National Institute of BUILDING SCIENCES™
Innovative Solutions for the Built Environment

Mitigation Saves:
Mitigation Saves up to $13 per $1 Invested

EVERY AMERICAN FACES NATURAL HAZARDS, AND THE RISK IS GROWING

U.S. disaster losses from wind, floods, earthquakes, and fires now average $100 billion per year, and in 2017 exceeded $300 billion—25% of the $1.3 trillion building value put in place that year. Fortunately, there are affordable and highly cost-effective strategies that policymakers, building owners, and the building industry can deploy to reduce these impacts. These strategies include adopting and strengthening building codes, upgrading existing buildings, and improving utilities and transportation systems. The benefits and costs associated with these mitigation measures have been identified through the most exhaustive benefit-cost analysis of natural hazard mitigation to date and documented in Natural Hazard Mitigation Saves. The study was funded by three federal agencies and four private-sector sponsors and produced by the National Institute of Building Sciences – the nation's Congressionally chartered convener of experts from the building professions, industry, labor, consumer interests, and government. For the report and accompanying fact sheets, see www.nibs.org/mitigationsaves. This fact sheet summarizes the study findings and significant savings associated with various mitigation measures.

- **Adopting the latest building code requirements is affordable and saves $11 per $1 invested.** Building codes have greatly improved society's disaster resilience, while adding only about 1% to construction costs relative to 1990 standards. The greatest benefits accrue to communities using the most recent code editions.
- **Above-code design could save $4 per $1 cost.** Building codes set minimum requirements to protect life safety. Stricter requirements can cost-effectively boost life safety and speed functional recovery.
- **Private-sector building retrofits could save $4 per $1 cost.** The country could efficiently invest over $500 billion to upgrade residences with 15 measures considered here, saving more than $2 trillion.
- **Lifeline retrofit saves $4 per $1 cost.** Society relies on telecommunications, roads, power, water, and other lifelines. Case studies show that upgrading lifelines to better resist disasters helps our economy and society.
- **Federal grants save $6 per $1 cost.** Public-sector investment in mitigation since 1995 by FEMA, EDA, and HUD cost the country $27 billion but will ultimately save $160 billion, meaning $6 saved per $1 invested.

National Institute of BUILDING SCIENCES™	ADOPT CODE	ABOVE CODE	BUILDING RETROFIT	LIFELINE RETROFIT	FEDERAL GRANTS
Overall Benefit-Cost Ratio	11:1	4:1	4:1	4:1	6:1
Cost ($ billion)	$1/year	$4/year	$520	$0.6	$27
Benefit ($ billion)	$13/year	$16/year	$2200	$2.5	$160
Riverine Flood	6:1	5:1	6:1	8:1	7:1
Hurricane Surge	not applicable	7:1	not applicable	not applicable	not applicable
Wind	10:1	5:1	6:1	7:1	5:1
Earthquake	12:1	4:1	13:1	3:1	3:1
Wildland-Urban Interface Fire	not applicable	4:1	2:1	not applicable	3:1

TABLE 1. Nationwide average benefit-cost ratio by hazard and mitigation measure. BCRs can vary geographically and can be much higher in some places. Find more details in the report.

THERE ARE MANY WAYS TO BETTER PROTECT SOCIETY FROM NATURAL DISASTERS

NIBS has updated and expanded its groundbreaking 2005 study for the U.S. Congress on the cost-effectiveness of natural-hazard mitigation. The new study examines more approaches to mitigation, beyond the federally funded retrofit measures considered in the first study. Other fact sheets summarize these big takeaways:

Adopting and enforcing current building codes is among the most efficient ways to build a resilient society.

- The home of Pamela and Warren Adams in Gilchrist, Texas, survived Hurricane Ike in 2008 because it complied with code requirements for elevation. Neighbors with noncompliant homes lost everything.
- Building 1 foot above the 100-year flood elevation is cost effective, adding only $90 million of construction cost per year for new construction, while saving $550 million, a 6-to-1 benefit-cost ratio.
- Building-code hurricane requirements save an average of $10 per $1 of added cost ($5.6 billion saved for an annual investment of $540 million), with benefit-cost ratios that reach as high as 30 to 1.
- Enhanced earthquake design requirement over the last 30 years save $7 billion per year of new construction while only adding $600 million per year in construction cost, with benefit-cost ratios that in some places reach as high as 32 to 1.

Model codes make buildings safe, but above-code design can reduce both damage and long-term costs.

- Paul Jackson of Mexico Beach, Florida, built his home to comply with the higher requirements of IBHS FORTIFIED Home. His home survived Hurricane Michael. Those of his neighbors didn't.
- Buildings in riverine floodplains could cost-effectively be built with up to 5 feet of freeboard rather than 1 foot, saving $4.2 billion in avoided future losses at a cost of $900 million, a savings of 5 to 1.
- In most coastal locations subject to hurricane surge, it can be cost effective to build the first floor up to 10 feet above base flood elevation, in some places saving more than $12 per $1 of added cost.
- Building along the Gulf and Atlantic coasts to comply with IBHS FORTIFIED Home requirements would cost $720 million, but save $3.8 billion per year, with some benefit-cost ratios over 16:1.
- New buildings in earthquake country could be made 3 times stronger and stiffer than code and cost less in the long run: $4.3 billion saved for $1.2 billion cost. Some places save more than $8 per $1 invested.
- In 10,000 census blocks across the country, adopting the International Wildland-Urban Interface Code would cost $800 million per year and save $3 billion, with some places saving over $6 per $1 invested.

The nation could invest over $500 billion to retrofit existing buildings but save over $2.2 trillion.

- Anheuser-Busch spent $11 million to retrofit its Van Nuys, California brewery just before the 1994 Northridge earthquake and saved $2 billion, while protecting its market share and employees.
- More than 1 million older houses stand in the 100-year floodplain. Buyouts, elevation projects, and other retrofits could save society $1.3 trillion at a cost of $230 billion—$6 saved per $1 invested.
- Private-sector retrofits for hurricane could save society $140 billion at a cost of $24 billion—a 6:1 benefit-cost ratio from retrofitting 3 million single-family dwellings and 130,000 manufactured homes.
- Seismic retrofits could save $330 billion at a cost of $25 billion by fixing soft-story dwellings, adding engineered tie-down systems to manufactured homes, and several low-cost nonstructural measures.
- It would save $430 billion to make 2.5 million homes in the wildland-urban interface comply with the 2018 International Wildland-Urban Interface Code. It would cost between $53 billion and $240 billion to do so, so the nationwide benefit-cost ratio could be as high as 8:1 or conservatively 2:1

Retrofitting lifelines protects the whole economy, saving up to $31 per $1 invested.

- A grant to Greenville Utilities of North Carolina was used to raise a berm and floodwall around its water treatment plant, protecting it from more than 3 feet of flooding during Hurricane Matthew in 2016.
- Activities that enhance resilience of water and wastewater facilities, electric utility substations, roads and railways, and communications equipment yielded benefit-cost ratios as high as 31 to 1.

Federal grants saved $160 billion and cost $27 billion, a 6:1 ratio, with savings in each state.

- Buyouts after the 1993 Midwest floods brought people peace of mind and protection.
- A variety of federal mitigation grants to make public buildings better resist floods, earthquakes, and hurricanes save the federal treasury almost $1 billion annually.

MUCH REMAINS UNKNOWN ABOUT POTENTIALLY VALUABLE MITIGATION MEASURES

No study provides all the answers. Figures 1-5 illustrate open questions about high-risk commercial buildings, business continuity plans, stricter lifeline design, warning systems, and protecting vulnerable populations.

Many more questions beg for answers that could save the nation billions of dollars and thousands of lives:

- What shall we do about tens of thousands of elevators that lack emergency power, and could trap occupants for days after a big earthquake?

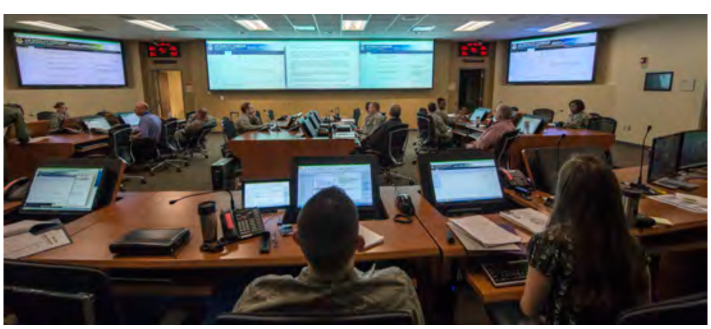

FIGURE 1. Continuity plans can make the difference between business survival and bankruptcy. What is their benefit-cost ratio?

FIGURE 2. Should we ignore, fix, or demolish thousands of vulnerable concrete and steel-frame buildings in earthquake country?

FIGURE 3. Should utilities and transportation infrastructure be designed to remain functional rather than merely not kill people?

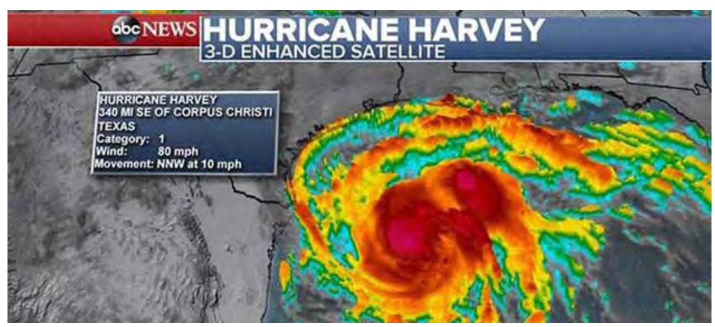

FIGURE 4. Government warning systems can provide hours or days of advanced warning. Does it make sense to cut their budget?

FIGURE 5. Disasters hit disadvantaged populations harder. How can benefit-cost analyses better account for that?

- Would it make sense to repair damaged buildings and infrastructure to current or above-code levels?
- How broadly does design or upgrade to meet or exceed code levels improve resale value?
- What are the most affordable, cost-effective measures for improving schools and other critical facilities?
- Does the Federal Office of Management and Budget (OMB) statutory discount rate of 7% make economic and ethical sense?
- Does OMB's valuation of mitigation measures accurately capture their benefit to the U.S. government?
- How can the economic analysis tools used by the Congressional Budget Office (CBO) Joint Committee on Taxation (JCT) be improved to adequately estimate future benefits of mitigation?
- How cost effective is incremental rehabilitation: strengthening buildings during normal maintenance?
- How can code developers estimate the benefits of new requirements when they consider adopting them?
- How can the people who benefit from mitigation without paying for it fairly incentivize owners to improve new and existing buildings?
- How can we best teach ordinary people about mitigation and resilience?

