounding rural boundaries during the day; this difference can be as high as 22°F in the evening with the release of stored heat from building materials and road surfaces.[4]

On top of managing water sources, GI also provides a passive cooling system that reduces land surface temperatures and air temperatures through evapotranspiration. During this process, water evaporates through plant leaves and is released into the atmosphere as water vapor, and the cooler water vapor absorbs the surrounding heat.[5] Consistently, studies measuring land surface temperatures during the warmer months find that areas with larger areas of green surface cover are cooler than other urban areas; on average, parks are found to be 1.69°F cooler.[6] Shade from trees also saves energy in residential buildings; shaded suburban residences use between 4.8 percent and 19.3 percent less energy than do houses with no shade.[7] Economically speaking, reducing outside heat by even a few degrees offers considerable cost savings because it reduces energy demand and consumption. For example, in Gainesville, Florida, trees are estimated to have generated $1.9 million in energy savings each year, based on 2007 electricity retail prices.[8]

GI is not without faults; it can have detrimental effects if an evaluation of it measures only its direct impact. For example, a dense tree canopy can inhibit the dispersion of particle air pollution in city neighborhoods, leading to air quality problems[9], or a large tree located on the south side of a house in a northern city could increase energy consumption because it blocks valuable warmth from sunlight during the colder months.[10] With factors such as these kept in mind, the direct and indirect benefits of GI can be achieved and maximized through thoughtful planning.

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improve the performance of the same buildings. Developers, homeowners, and community stakeholders involved in new building and renovation efforts do not always have the same goals. Developers are typically profit driven, whereas community stakeholders or homeowners may be more interested in building long-term, durable residential properties. Making communities disaster resilient with high-performance technologies often increases build time and material costs.[7]

Energy efficiency and disaster management share some benefits and challenges, and integrating these two within public policy and programs would benefit society. Following a natural disaster, however, state and local governments and residents face many decisionmaking challenges that complicate the integration of energy efficiency and resiliency into residential rebuilding. These challenges include "motivating property owners and developers to value energy efficiency and disaster resilience during the rebuilding process; identifying and understanding the various sources of federal, state, and private rebuilding funding and assistance; and working with property insurance providers to allow upgrades of rebuilt homes above the value of the pre-existing structure."[8]

Strategies for Effective Disaster Mitigation and Rebuilding Efforts

A lack of awareness is one of the most significant factors limiting the integration of energy efficiency and resilience. Campaigns to increase public awareness should focus on three areas: the value of residential energy efficiency and resilience; available state, utility, and federal programs; and energy-efficient and resilient design and building technologies. Increasing public awareness directly influences the adoption and implementation of energy-efficient and resilient design in post-disaster rebuilding.

Disaster rebuilding coordination is most effective when relationships are in place before a disaster and all stakeholders share the same vision. In an analysis of U.S. public policies addressing energy efficiency and disaster management, Martel finds, "energy efficiency and disaster management have some complementary policies, actors, interest groups, regulatory systems, goals, and desired outcomes… [but] these two fields have not comprehensively converged, missing opportunities for greater positive impact on society."[9] Connecting stakeholders (including state and federal emergency management agencies), utility providers, contractors and homebuilders, financial institutions, public housing agencies and home associations, and large retailers and hardware stores ensures that stakeholders are working toward the same shared vision.[10]

Increasing public awareness directly influences the adoption and implementation of energy-efficient and resilient design in post-disaster rebuilding.

Certain building technologies advance the goals of both helping homes become more resilient to natural disasters and improving the energy performance of the building. Innovations in resource-efficient and durable residential design and construction have become a reality in several places, from model housing developments in tornado-prone Greensburg, Kansas, to rebuilding efforts in Long Island, New York, following Superstorm Sandy. These strategies include incorporating onsite renewable energy sources to reduce environmental impacts and reliance on the electrical grid as well as elevating buildings and moving mechanical systems to the roof to make buildings more flood resistant.

Disaster-resistant and energy-efficient homes have common structural benefits, such as greater construction durability and performance. Recent technology advancements have helped homeowners more easily invest in elements that make their homes more resilient to natural disasters while also improving their energy efficiency.[11]

Extreme Heat and Cold. Vulnerable populations, such as children, the elderly, and the economically disadvantaged are at heightened risk of death and illness during periods of extreme heat or cold.[12] Building technologies can help prepare residential homes for the potential impacts of extreme heating and cooling events while protecting the health, safety, and welfare of residents.[13] Homes with effective air sealing and high insulation have an energy-efficient building envelope that reduces heating and cooling loads. Residential buildings with smaller load demands not only decrease the strain on regional electrical grids during emergencies such as natural disasters but also are more likely to keep occupants safe and minimize the negative effects of extreme heat or cold.[14]

In regions at risk of extreme cold, water pipes are more likely to freeze, and moisture flow due to air leakage and vapor diffusion from the inside to the outside can cause discomfort. Insulation is an energy-efficient solution that protects residents and buildings from extreme cold. Insulated walls reduce the risk of frozen water lines, keep homes warmer, reduce energy costs, and maintain comfortable indoor temperatures. Elements such as double-paned windows also improve a home's response to extreme cold while reducing energy consumption.[15]

Land modifications and building materials that absorb the sun's heat, especially in urban or metropolitan areas, can raise surrounding air temperatures in a phenomenon known as the urban heat island effect. Design elements for the roof are among the most common and cost-effective solutions to reducing the effects of extreme heat while reducing energy consumption. A garden planted on a rooftop, known as a green roof, reduces the roof's surface temperature. Similarly, a "cool roof" that reflects sunlight and heat lowers the surface temperature. (See "Green Infrastructure: Revisiting Natural Systems Technology To Meet Present and Future Resilience Needs," p. 10.) Strategies such as green and cool roofs lower indoor temperatures, increase occupant comfort, and reduce the amount of air conditioning needed on hot days.[16]

A hipped roof, in which the roof slopes on four sides instead of two, with a wide overhang can provide solar shading. To protect against uplift during high-wind events, additional connections are needed to secure the roof to the exterior wall.[17]

External strategies such as planting trees and vegetation that directly shade homes can also lower surrounding temperatures. Trees provide passive cooling through their shade, reduce the urban heat island effect, and may reduce flooding by slowing down water flow, increasing water absorption into the ground, and preventing soil erosion.[18]

Seismic Hazard. Earthquakes pose a particular risk for older homes because they often are not adequately anchored to their foundations and were not designed to withstand the shaking and movement typical of an earthquake. Identifying potential hazards in advance allows homeowners to undertake projects that simultaneously target energy efficiency and seismic resilience.

Although building materials and technologies tend to focus on either energy efficiency or seismic resilience, opportunities exist to combine the two elements. Some wood-framed homes use weak bracing materials such as cement plaster or wood siding, which are not strong enough to survive moderate to strong earthquakes, leak heated or cooled air, and risk the home's longevity. Replacing the bracing materials with plywood or concrete can help reduce the home's energy consumption and increase its structural strength.[19]

Wind Hazard. High wind events such as tornadoes, hurricanes, windstorms, and severe winter storms can affect homes in two ways. First, differential pressures act on the building envelope, which includes the roof and walls. Excessive differential pressures caused by wind can deform or dislodge building materials. For example, roof shingles and siding can be broken or lifted off. Second, windborne debris may strike the home.

Expanding the use of certain materials can be a more cost-effective way for new and existing homes to be more resilient and energy efficient. Multipane windows, for example, reduce the risk of breakage during a high-wind event and reduce energy consumption during heating and cooling. Concrete homes and structurally insulated walls both conserve energy used for heating and cooling and are resistant to falling or flying debris.

Flood Hazard. Typically, builders increase residential resilience to flooding through improvements to building codes rather than by using innovative technologies and building materials. But common strategies, such as elevating homes, do not capture energy

FEMA Photo by Sharon Karr

Crews work to restore electricity in New Jersey following Superstorm Sandy, which caused outages for more than 8.5 million customers.

savings. Researchers, however, are testing new flood-resilient construction materials that are also sustainable. Researchers at the University of Bath are testing the flood resilience and structural integrity of timber walls, which may be used to floodproof future homes.[20]

Community-Based Technologies

Community-based strategies for improving energy efficiency and flood resilience can also be effective. In Hackbridge, United Kingdom, solar panels, biomass, and heat pumps — renewable energy sources that can operate during a flood — will power new buildings located in the city's flood zone. Other cities such as Hoboken, New Jersey; New York City; and Washington, DC, are implementing microgrids to improve resilience to coastal flooding.[21]

Technologies such as cogeneration systems and smart meters are also examples of opportunities that combine resiliency with energy efficiency at the community level. These technologies are most effective when they work concurrently toward achieving those goals.