NIBS hopes to answer these questions and more, in furtherance of its mission to resolve present and future problems and to promote the construction of safe, affordable structures for housing, commerce, and industry throughout the United States. To help NIBS do that, please contact Jiqiu (JQ) Yuan, jyuan@nibs.org, Executive Director of the Multihazard Mitigation Council and Building Seismic Safety Council, National Institute of Building Sciences. Visit nibs.org to learn more about how NIBS helps to advance building sciences and technology for the benefit of the nation.

HURRICANE WIND
FACT SHEETS

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Mitigation Saves:
Hurricane Requirements Save $10 for Each $1 Invested

MEETING COMMON CODE REQUIREMENTS FOR HURRICANE

In 1990, just before Hurricane Andrew struck, new buildings built to the 1990 BOCA National Building Code or the 1991 Standard Building Code had several vulnerabilities when subjected to intense hurricane winds. Poor connections between roof and walls, loss of roof decking, increased internal pressures, and water intrusion from windborne debris penetrating the building envelope, amongst many other deficiencies, resulted in widespread hurricane wind damage. Substantive changes to building codes were applied to mitigate these deficiencies. Codes were further strengthened in successive editions based on lessons learned after later hurricanes. These aspects of the 2018 I-Codes save $5.6 billion in the long term for every year of new buildings built to the code, at a cost of $540 million, producing a benefit-cost ratio of 10:1. Figure 1 shows the sources of these benefits. Figure 2 shows that the benefitcost ratio is highest at locations nearest the Gulf and Atlantic Coasts where hurricane winds are strongest and most frequent.

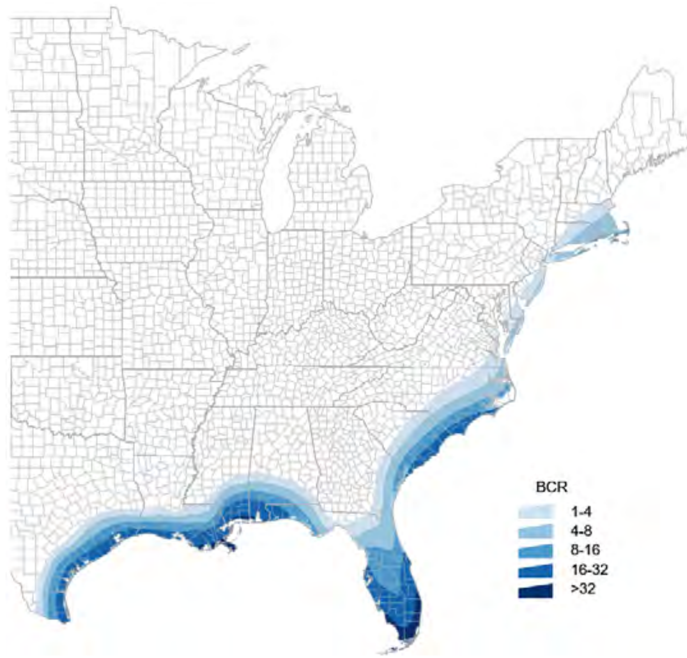

FIGURE 2. Stakeholder net benefits of new design to comply with 2018 IBC and IRC requirements, relative to 1990 requirements.

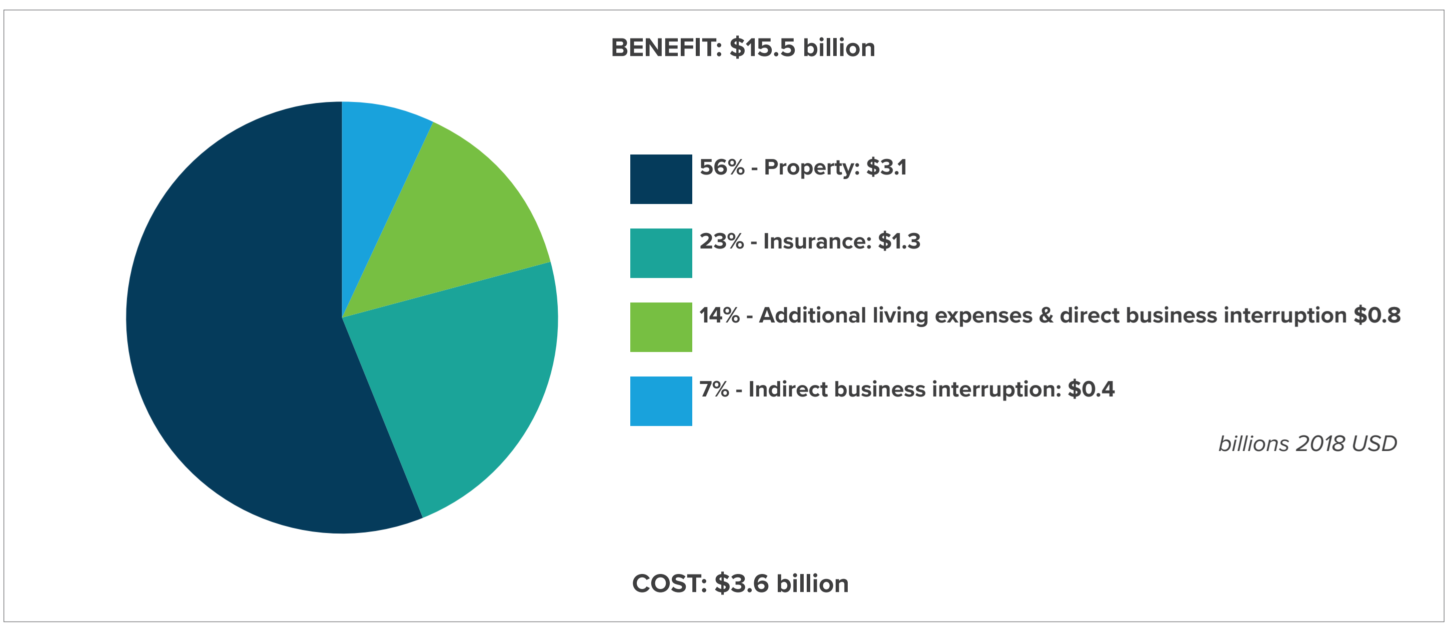

FIGURE 1. Total costs and benefits of new design to comply with 2018 I-Code requirements for hurricane, relative to 1990.

RESULTS OF EXCEEDING CODE FOR HURRICANE WIND

If all new homes were built to the incrementally efficient maximum (IEMax) Insurance Institute for Business and Home Safety (IBHS) FORTIFIED Home program level for 1 year, it would cost approximately $720 million extra and would produce approximately $3.8 billion in avoided future losses. The aggregate benefit-cost ratio (BCR) (summing benefits and costs over all states) is approximately 5:1, e.g., $5 saved for every $1 spent to build new buildings better along the Gulf and Atlantic Coasts.

Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the overall ratio of costs to benefits for the design of new buildings to exceed hurricane related coastal flooding requirements of the 2015 IRC. Compliance with the IBHS FORTIFIED Home Hurricane program appears to be cost-effective everywhere along the Atlantic and Gulf Coast. The IEMax FORTIFIED level varies by state, as illustrated in Figure 2. The project team aggregated state and local BCRs to determine the national-level BCR. The costs reflect only the added cost relative to the 2015 IRC.

The stringency of codes adopted at the state and local level varies widely. The project team used the unamended 2015 IBC and IRC as the baseline minimum codes for this study. While minimum codes provide a significant level of safety, society can save more by designing some new buildings to exceed minimum requirements of the 2015 Codes. Where communities have an older code or no code in place, additional costs and benefits will accrue. If all new buildings built the year after were also designed to exceed select I-Code requirements, the benefits would be that much greater, in proportion to the quantity of new buildings.

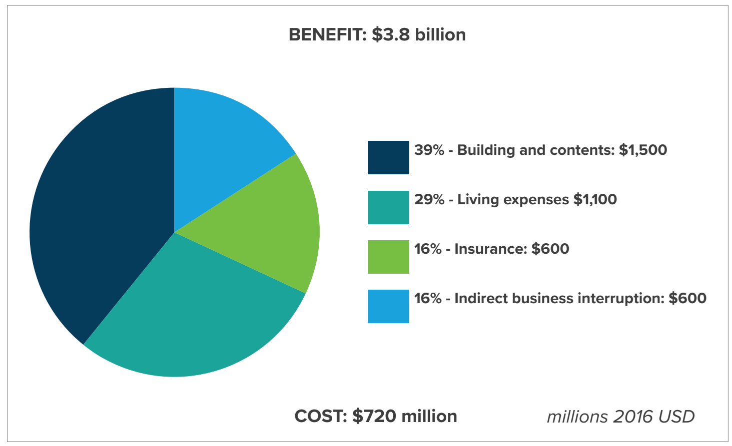

FIGURE 1. Benefits and costs for 1 year of new construction at the IEMax IBHS FORTIFIED Home Hurricane levels.

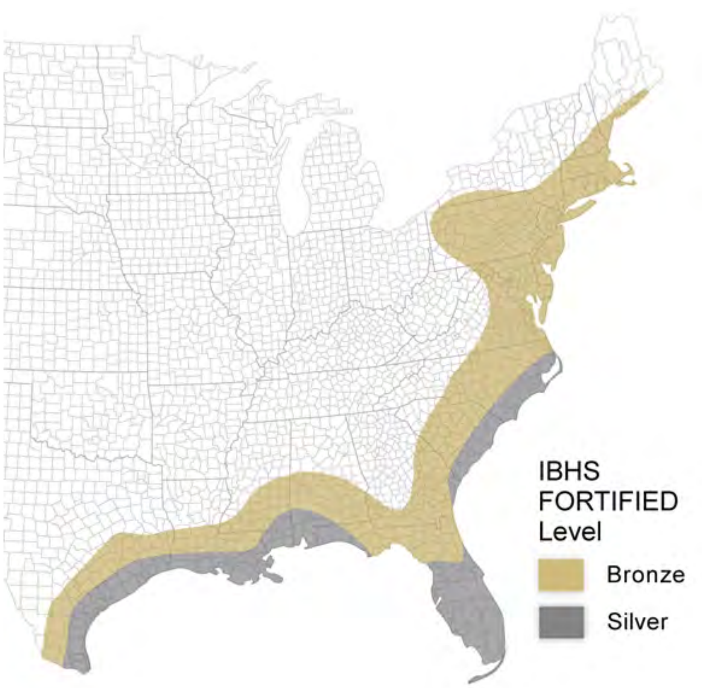

FIGURE 2. Maximum level of the IBHS FORTIFIED Home Hurricane design for new construction where the incremental benefit remains cost-effective.benefit remains cost-effective.