Cogeneration Systems. Cogeneration, also known as combined heat and power (CHP), refers to multiple technologies that operate concurrently to generate electricity and heat. When incorporated widely within a community, the community can be self-sufficient even if it becomes disconnected from the central utility and can better meet surges in power demand associated with extreme weather or natural disasters.[22]

South Oaks Hospital in Amityville, New York, for example, used a natural gas-fired CHP system to operate and serve patients despite being disconnected from the Long Island Power Authority grid for 15 days.[23]

Microgrids. From 2003 to 2012, the United States experienced more than 675 widespread power outages due to extreme weather, costing the U.S. economy an average of $18 billion to $33 billion annually.[24] Major natural disasters result in widespread power outages, leaving thousands without access to heating, cooling, and hot water. Both seismic events and floods associated with tsunamis and hurricanes can damage electricity transmission and distribution systems, and can impede the delivery of fuel to local generators. Other natural disasters, such as ice storms and wildfires, can also affect the delivery of electricity. [25]

Increased grid resilience in the form of microgrids may help communities maintain power during natural disasters because a microgrid is a localized grid that is able to disconnect and isolate itself from the utility.[26] Although microgrids are often seen as a way to encourage the adoption of renewable energy sources and address the challenges of peak demand, they can also contribute significantly to a community's disaster preparedness and recovery. By relying on multiple generators, a microgrid system avoids the single point of failure of traditional electricity grids. Microgrids may disconnect from the grid during power outages to allow facilities receiving backup power to double as shelter for displaced residents; they can also reduce energy overconsumption and expenses.[27]

In September 2015, the Butte Fire in California's Calaveras County burned more than 545 homes and charred nearly 71,000 acres, destroying power lines in its path.[28] Although many homes lost power as firefighters battled to control the flames, the lights stayed on at the Miwuk Tribe's Jackson Rancheria Casino and Hotel Resort. Jackson Rancheria used its microgrid to disconnect from the regional power grid and generate its own electricity. In a time of crisis, Jackson Rancheria served as a haven for firefighters and a temporary home for hundreds of evacuees. After seeing the success at Jackson Rancheria, other Tribes in high-risk wildfire areas are also planning to implement microgrids. Plans for a microgrid at Blue Lake Rancheria estimated savings of at least $75,000 per year in energy expenses.[29]

Smart Meters. Smart meters, electronic devices that record electricity consumption in intervals of an hour or less, aid both energy efficiency and disaster resilience. During natural disasters, smart meters provide power companies with crucial information on the location of power outages, reducing both emergency response times and the duration of outages.

In October 2012, Superstorm Sandy made landfall on the east coast, damaging more than 650,000 homes and causing power outages for 8.5 million

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Passivhaus in Austria

In the alpine climate of Austria, high-performance building technologies have been implemented successfully to offer resilience against cold climates.

Schiestlhaus, a Passivhaus-standard building in an alpine climate located on the Hochschawb mountain in Austria, was built to withstand extreme temperatures and operate year-round off the grid.

A Passivhaus is a superinsulated house that meets a strict airtightness standard of 0.6 air changes per hour at 50 pascals. The wood-framed home has double-stud walls that are 16 inches thick and have at least 10 inches of exterior rigid foam. The Passivhaus standard also calls for thick roofs and triple-glazed windows to protect against extreme cold.[1]

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Rebuilding in Greensburg, Kansas

In May 2007, a tornado devastated the small town of Greensburg, Kansas, destroying or damaging 90 percent of the structures in town. The town was declared a disaster area, but many Greensburg citizens saw the devastation as an opportunity to rebuild using strategies for sustainable living.

Although no mandates required residents to rebuild in a particular way, about 150 of the 300 newly constructed homes adopted energy-efficient and sustainable building strategies. Throughout the reconstruction process, developers and builders emphasized the importance of constructing homes with several sustainable and resilient design features such as bolting the walls of the homes to the concrete foundation, increasing the chances of a structure's survival during high wind events.

The Meadowlark House incorporates a toxin-free wall system that consists of wood blocks from sustainable resources. The wall system is highly insulated to reduce energy costs and can withstand winds of up to 195 miles per hour.

The Commercial Group, a Kansas-based company focusing on low-income housing development, built affordable single-family homes in Greensburg. These homes were financed by the Kansas Housing Resource Corporation (KHRC) through tax credits and grants. As part of the construction process, KHRC followed specific guidelines set forth by the U.S. Department of Energy. The new construction adhered to specific guidelines for energy efficiency and withstanding high winds. To ensure resident safety during another natural disaster, the affordable housing units also include storm shelters built under the front porch and separated from the rest of the basement by a steel door.

Source: John McIlwain, Molly Simpson, and Sara Hammerschmidt. 2014. "Housing in America: Integrating Housing, Health, and Resilience in a Changing Environment," Urban Land Institute, 12–6.

FEMA Photo by John Shea

Many of the homes constructed in Greensburg, Kansas, after a tornado devastated the town feature energy-saving lighting and appliances, including tankless water heaters.

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customers. The greatest damage occurred in New York and New Jersey, but smart grid investments in Pennsylvania and Washington, DC, reduced the storm's impact for thousands of electric customers. With funding from a Smart Grid Investment Grant from the U.S. Department of Energy, Philadelphia implemented roughly 186,000 smart meters before Superstorm Sandy hit. PECO, formerly called the Philadelphia Electric Company, estimates that approximately 50,000 of its customers experienced shorter outages during the storm because of its new smart grid system. Advanced smart meter infrastructure in Washington, DC, allowed the Potomac Electric Power Company to quickly pinpoint outage locations, enabling the utility to respond to customers quickly and effectively.[30]

Future Research Needs

Energy efficiency is an essential component of any resilience strategy because it aids emergency response and recovery, helps with disaster mitigation, and provides social and economic benefits. In addition, there is strategic value in coupling energy efficiency and hazard mitigation features in homes. These high-performance buildings result in:

- Greater occupant comfort and safety;
- Increased durability of properties, resulting in energy savings over time and reduced waste from damaged or destroyed buildings; and
- Reduced operating costs and increased cost savings for homeowners through lower energy bills and insurance premiums.

Although some concerted research efforts link energy efficiency and disaster resilience, Oluwateniola E. Ladipo notes several remaining gaps in these efforts. In general, stakeholders lack consensus on how to define resilience in the residential building sector and how best to evaluate the performance of resilience-enhancing technologies and strategies for residences, which makes comparing and prioritizing these technologies and communicating outcomes difficult. Because this is a new field, stakeholders are encouraged to further explore and examine design and installation techniques.[31]

Most resilience research in response to natural disasters has been focused on seismic history at the expense of other natural hazards, such as extreme heat and cold or high winds. As a result, efforts to protect buildings against earthquakes have made the most progress. Future research should focus on making buildings more resilient to these and other natural hazards while also integrating energy-efficient technologies. In addition, research has focused on infrastructure and large commercial buildings, such as hospitals, rather than residences, overlooking the significant economic and social impact of incorporating energy efficiency and disaster resilience technologies into homes.[32]

Finally, research is limited on the proposed methodologies and decision-making processes. Future research should address best practices or provide a framework for stakeholders to use when considering and prioritizing technologies for rebuilding after natural disasters.[33] EM

— Caitlin Phillips, *Former HUD Intern*

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In Practice

Retrofits Improve Affordability and Resilience

Highlights

- To decrease utility costs and maintain affordable housing, retrofit programs such as Chicago's Energy Savers program assist multifamily building owners with technical and financial expertise to improve heating, lighting, and insulation.
- The South Carolina Safe Home program offers grant funding to residents to improve their homes' roofing, gables, windows, and doors and strengthen them against storm damage.
- With upgrades using materials proven to withstand high winds, MyStrongHome helps homeowners in South Carolina, Alabama, and Louisiana improve their homes' resilience to hurricanes and reduce their insurance premiums.

Upgrades to improve the energy efficiency of building components such as boilers and heating, cooling, and lighting systems can help owners of multifamily properties reduce their operational costs over time. For homeowners living in areas prone to wind and storm surges, retrofits using resilient building materials can mitigate the risk of property damage and reduce insurance premiums. The upfront costs of performing retrofits, however — along with not knowing which retrofits are appropriate to pursue — often hinder property owners from moving forward. Several public, private, and nonprofit programs are currently working to address these challenges and support residential retrofits that promote energy efficiency and mitigate damage from natural hazards.

The Energy Savers program offers technical support and financing to retrofit aging multifamily buildings in the city of Chicago and surrounding counties. Homeowners in South Carolina have access to two programs that support home retrofits to mitigate storm damage. The state-funded South Carolina Safe Home Program provides grants for home retrofit activities such as strengthening gables, providing roof water barriers, and examining weak studs and foundations. A private-sector program, MyStrongHome, offers upgrades at minimal or no upfront cost using building materials proven to withstand high winds.

Energy Savers Retrofits in Chicago

Launched in 2008, the Energy Savers program is a collaboration between the nonprofit Elevate Energy and Community Investment Corporation (CIC), a community development financial institution. The Energy Savers program allows owners of multifamily buildings to decrease their utility costs through energy-efficient upgrades, which helps keep this housing affordable.[1] Currently, Energy Savers targets affordable rental housing in multifamily buildings with five or more units in seven counties in the greater Chicago area as well as the city of Rockford, Illinois.[2]

Multifamily housing makes up 77 percent of Chicago's housing stock, and much of that stock was constructed before 1942 and lacks modern, energy-efficient lighting, insulation, heating, and cooling upgrades.[3] Most of the buildings in the Energy Savers program are three-story brick walkups that typically have flat roofs, radiators that generate heat from single-pipe steam heat systems, and gas boilers that are 15 to 20 years old.[4] As Jackie Wiese, assessment field services manager at Elevate Energy, says, "Part of Elevate Energy's mission of smarter energy use for all is reaching markets that would not otherwise see energy efficiency benefits."[5]