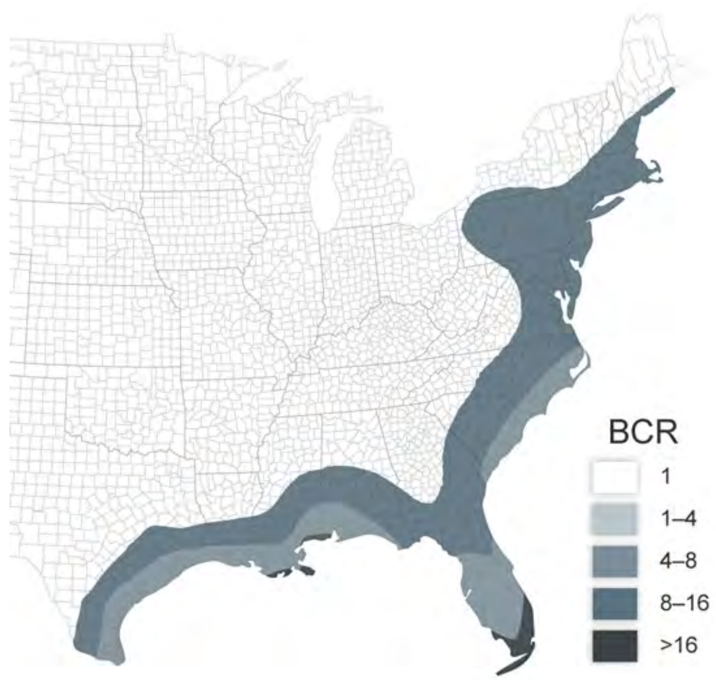

FIGURE 3. BCR of hurricane wind mitigation by building new homes under the FORTIFIED Home Hurricane Program
(by wind band).

PRIVATE-SECTOR RETROFITS FOR HURRICANE COULD SAVE SOCIETY OVER $140 BILLION

The International Residential Code and International Building Code provide minimum life-safety requirements for new buildings. The U.S. Department of Housing and Urban Development develops structural design and installation requirements for manufactured housing. Both the I-Codes and HUD requirements have developed over time, but there is room for improvement for 130,000 manufactured homes along the Gulf and Atlantic coasts that are not anchored to the ground, and 3 million single-family dwellings there have relatively weak roofs, windows, doors, and connections.

To make those single-family dwellings more hurricane resistant, one can use the Insurance Institute for Business and Home Safety's (IBHS) FORTIFIED Home Hurricane standards. Applying the IBHS standards where they would be most cost effective would cost $24 billion, but save society $141 billion in the long run -- a benefit-cost ratio of 6:1. Adding an engineered tie-down system (ETS) to the unanchored manufactured homes would cost $200 million and save $800 million, or $4 saved per $1 spent. Together, the two measures would save society approximately $142 billion at a cost of $24 billion, a 6:1 benefit-cost ratio. Figure 1 shows the sources of these benefits, totaling the two hurricane retrofit options considered here, and rounding slightly to reduce the appearance of excessive accuracy. The benefit-cost ratios are greatest for homes near the coast. Figure 2 shows that BCRs can exceed 8:1 for either retrofit measure.

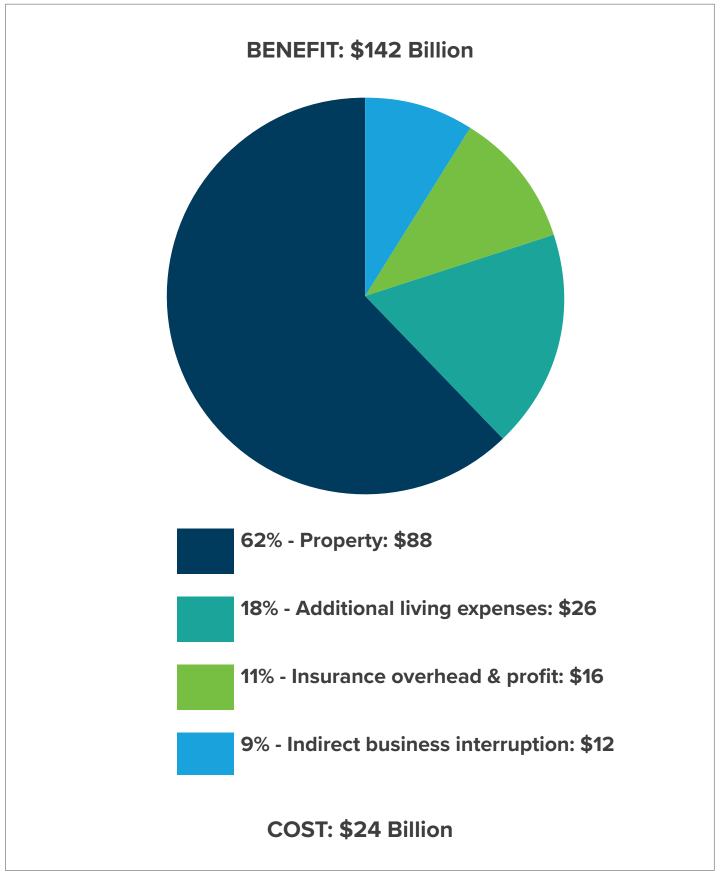

FIGURE 1. Total costs and benefits of private-sector retrofit options considered here.

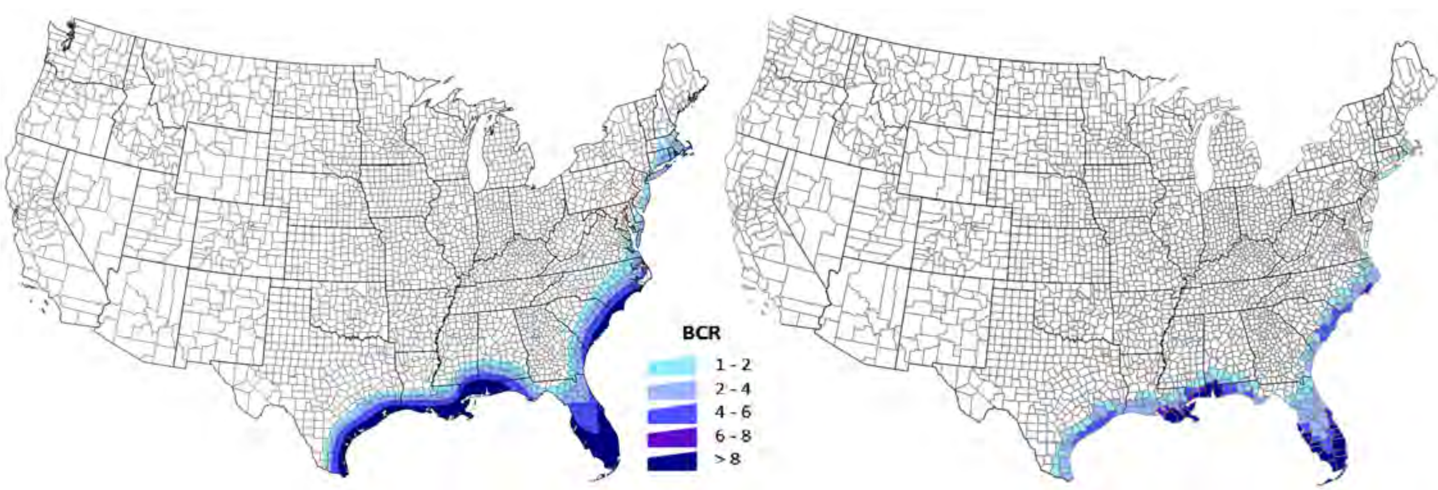

FIGURE 2. Benefit-cost ratios of hurricane retrofit measures: (left) IBHS FORTIFIED Home Hurricane retrofit; (right) adding an engineered tie-down system to an unanchored manufactured home.

RESULTS OF FEDERAL GRANTS FOR FIRE MITIGATION

Federal grants to mitigate wind damage are highly cost-effective. In 23 years, public entities have spent $13.6 billion to mitigate future wind losses; these efforts will ultimately save the United States an estimated $70 billion in avoided property losses, additional living expenses, business impacts, and deaths, injuries, and post-traumatic stress disorder (PTSD). Their total benefit-cost ratio (BCR) is approximately 5:1.

For wind resistance the mitigation measures examined include the addition of shutters, safe rooms, and other common measures. Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the benefits specifically attributable to federal flood mitigation grants. The national-level BCRs aggregate study findings across natural hazards and across state and local BCRs.

The estimated BCR depends largely on the level of hazard, alternative use of the facility, and accessibility. In-home safe rooms generally appear to be cost-effective, exhibiting an average BCR of 4.25. Large facilities with dual purposes, such as school gymnasia and cafeterias, exhibit an average BCR of 8.0. In these cases, the cost of mitigation is simply the additional cost of hardening the facility.

Accessibility and use also strongly affect cost-effectiveness. For example, a shelter located at a hospital will likely protect life at any time of day throughout the year. Shutters appear to be highly cost-effective, particularly those that protect valuable equipment at utilities or industrial facilities. Shutters for ordinary public buildings without high-value contents produce a lower but still impressive BCR (about 3.5).

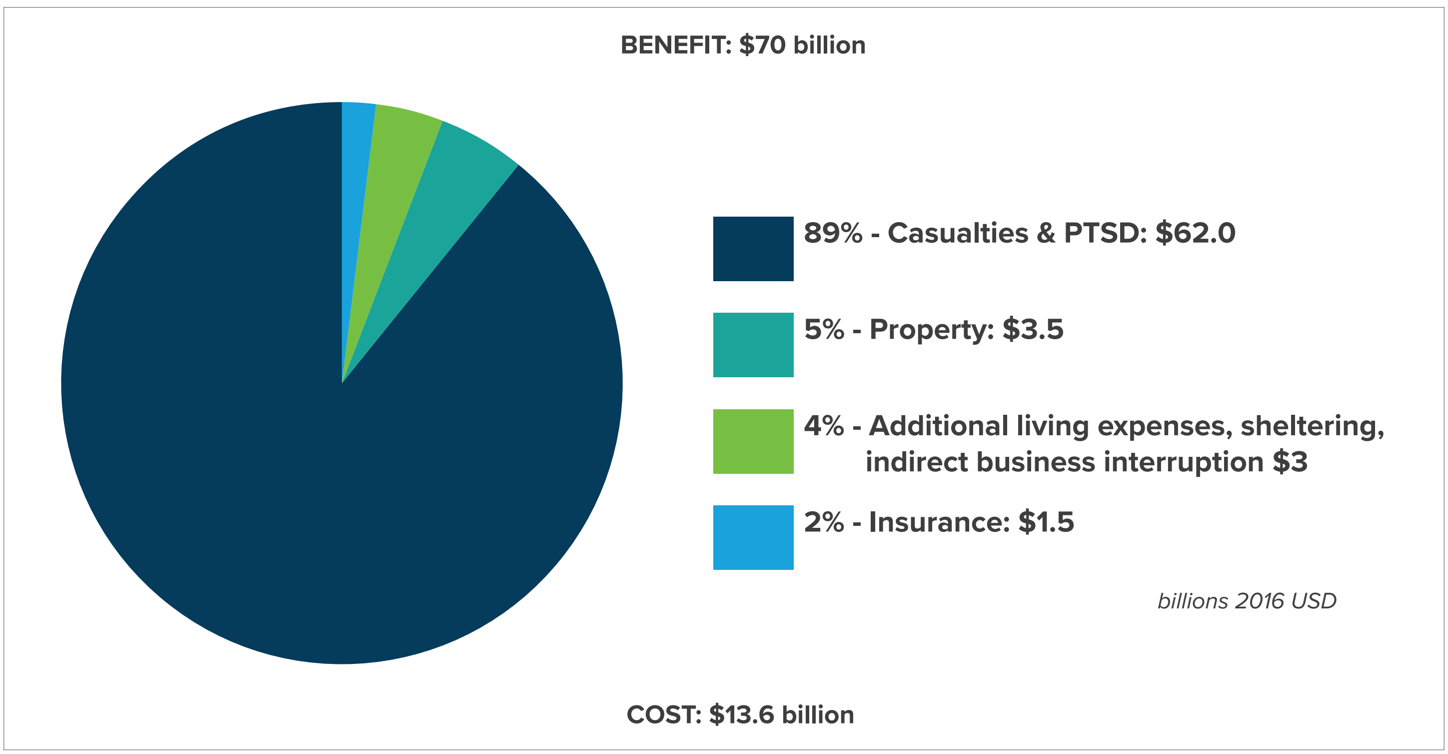

FIGURE 1. Contribution to benefit from federally funded wind grants.