The Energy Savers program arose out of the need to reverse the loss of Chicago's affordable rental housing, some of which was being converted to condominiums.[6] Recognizing that preserving affordable rentals was more cost effective than new construction, a large policy collaborative led by CIC called the Preservation Compact — composed of government and nonprofit officials, resident advocacy groups, civic and other nonprofit organizations, and property owners — participated in conversations with the MacArthur Foundation and housing stakeholders from 2005 to 2006 to address ways to preserve affordable rentals.[7] The Preservation Compact helps building owners maintain affordable housing by reducing their operating costs and strengthening their ability to undertake rehabilitation projects.[8] Stacie Young, director of the Preservation Compact at CIC, observes that building owners, who were facing rapidly rising utility bills, were keen to reduce their operating costs. The Preservation Compact and housing stakeholders agreed that if more building owners could retrofit their rentals, then utility bills would decrease, leaving owners with more resources to maintain their buildings and keep rents low as well as run their buildings more efficiently.[9] Among the barriers to performing the retrofits were a lack of information about which retrofits to perform and the estimated savings from retrofits as well as access to financing. The original goals of the Energy Savers program were to perform building assessments through Elevate Energy to determine owners' energy retrofit needs and provide financing for these retrofits through CIC. CIC believed that more retrofits would be possible if a financing product included underwriting to postretrofit savings. CIC also knew that few lenders were willing to add a second mortgage for retrofit work. Elevate Energy and CIC partnered to fill these gaps in 2008 with the Energy Savers program.[10]

A One-Stop Shop

Elevate Energy is a one-stop shop that provides building owners with free energy assessments, technical assistance, CIC financing, information on rebates and other incentives, and postretrofit followups.[11] As part of Elevate Energy's multifamily application, building owners answer questions pertaining to their interest in loan financing options. Building owners who are interested in obtaining a loan can apply for one through the Energy Savers Loan program, a partnership between Elevate Energy staff and CIC. While CIC begins the loan application with the building owner, Elevate Energy schedules a free onsite energy assessment. CIC and Elevate Energy communicate regularly to keep track of the recommended retrofits that will influence loan amounts.[12]

Elevate Energy conducts its energy assessments using a team of energy analysts with support from an internal construction management team. The assessments examine the building envelope; heating, cooling, and hot water heater systems; lighting; water usage; and opportunities for roof cavity air sealing and insulation.[13] Multifamily building owners also receive free in-unit programmable thermostats and energy-efficient lighting in common areas.[14] Building owners must submit one year of paid gas and electric bills so that Elevate Energy can estimate the projected energy savings.[15] After the onsite assessment and upon receipt of owners' utility data, Elevate Energy uses the onsite assessment and utility bill data to develop a list of recommended upgrades and projected gas and electric savings. Owners are not required to implement all the recommended upgrades; instead, they can prioritize some upgrades over others as their budget allows.[16]

> The Energy Savers program arose out of the need to reverse the loss of Chicago's affordable rental housing, some of which was being converted to condominiums.

Elevate Energy

A contractor examines boilers and hot water heaters to determine whether they are performing efficiently.

Elevate Energy staff maintain a list of vetted, insured, and licensed contractors that they trust to complete quality work.[17] A critical part of the construction oversight is to ensure that the new building technologies are working to their full capacity and achieving the predicted savings.[18] As new building technologies emerge, assessments are critical to determine which retrofits generate the greatest cost savings.

Loan Pool Financing

CIC originally financed Energy Savers through a separate pilot loan pool because financing multifamily retrofit activity based on projected energy savings, and using a second mortgage, was untested, and potential investors perceived the strategy as too risky. The Chicago Metropolitan Agency for Planning and the city of Chicago provided $2.75 million and $1 million, respectively, to increase the loan loss reserve. CIC also secured $6 million and $8.5 million in additional loan capital from the MacArthur Foundation and Bank of America, respectively.[19] Although no monetary ceiling currently exists for what CIC finances, typical retrofit costs range from $2,500 to $3,000 per unit. The comprehensive support that Elevate Energy provides during the entire process and the relationships that Elevate and CIC have with building owners, contractors, and utility companies have facilitated retrofits for more than 27,000 units throughout the Chicago metropolitan area. CIC has financed $21.5 million to retrofit 10,000 of those units, leading to substantial energy savings.[20]

Although CIC initially wanted to accommodate building owners undertaking energy retrofits separate from larger rehabilitation projects, CIC staff determined that little demand exists for retrofits alone; most owners implement retrofits as part of larger rehabilitation projects. In addition, many building owners preferred the terms for CIC's $200 million primary multifamily loan pool to those of the pilot loan pool. The pilot pool had a shorter amortization period of 7 years compared with 25 years for the larger multifamily loan pool. Because CIC had only one loan loss in the pilot stage, CIC and its investors and board of directors are currently in the process of rolling Energy Savers loans into CIC's primary multifamily loan pool.[21]

Overcoming Challenges

One of the barriers to implementing energy retrofits is the split incentives problem, in which building owners pay for energy-saving investments, but the tenants pay the utility bills (see "Leveraging Building Innovations for Housing Affordability," p. 1). This division creates a financial split between those who pay for energy-saving measures and those who actually benefit from them.[22] In cases where building owners pay for both the energy upgrades and utility bills, however, creating incentives for tenants to adopt energy saving practices, such as closing windows, adjusting thermostats, or reducing water usage, can be difficult.[23] One way the Energy Savers program has addressed this problem is by recommending that building owners install central boiler control panels to regulate a steady building temperature. Building owners might also consider installing low-flow showerheads to improve overall water efficiency and reduce utility costs.[24]

Another way to encourage building owners to adopt energy retrofits, says Wiese, is to highlight their nonenergy benefits. For building owners, nonenergy benefits include reduced operations and maintenance costs, and reduced tenant turnover. Tenants, especially those facing housing cost burdens, can enjoy improved comfort and, thanks to lower utility bills, greater financial stability. Tenants and building owners can also safeguard against fire hazards caused by alternative heating sources such as space heaters or candles.[25] Although most of the buildings that CIC finances are master metered, some building owners still seek financing from CIC to retrofit individually heated buildings. In these cases, building owners value tenant retention, which they know can be maintained if residents see a reduction in their utility bills.[26]

Elevate Energy

Elevate Energy contractors retrofit a building envelope to improve durability and ventilation.

In 2013, the Partnership for Advanced Residential Retrofit (PARR) and the Center for Neighborhood Technology conducted a study of three multifamily buildings in Chicago that were retrofitted through the Energy Savers program. PARR used TREAT Multifamily software — an energy auditing program approved by the U.S. Department of Energy for all residential building types.[27] Using this program, the researchers analyzed building performance elements such as building size, windows, doors, thermostats, hot water heaters, lighting, and appliances. The researchers note that the building owners in this study saved between $2,667 and $7,774 each year.[28] Energy Savers provides the most cost savings when upgrades prioritize the thermal envelope and the heating and electrical systems.[29] On average, building owners who use the Energy Savers program to finance their retrofits save between 20 and 30 percent per year on their heating, cooling, and water bills, which improves their ability to preserve affordable housing stock.[30] Another PARR study with a slightly bigger sample of 13 buildings also found positive results for building owners, who saw decreases of more than 25 percent in their natural gas bills.[31]

In a 2014 study, Stewards of Affordable Housing for the Future and Bright Power, Inc., found that in a sample of 57 Chicago multifamily rental buildings with master meters, the Energy Savers program resulted in a 26 percent reduction in natural gas consumption, or a savings of approximately $195 per unit each year.[32]

The biggest driver of success has been information sharing among building owners about the benefits of the retrofits and their positive experiences. Young

Elevate Energy

Interior of a multifamily building that Elevate Energy rehabbed to improve heating, lighting, and insulation.

notes that client testimonials, word of mouth, and positive relationships with CIC have all contributed to building owners' willingness to finance retrofits.[33]

Improving Resilience in South Carolina

In September 1989, Hurricane Hugo ravaged South Carolina as well as North Carolina, Puerto Rico, and the U.S. Virgin Islands, leaving $17.6 billion of property damage in its wake.[34] Research shows that for every dollar disaster-prone areas spend on mitigation activities, they can save $4 in potential recovery costs. The high insurance rates associated with coastal living in South Carolina led the state to create the South Carolina Safe Home (Safe Home) program as part of the Omnibus Coastal Property Insurance Reform Act of 2007. The Safe Home program provides eligible homeowners with grant funding for retrofits that help their homes resist hurricane damage. Retrofits can include reinforcing gable ends; installing double water barriers for roofing; strengthening roof-to-wall supports; and strengthening windows, doors, and garages.[35] The South Carolina Department of Insurance manages all aspects of the program, including administering grant funds and overseeing the homeowners' applications.[36]

The South Carolina Department of Insurance requires homeowners to complete necessary upgrades within three months of the grant award notification.[37] To qualify for the program, a Safe Home inspector must assess an applicant's home to determine which retrofits are necessary. To strengthen gables, the Safe Home program requires that the triangular part of the gable be affixed to the roof and ceiling of the house. The connection between the triangular part of the gable and the rectangular wall underneath it should also be strengthened.[38] When upgrading roofing, the program requires that homeowners install a water barrier that will protect the house if high winds blow away the roof's first layer. One mechanism for creating such a barrier is to use roofing tape that adheres to the joints of the roof to prevent water from entering the house. Alternatively, a spray-on adhesive can secure the attic joints from water seepage.[39] Roof-to-wall connections can be improved using support nails, strapping, and brackets that are strong enough to withstand high winds.[40] In addition, Safe Home recommends that roof decking have wood planks 12 inches wide secured with 2¼-inch nails.[41] To meet the Safe Home program requirements for wind uplift, fasteners for roofing that uses wood structural panels should be a maximum of six inches apart. Using permanent installations such as Bahama or accordion shutters along with "impact rated" windows, doors, and skylights can further strengthen houses against high winds.[42]

Financing Positive Outcomes

Funding for the grants comes in part from a 1 percent state tax on insurance premiums, which also includes the state's wind pool insurance policies.