FLOOD/SURGE
FACT SHEETS

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Mitigation Saves:
Common Flood Requirements Save $6 for Each $1 Invested

MEETING COMMON CODE REQUIREMENTS FOR RIVERINE FLOOD

In 1990, new buildings were commonly required to be built so that their first floor elevation was at the height of the special flood hazard area, commonly called the base flood elevation (BFE) or 100-year floodplain. The 2018 I-Codes require the first floor to be 1 foot above BFE. This aspect of the 2018 I-Codes saves $550 million in the long term for every year of new buildings built to the code, at a cost of $90 million, producing a benefit-cost ratio of 6:1. Figure 1 shows the source of the benefits. Figure 2 shows that all stakeholder groups enjoy a net benefit from this requirement.

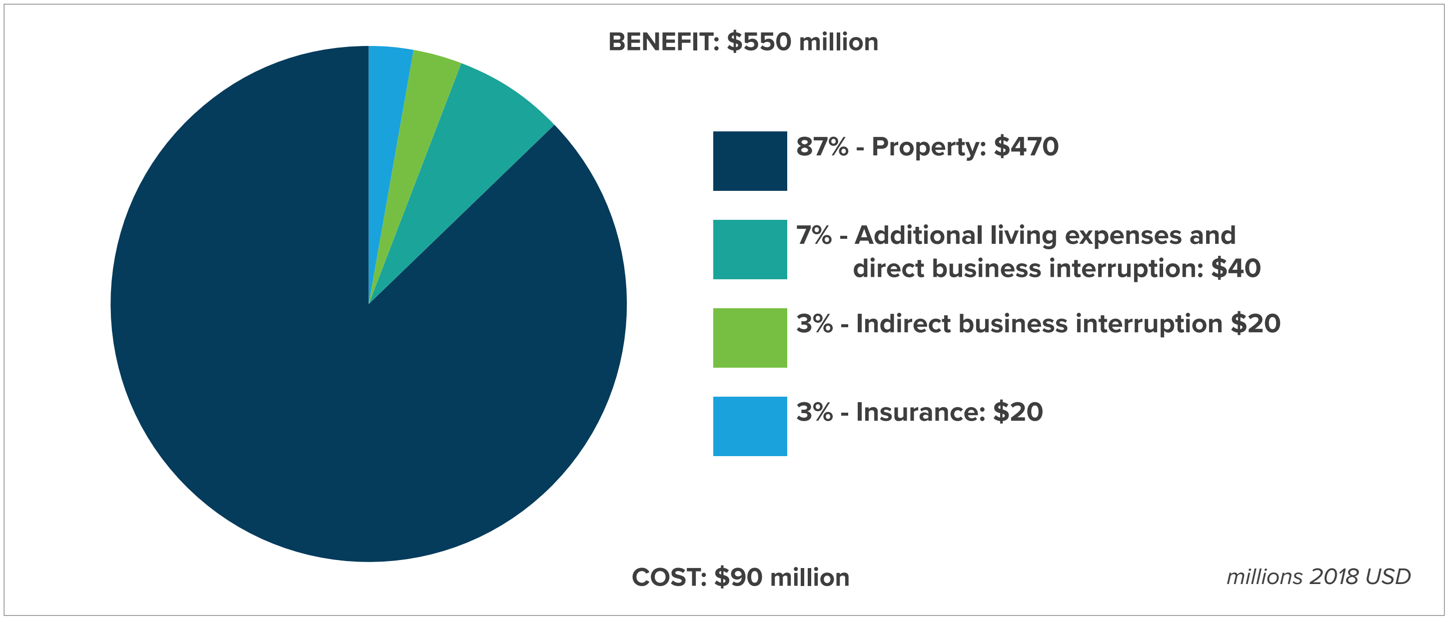

FIGURE 1. Total costs and benefits of new design to comply with 2018 I-Code requirements for flood, relative to 1990.

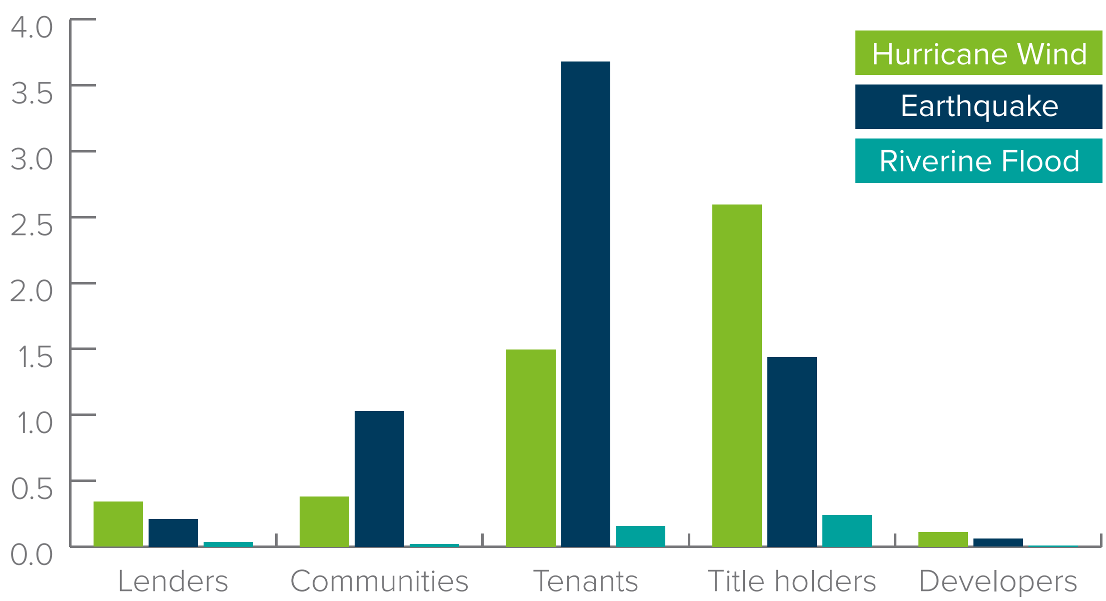

FIGURE 2. Stakeholder net benefits of new design to comply with 2018 IBC and IRC requirements, relative to 1990 requirements.

Mitigation Saves:
Riverine Flooding: Designing to Exceed 2015 Codes Provides $5 Benefit for Each $1 Invested

RESULTS OF EXCEEDING CODE FOR RIVERINE FLOODING

The cost to build all new buildings 5 feet above the base flood elevation (BFE) for one year is approximately $900 million. This would produce approximately $4.2 billion in benefits, for an aggregate benefit-cost ratio (BCR) of approximately 5:1, e.g., $5 saved for every $1 spent to build new buildings higher out of the floodplain.

Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the overall ratio of costs to benefits for the design of new buildings to exceed riverine flooding requirements of the 2015 IBC. The strategy to exceed minimum requirements of the 2015 Codes for riverine flooding is to build new buildings in the 1% annual chance floodplain higher above base flood elevation (BFE) than required by the 2015 IBC. The project team aggregated state and local BCRs to determine the national-level BCR. The costs reflect only the added cost relative to the 2015 IBC.

The stringency of codes adopted at the state and local level varies widely. The project team used the unamended 2015 IBC and IRC as the baseline minimum codes for this study. While minimum codes provide a significant level of safety, society can save more by designing some new buildings to exceed minimum requirements of the 2015 Codes. Where communities have an older code or no code in place, additional costs and benefits will accrue. If all new buildings built the year after were also designed to exceed select I-Code requirements, the benefits would be that much greater, in proportion to the quantity of new buildings.

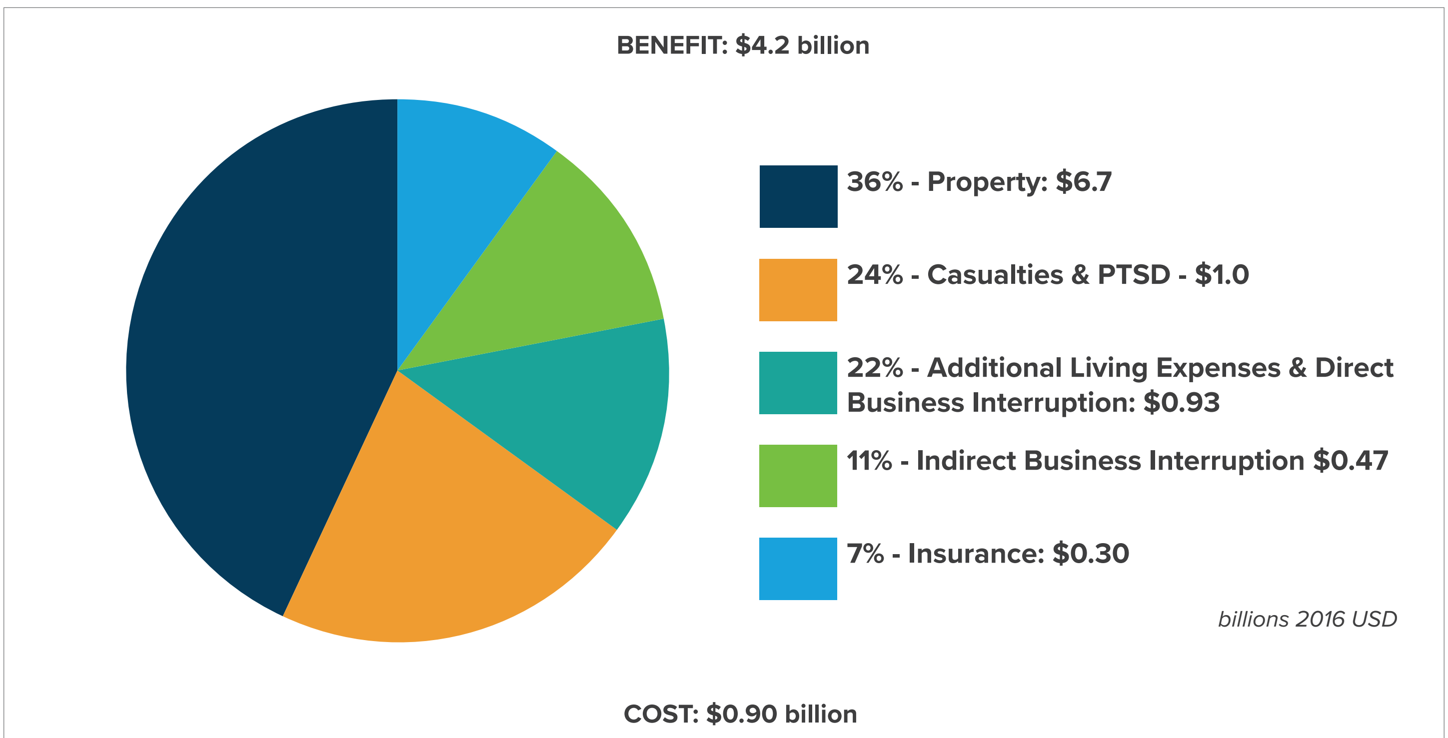

FIGURE 1. Nationwide benefits by category for designing to exceed 2015 I-Code requirements for flood.