The program offers matching and nonmatching grants of up to $5,000 for retrofits based on the value of the home and the homeowners' income.[43] Low-income homeowners of properties valued at less than $150,000 can receive grants in the maximum amount of $5,000 to use for the retrofits, whereas middle-income homeowners of properties valued between $150,000 to $300,000 are eligible for a matching grant, based on a dollar-for-dollar amount, not exceeding a state contribution of $5,000.[44]

Each year, the Safe Home awards approximately $2.2 million in grants to homeowners.[45] Since 2007, the program has issued more than 4,800 grants totaling more than $20.8 million.[46] Most homeowners (about 95%) use the funding to retrofit their roofs, and homeowners who opt to install impact-resistant windows and shutters report saving up to 29 percent on energy costs. Owners of homes retrofitted through the Safe Home program report that their homeowners insurance premiums fell by 24 percent. In addition, the South Carolina Department of Insurance estimates that the program reduces the societal costs of hurricane and wind damage by more than $83.2 million.[47]

MyStrongHome

The Safe Home program depends on government grants, and when the South Carolina Department of Insurance reaches its funding threshold, homeowners can turn to MyStrongHome (MSH).[48] A public benefit corporation that maintains a social mission in addition to its for-profit goals, MSH retrofits homes in hurricane-prone areas.[49] MSH emerged in 2012 in the aftermath of Superstorm Sandy, which caused up to $68.9 billion in damage.[50] The program currently helps homeowners living along the coasts of Alabama, Louisiana, and South Carolina retrofit their houses to withstand hurricane and wind damage at minimal or no upfront cost.[51] According to Ramsey Green, cofounder and chief operating officer of MSH, local, state, and federal governments have spent years looking for ways to strengthen homes in hurricane-prone areas despite volatile insurance prices. One effort to address this problem is the FORTIFIED Home standards program initiated by the Insurance Institute for Business & Home Safety (IBHS) in the years following Hurricane Katrina in 2005.[52] Investment funding from the Rockefeller Foundation and Prudential Insurance granted MSH the opportunity to test the business model in 40 pilot projects.[53]

Fortifying Houses

MSH incorporates a start-to-finish approach that maintains contact with the homeowner throughout the home assessment, construction process, insurance connection, and FORTIFIED Home certificate stages. MSH has no income requirements.[54] The program requires only that eligible homeowners reside in the MSH service area.[55]

FEMA Photo by Marvin Nauman

A home severely damaged by high winds in Sumter County, South Carolina.

The first part of the retrofit process is a home assessment to determine what retrofits are needed to withstand potential hurricane and wind damage. Shortly after registering online with MSH, the homeowner receives an estimate (conducted using Google Earth) for the cost of the retrofits and the value of the expected insurance savings. After a homeowner registers for MSH, contractors located within the area receive an email notifying them that the homeowner needs an onsite assessment.[56]

The homeowner decides whether to proceed with recommended retrofits based on different levels of IBHS standards: Bronze, Silver, or Gold. At the Bronze level, the homeowner can prioritize the roof, rafters, and gables using materials proven to withstand high winds.[57] To ensure that the plywood layer is well attached to the trusses, FORTIFIED Home standards require securing the roof decking with 8d ring shank nails that are 2 3/8 inches long to resist wind uplift.[58] In addition, reinforcing the gables and ensuring proper ventilation in the attic can limit water penetration during a storm.[59]

The higher FORTIFIED Home standards provide more comprehensive attention to the entire house. In addition to meeting the minimum Bronze standards, the Silver and Gold standards focus on openings such as garages, carports, porches, doors, and windows, which must be rated to withstand the area's typical exposure to wind speed and pressure. In addition, gables of more than 48 inches must be braced to resist high winds. Strong brackets and braces also ensure a continuous load connection among the roof, walls, and foundation.[60] Simulation studies by IBHS show that houses built to FORTIFIED Home standards perform considerably better than conventional houses when subjected to high wind and storm conditions.[61]

MyStrongHome

MyStrongHome provides homeowners with contractors who perform quality work to strengthen roofing against wind uplift.