RESULTS OF EXCEEDING CODE

Building new single-family dwellings higher above the base flood elevation (BFE) than the 1-foot required by the 2015 IRC appears to be cost-effective in coastal surge areas identified as V or VE by FEMA in all states. Surge in coastal V-zones is different from riverine flooding, and so its costs and benefits are different.

When the incrementally efficient maximum (IEMax) increase in building height is assessed on a state level, the aggregate BCR (summing benefits and costs over all states) is approximately 7:1, e.g., $7 saved for every $1 spent to build new coastal buildings in V- and VE-zones higher above the shoreline. It would cost approximately $7 million extra to build all new buildings to the IEMax elevation above BFE for one year, and would produce approximately $51 million in benefits.

Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the overall ratio of costs to benefits for the design of new buildings to exceed hurricane related coastal flooding requirements of the 2015 IRC. The IEMax additional height varies by state, as illustrated in Table 2. The results strongly suggest that greater elevation of new coastal single-family dwellings in V-zones is widely cost-effective. All states have an IEMax building height above code of at least 5 feet. These costs and benefits refer to building new coastal single-family dwellings higher above BFE, not of elevating existing houses. The project team aggregated state and local BCRs to determine the national-level BCR. The costs reflect only the added cost relative to the 2015 IRC.

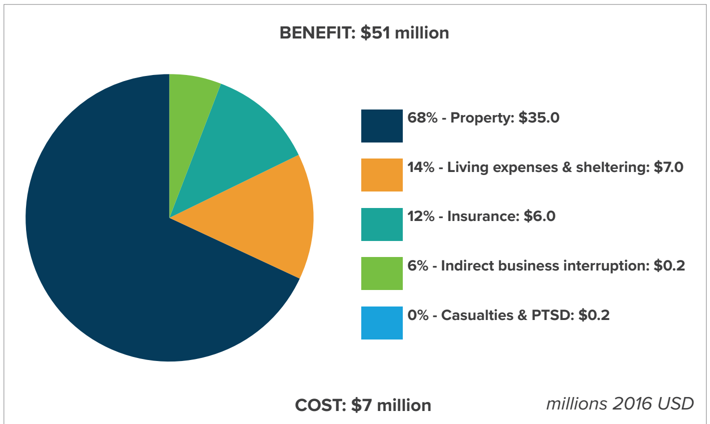

FIGURE 1. Nationwide benefits by category for designing to exceed 2015 I-Code requirements for flood.

The stringency of codes adopted at the state and local level varies widely. The project team used the unamended 2015 IBC and IRC as the baseline minimum codes for this study. While minimum codes provide a significant level of safety, society can save more by designing some new buildings to exceed minimum requirements of the 2015 Codes. Where communities have an older code or no code in place, additional costs and benefits will accrue. If all new buildings built the year after were also designed to exceed select I-Code requirements, the benefits would be that much greater, in proportion to the quantity of new buildings.

STATE	FIRST FLOOR HEIGHT ABOVE BFE UP TO IEMAX	BCR
Texas	+2 to 8	20.2 to 9.1
Louisiana	+2 to 10	11.3 to 4.8
Mississippi	+2 to 10	27.6 to 10.1
Alabama	+2 to 10	31.1 to 11.7
Florida	+2 to 10	21.1 to 8.4
Georgia	+2 to 6	6.7 to 3.8
South Carolina	+2 to 10	11.8 to 5.0
North Carolina	+2 to 10	12.6 to 5.2
Virginia	+2 to 6	6.7 to 3.8
Delaware	+2 to 6	6.7 to 3.8
Maryland	+2 to 6	6.7 to 3.8
New York	+2 to 6	6.7 to 3.8
New Jersey	+2 to 6	6.7 to 3.8
Connecticut	+2 to 6	6.7 to 3.8
Rhode Island	+2 to 6	6.7 to 3.8
Massachusetts	+2 to 6	6.9 to 3.9
TOTAL		**16.9** to **7**

TABLE 2. BCRs for various heights above BFE for new coastal V-zone buildings up to the point where the incremental benefitremains cost-effective.benefitremains cost-effective.

Mitigation Saves:
For Hurricane Surge, Designing to Exceed 2015 Codes Provides $7 Benefit for Each $1 Invested

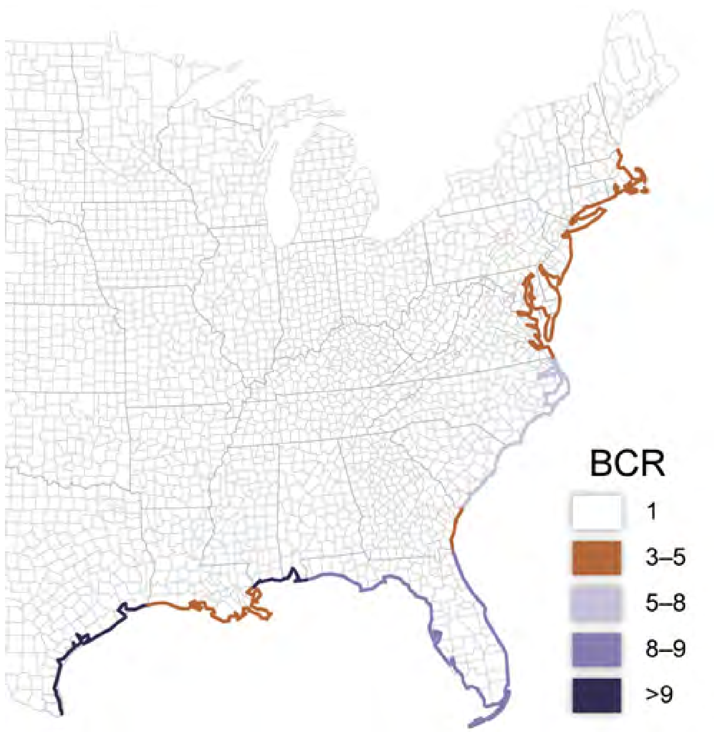

FIGURE 2. BCR of coastal flooding mitigation by elevating homes above 2015 IRC requirements (by state).

Mitigation Saves:
Private-Sector Flood Retrofit Saves $6 for Each $1 Invested

RETROFITTING PRIVATE-SECTOR BUILDINGS FOR FLOOD COULD SAVE SOCIETY $1.3 TRILLION

Recent code developments require new buildings to have up to 2 feet of freeboard—the difference between the elevation of the lowest floor and that of the floodwaters that have 1% probability of being exceeded in any given year (or just over 50% chance of being exceeded in 75 years). That means buildings that predate modern codes can be much more susceptible to flooding.

More than 1 million older houses currently stand in the 100-year floodplain and are more likely than not to be flooded during their economically useful life. A variety of retrofit measures could make these buildings safer and more efficient to own, meaning that a retrofit investment now would make their long-term cost of ownership lower. A combination of buyouts, elevation projects, and less-expensive modifications to basements, heating, and air conditioning equipment could save society almost $1.3 trillion at a cost of approximately $230 billion—a benefit-cost ratio of $6 saved per $1 invested.

Removing many of these houses from the floodplain and converting their land to open space could avoid almost $1.2 trillion in future losses at a cost of $180 billion—a BCR of over 6:1. It is practical to raise many of these buildings to have a taller foundation (called elevation retrofits). Doing so could save society $84 billion at a cost of $43 billion: $2 saved per $1 invested.

A less-expensive measure called wet floodproofing, which involves the removal of damageable finishes and contents from basements, could prevent $7.7 billion in future losses at a cost of $3.2 billion, saving over $2 per $1 invested. Elevating air conditioning equipment and ductwork above the 100-year flood elevation could save $1.1 billion at a cost of $700 million, a 2:1 benefit-cost ratio. And elevating heaters and furnaces could save $2.7 billion at a cost of $1.2 billion, another 2:1 BCR. Figure 1 shows the sources of these benefits, totaling over the five private-sector flood retrofit options considered here, and rounding slightly to avoid the appearance of excessive accuracy.

The total number of older buildings in the floodplain is uncertain. It could be much greater than 1 million, in which case the dollar figures presented here would increase in proportion.

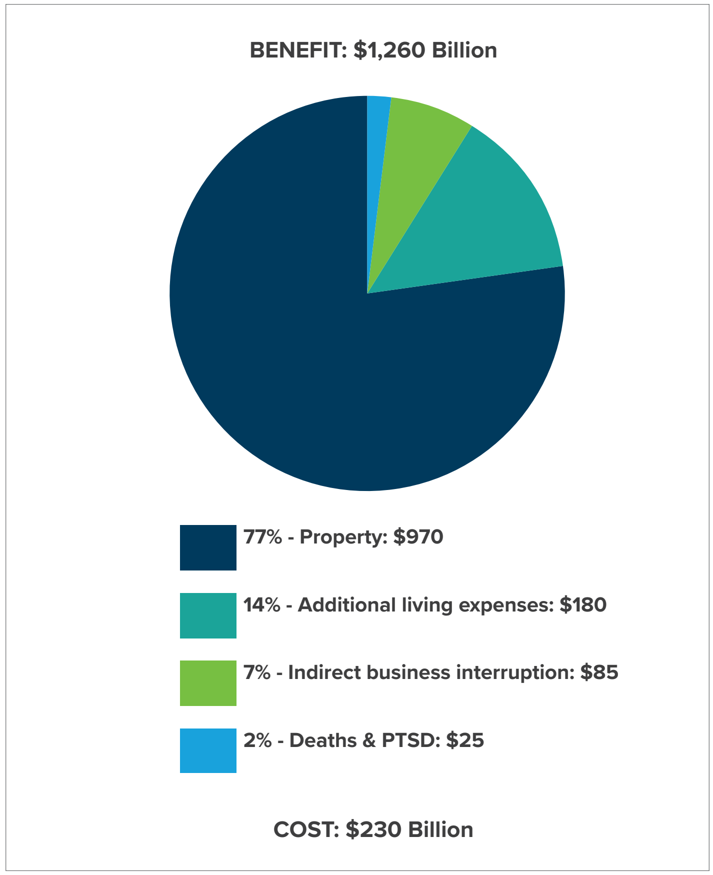

FIGURE 1. Total costs and benefits of private-sector retrofit options

Mitigation Saves:
For Riverine Flood Mitigation, Federal Grants Provide $7 Benefit for Each $1 Invested

RESULTS OF FEDERAL GRANTS FOR FIRE MITIGATION

The public-sector mitigation strategy examined for flood resistance is the acquisition or demolition of flood-prone buildings, especially single-family dwellings, manufactured homes, and 2- to 4-family dwellings. While the benefit-cost ratio (BCR) varies across projects, public-sector mitigation spending for the acquisition of buildings exposed to riverine flooding appears to be cost-effective. The average BCR across the sample projects is approximately 7:1. The implication is that past federally funded riverine flood mitigation is cost-effective (at the cost-of-borrowing discount rate). Given that the total cost of all riverine flood-mitigation grants was $11.5 billion, a BCR of 7:1 implies that federally funded flood mitigation will ultimately save the United States $82 billion. Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the benefits specifically attributable to federal flood mitigation grants. The national-level BCRs aggregate study findings across natural hazards and across state and local BCRs.

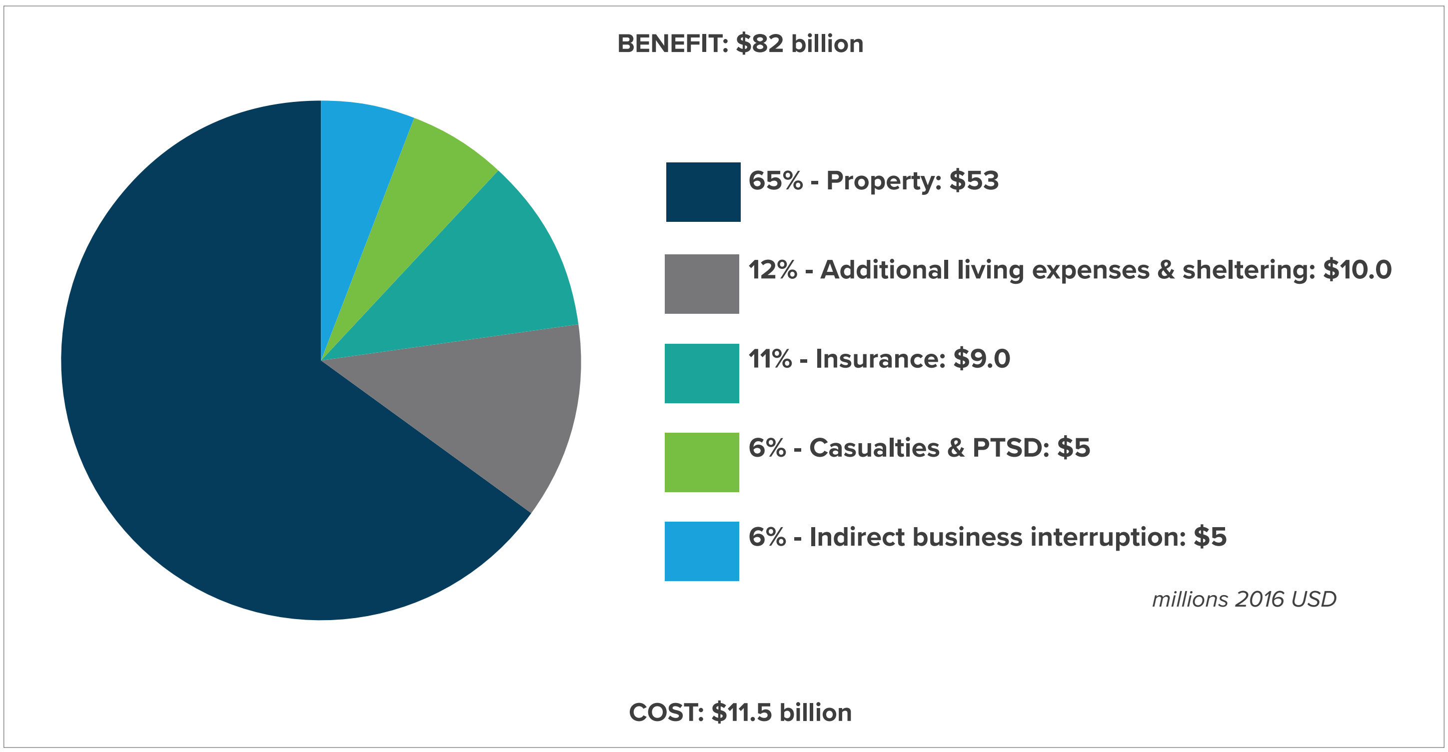

FIGURE 1. Contribution to benefit from federally funded riverine flood grants.

EARTHQUAKE
FACT SHEETS

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Mitigation Saves:
Earthquake Requirements Save $12 for Each $1 Invested

MEETING COMMON CODE REQUIREMENTS FOR EARTHQUAKE

Over the long term, building codes have gradually increased the required strength and stiffness of new buildings to resist earthquakes, along with numerous improvements to structural details. Building strength and stiffness increases on the order of 50% every 30 years in the higher-risk areas in the western United States. Thus, the average West Coast building built today to comply with I-Codes is about 1.5 times as strong and stiff as it would have been under the 1988 Uniform Building Code. The greater strength makes the building less likely to collapse or to be red-tagged in a large earthquake. The greater stiffness makes it less likely to suffer damage to many architectural elements such as walls and windows. These aspects of the 2018 I-Codes save $7 billion in the long term for every year of new buildings built to the code, at a cost of $600 million, producing a benefit-cost ratio of 12:1. Figure 1 shows the sources of these benefits. Figure 2 shows that benefit-cost ratios are highest in high-seismicity areas. Note that in much of the country, wind design forces exceed those for earthquake, so those areas are shown in gray, along with a small portion of Oklahoma where design forces have been raised to better protect people from seismicity associated with deep well injection of fracking waste fluid.

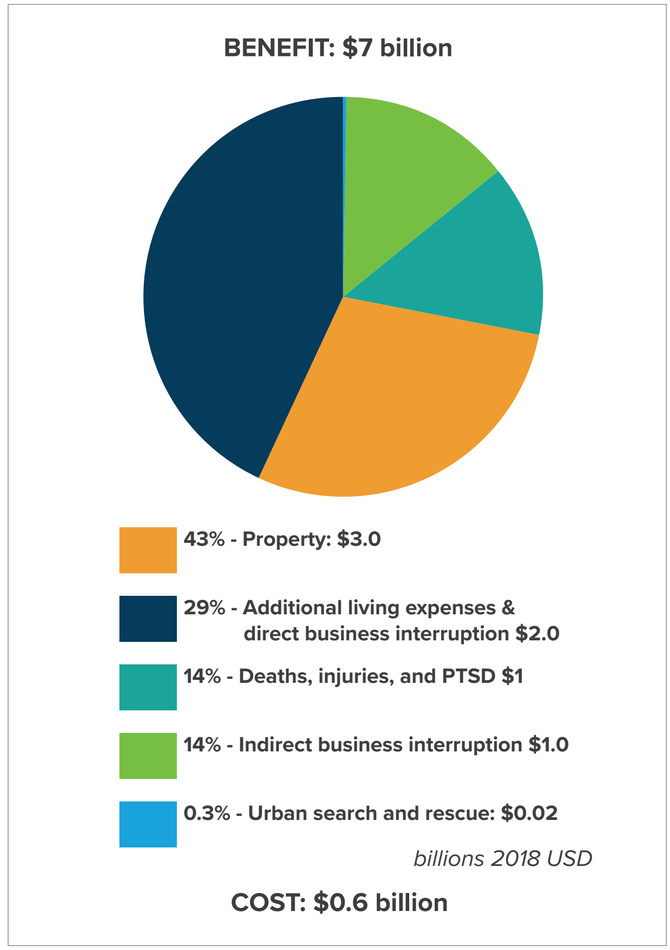

FIGURE 1. Total costs and benefits of new design to comply with 2018 I-Code requirements for earthquake, relative to 1990.

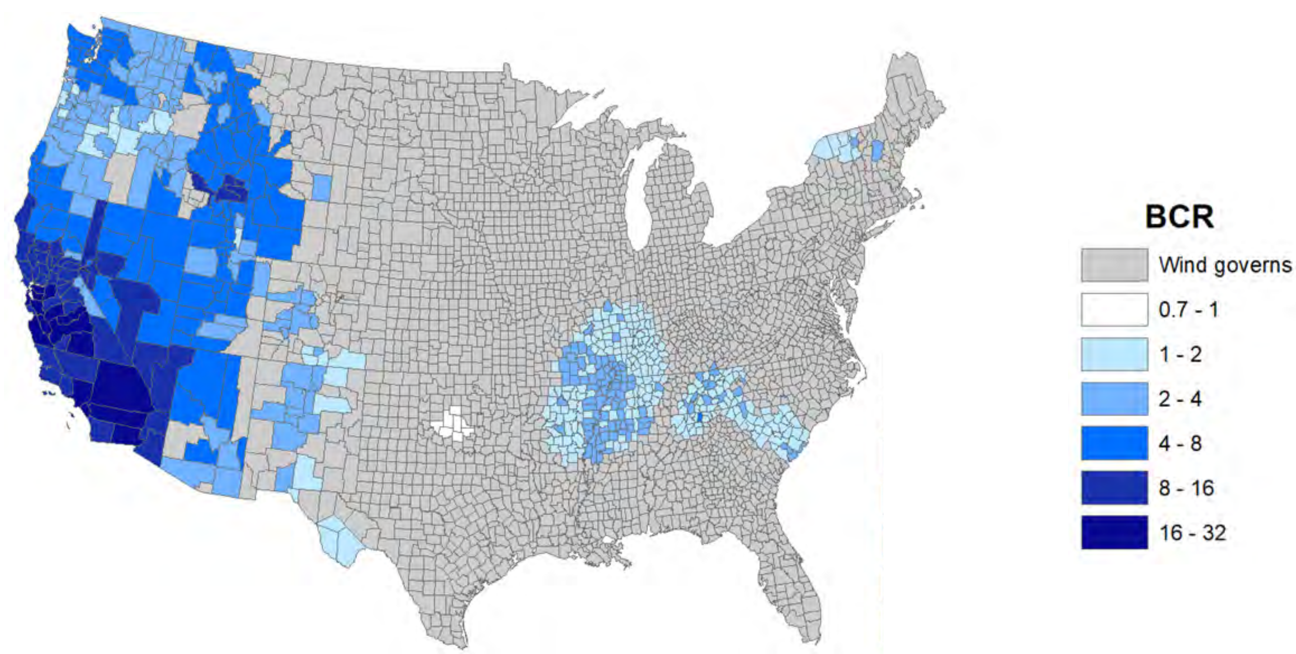

FIGURE 2. Benefit-cost ratios for seismic code compliance are highest in high-seismicity areas.