Financing Retrofits Through Insurance Savings

Once retrofits are completed, MSH becomes the homeowner's insurance agent through its insurance partner, SageSure. A retrofitted home is less risky to insure, resulting in lower insurance premiums. The homeowners, however, continue paying the same premium amount that they paid before the retrofits, and MSH takes the difference between the new and old insurance premiums for seven years to cover the cost of the retrofit. After 7 years, the homeowner can pocket the insurance savings from a roof that will last between 20 and 30 years.[62]

Realizing the Benefits

Although MSH is still in its formative years, anecdotal evidence indicates that the 40 pilot projects throughout South Carolina, Alabama, and Louisiana are doing well. Hurricane Matthew impacted South Carolina in 2016, and according to Green, the MSH pilot houses "held up really well" during the storm.[63]

An estimated 75 percent of a coastal homeowner's premium can be attributed to hurricane and wind risk; by completing the retrofits, homeowners can save up to 48 percent on their insurance premiums.[64] The benefits of adopting hurricane- and wind-resistant building materials outweigh the costs of destruction following a natural disaster and the difficulties associated with finding temporary housing.[65] Furthermore, a major indication of success is determining the resale value of houses that are FORTIFIED Home certified. One study examined home resale value trends in Alabama from 2004 through 2016 and found a positive association between FORTIFIED Home retrofits and resale value.[66]

Conclusion

The Energy Savers program provides multifamily building owners with financing and construction resources to complete energy retrofits that reduce utility bills over time. Elevate Energy is currently developing partnerships beyond Illinois with organizations looking to learn from and replicate the Energy Savers model.[67] When sharing information across organizations that seek to finance energy retrofits, CIC's Young emphasizes the need to truly understand demand and owner preferences.

A key takeaway from the pilot stage of the Energy Savers Program was that building owners typically coupled retrofit activity with larger acquisition or refinance transactions and preferred a longer amortization period that would yield smaller monthly payments.[68]

The South Carolina Safe Home program offers eligible homeowners grants to finance retrofits to mitigate hurricane damage; however, a critical challenge of this program is its long waiting list and funding limits. MyStrongHome offers homeowners an innovative way to finance wind damage mitigation retrofits with minimal or no upfront costs. Green believes that room exists for competition in the private sector to develop new solutions to mitigate flood damage and reduce homeowners' flood insurance premiums.[69] Going forward, impact assessments will be useful for evaluating these programs' long-term effectiveness.[70] EM

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Additional Resources

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- Oak Ridge National Laboratory's "Innovations in Buildings" website contains research and tools that allow users to evaluate potential savings and get recommendations on insulation, roof surfaces, wall assemblies, and other materials based on user-specific data such as the size and climate of the home. **web.ornl.gov/sci/buildings/tools/**.

- "Tests and methods of evaluating the self-healing efficiency of concrete: A review" (2016), by Nasiru Zakari Muhammad and colleagues, surveys the research and methods used to test the ability and efficiency of concrete to self-heal cracks — an advance in the durability of residences built with concrete. **www.sciencedirect.com/science/article/pii/S095006181630304X**.

- The Home Innovation Research Labs "Home Innovation" website contains reports and other resources on a range of building topics, including energy efficiency, natural disaster mitigation, and structural performance. **www.homeinnovation.com**.

- "Affordable passive solar design in a temperate climate: An experiment in residential building orientation" (2011), by John Morrissey, Trivess Moore, and Ralph Horne, tests the effects of building orientation on the modeled energy efficiency of various design standards and their implications for costs and affordability. **www.sciencedirect.com/science/article/pii/S0960148110003836**.

- "Awareness, perceptions and willingness to adopt Cross-Laminated Timber by the architecture community in the United States" (2015), by Maria Fernanda Laguarda Mallo and Omar Espinoza, offers a case study examining the barriers to adoption of an innovative building material — Cross-Laminated Timber — in the United States. **www.sciencedirect.com/science/article/pii/S0959652615001031**.

- "A life-cycle framework for integrating green building and hazard-resistant design: examining the seismic impacts of buildings with green roofs" (2016), by Sarah J. Welsh-Huggins and Abbie B. Liel, presents a framework for assessing the environmental impacts and hazard resistance of buildings through the case study of an office building. **www.tandfonline.com/doi/abs/10.1080/15732479.2016.1198396**.

- "Multifamily Green Rehabilitation Guide" (2017), by International Center for Appropriate and Sustainable Technology, provides information on the performance of energy-efficient retrofits for multifamily affordable housing and identifies ways to overcome the split-incentive barrier. **www.icastusa.org/wp-content/uploads/2017/01/ICAST-Multifamily-Green-Rehab-Resource-Guide-Old.pdf**.

For additional resources archive, go to **www.huduser.gov/portal/periodicals/em/additional_resources_2017.html**.

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