RESULTS OF EXCEEDING CODE FOR EARTHQUAKES

Considering just counties where design to exceed 2015 I-Code requirements for earthquakes has a benefit-cost ratio (BCR) greater than 1.0, if all new buildings were built to their county's incrementally efficient maximum (IEMax) level of strength and stiffness for one year the costs would total approximately $1.2 billion. The sum of the benefits totals approximately $4.3 billion. Therefore, the overall average BCR is approximately 4:1, e.g., an average of $4 saved for every $1 spent to build new buildings stronger and stiffer.

Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the overall ratio of costs to benefits for the design of new buildings to exceed earthquake design requirements of the 2015 IBC. The IEMax strength and stiffness for approximately 2,700 counties (from a BCR perspective) is 1.0, e.g., current code minimum. For approximately 400 counties however, design to exceed 2015 I-Code earthquake requirements appears to be cost-effective. Approximately 40 million people, 13% of the 2010 population of the U.S., live in counties where the IEMax strength and stiffness is twice the code minimum. Another 30 million people—10% of the United States population—live where it would be cost-effective to design to 25% or 50% greater than code-minimum strength and stiffness. The current code makes economic sense on a benefit-cost basis for about three-quarters of the United States population. The IEMax strength and stiffness by county is illustrated in Figure 2. The national-level BCRs aggregate study findings across state and local BCRs. The costs reflect only the added cost relative to the 2015 IBC.

The stringency of codes adopted at the state and local level varies widely. The project team used the unamended 2015 IBC and IRC as the baseline minimum codes for this study. While minimum codes provide a significant level of safety, society can save more by designing some new buildings to exceed minimum requirements of the 2015 Codes. Where communities have an older code or no code in place, additional costs and benefits will accrue. If all new buildings built the year after were also designed to exceed select I-Code requirements, the benefits would be that much greater, in proportion to the quantity of new buildings.

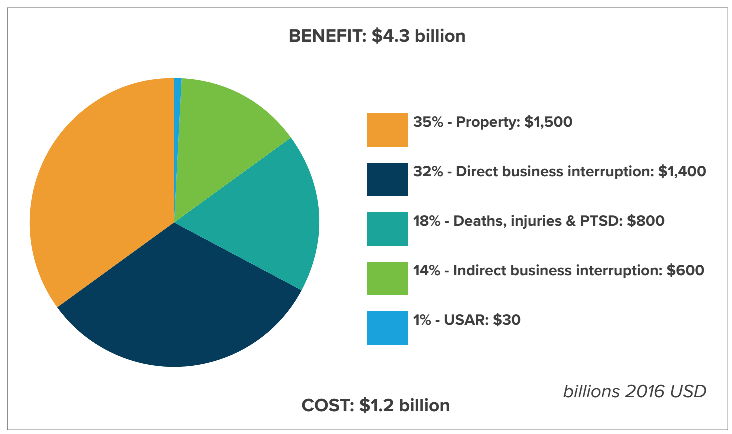

FIGURE 1. Contribution to benefits from exceeding 2015 I-Code earthquake requirements.

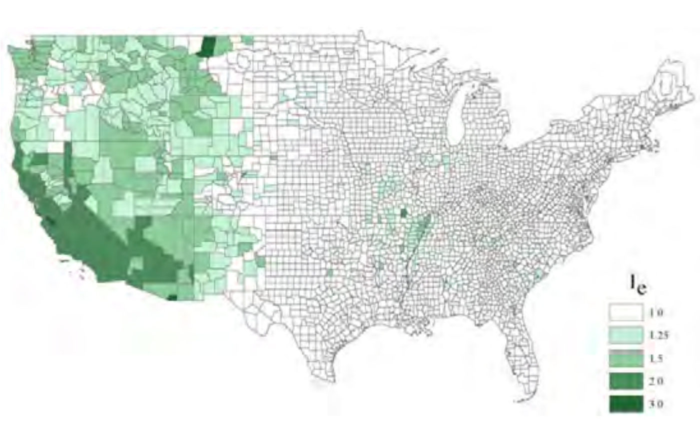

FIGURE 2. Maximum strength and stiffness factor Ie to exceed 2015 IBC and IRC seismic design requirements where the incremental benefit remains cost-effective.

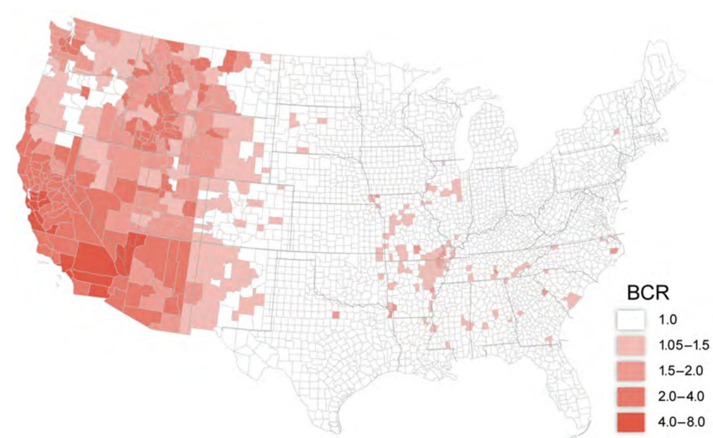

FIGURE 3. BCR of earthquake mitigation by increasing strength and stiffness in new buildings (by county).

SEISMIC RETROFIT OF RESIDENCES COULD SAVE $330 BILLION

There are many ways to make existing residential buildings more earthquake resistant. Some of the leading ones include strengthening the first story of soft-story wood-frame dwellings; adding engineered tie-down systems (ETS) to manufactured homes that are not anchored to the ground; strapping water heaters to the building frame; adding child-safety latches to kitchen cabinets; securing tall bookcases to the wall; strapping computer monitors and televisions to desks or shelves; and securing fragile objects to their shelves with museum putty. Homeowners and tenants can do some of these things at very low cost: $10 to $20 for straps or museum putty and an hour or two of time. Others require a substantial investment: The soft-story retrofit of an apartment building can cost about $9 per square foot. But the measures broadly are cost effective. Figure 1 shows the sources of these benefits.

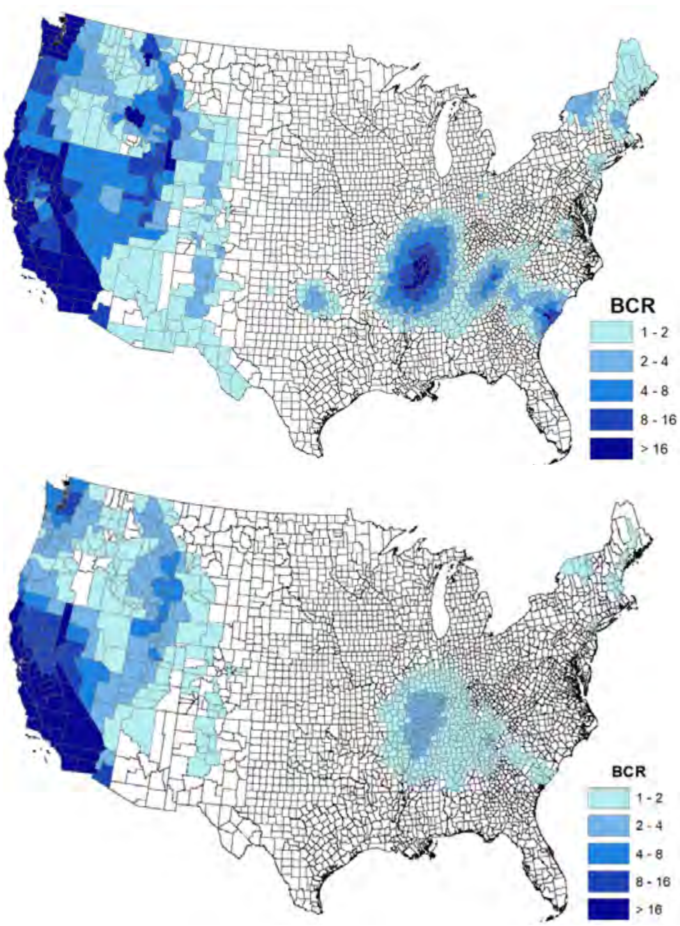

FIGURE 2. Benefit-cost ratios of seismic retrofit of two leading measures: (above) soft-story retrofit, and (below) strap water heaters.

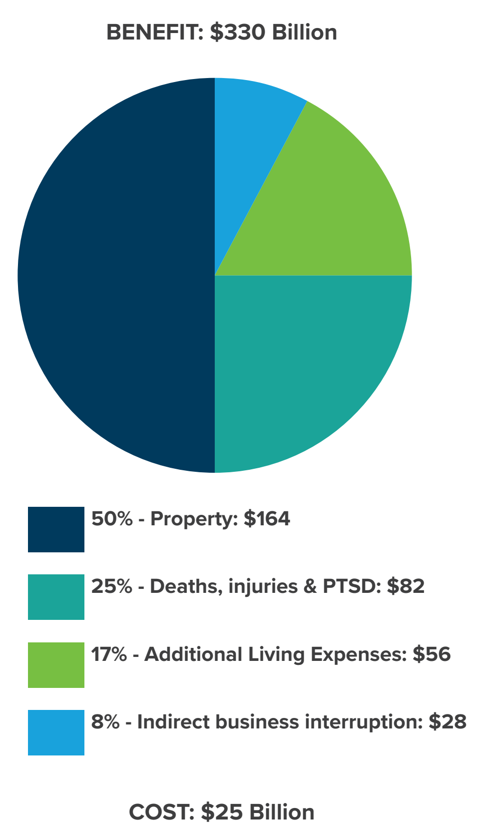

FIGURE 1. Total costs and benefits of private-sector earthquake

The BCRs for the seven earthquake retrofit measures varied widely, but averaged between 2:1 and 24:1. Soft-story retrofit had a BCR of 12:1. Engineered tie-down systems had an overall average BCR of 3:1. Strapping water heaters had an overall average BCR of 24:1, because of how effective the measure is in reducing post-earthquake fires. Kitchen cabinet latches produced a BCR of 8:1. Strapping bookcases to the wall saves $13 per $1 invested. Strapping monitors and televisions saves $2 per $1 of cost. And securing fragile objects with museum putty had a benefit-cost ratio of 3:1. BCRs also varied geographically. Each measure had its highest BCR in the places with the greatest seismicity, that is, in places where earthquakes are biggest, most frequent, or both. They all were cost effective in some places, but in many cases exceeded 16:1 in some counties. Figure 2 shows how much location matters to the BCR for the two most cost-effective measures: soft-story retrofit and strapping water heaters to the building frame.

RESULTS OF FEDERAL GRANTS FOR EARTHQUAKE MITIGATION

Considering mitigation costs totaling $2.2 billion, the average benefit-cost ratio (BCR) of approximately $3 to $1 implies that federally funded earthquake hazard mitigation between 1993 and 2016 saves society $5.7 billion.

For earthquake resistance the mitigation measures examined include strengthening various structural and nonstructural components. Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the benefits specifically attributable to federal earthquake mitigation grants. The national-level BCRs aggregate study findings across natural hazards and across state and local BCRs.

As with the 2005 study, property benefits alone do not equal mitigation cost, but the sum of property and casualties do. By adding other societal benefits—business interruption losses and especially loss of service to society—earthquake mitigation more than pays for itself. That observation reinforces the notion that earthquake risk mitigation broadly benefits society. That is, strengthen one building and the benefits extend far beyond the property line: to the families of the people who work in the building and to the community that the building serves.

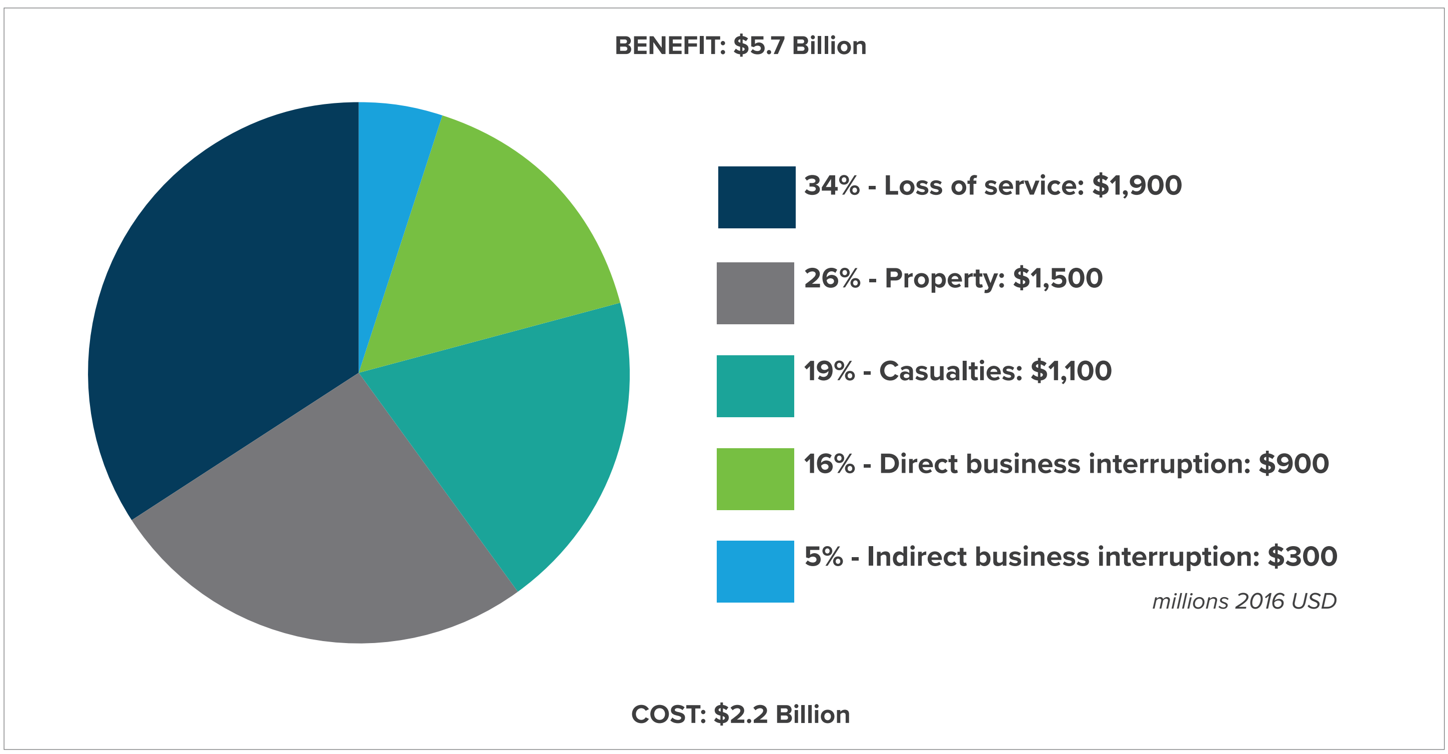

FIGURE 1. Contribution to benefit from federally funded earthquake mitigation grants.

WILDLAND-URBAN INTERFACE FIRE FACT SHEETS

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RESULTS OF COMPLIANCE WITH THE IWUIC

If all new buildings built in one year in census blocks with a benefit-cost ratio (BCR) over 1 complied with the 2015 IWUIC, compliance would add about $800 million to total construction cost for that year. The present value of benefits would total approximately $3.0 billion, suggesting a BCR of approximately 4:1, e.g., $4 saved for every $1 of additional construction and maintenance cost.

Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the overall ratio of costs to benefits for the design of new buildings to comply with requirements of the 2015 IWIUC. The BCR only exceeds 1.0 where the fire risk is moderate or higher. Of the 47,870 census blocks, about 10,000 of them (21%) have a BCR greater than 1.0. About 10.5% have BCR > 2.6. About 2% have BCR > 8, and the highest BCR is 15.3. Figure 2 provides the BCR by county. The project team aggregated state and local BCRs to determine the national-level BCR.

If all new buildings built the year after were also designed to meet IWUIC requirements, the benefits would be that much greater, in proportion to the quantity of new buildings.

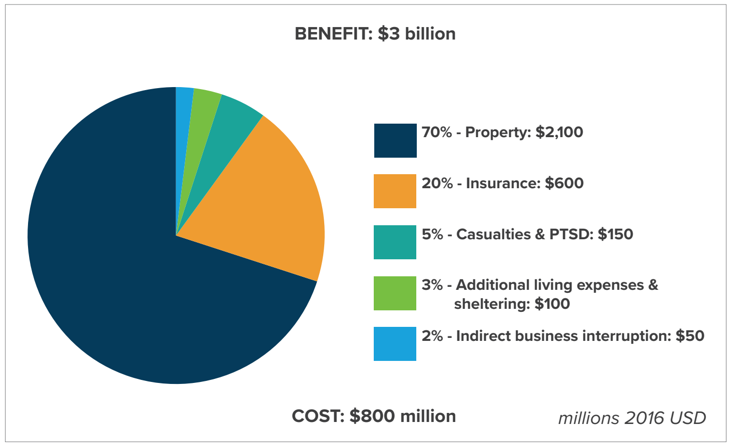

FIGURE 1. Contribution to benefits from 1 year of compliance with the 2015 IWUIC where it is cost-effective to do so.

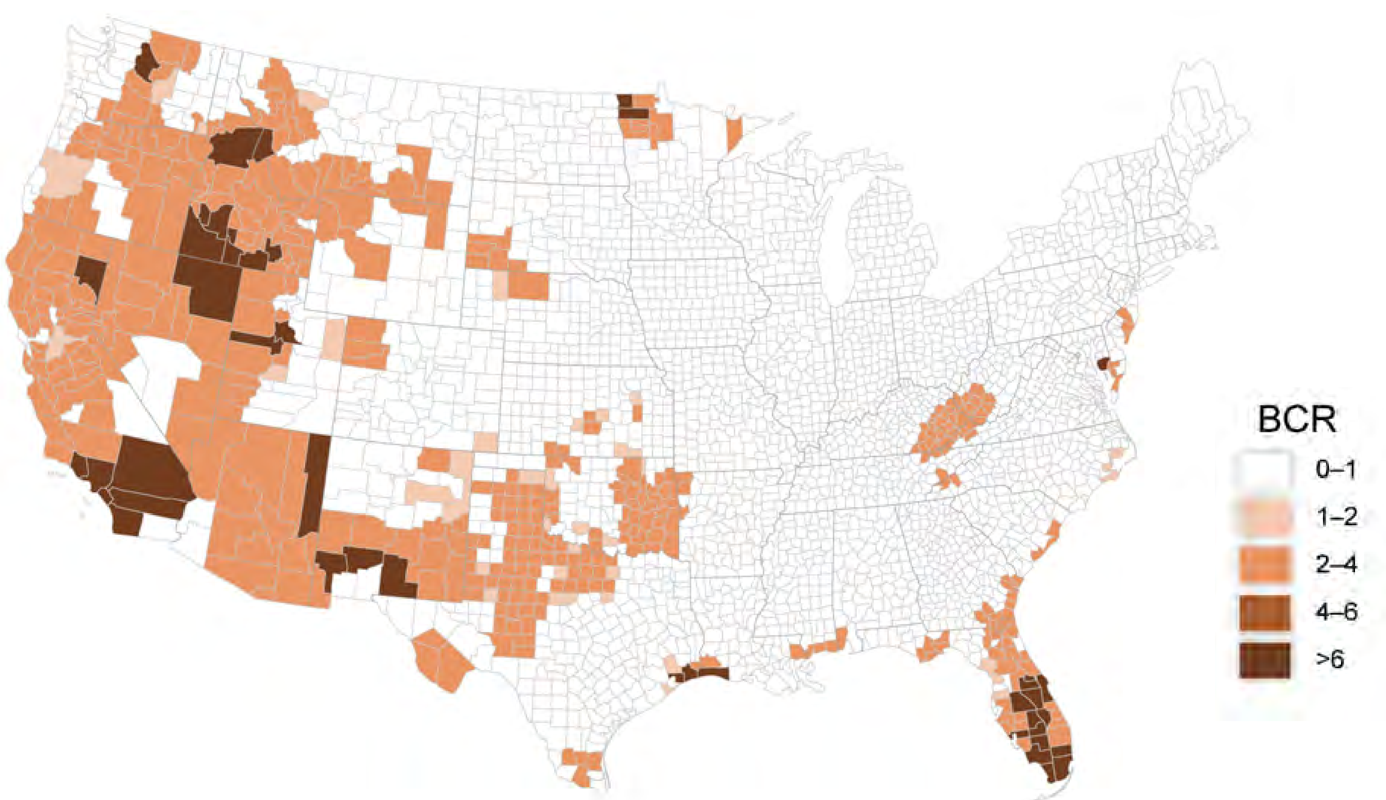

FIGURE 2. BCR of WUI fire mitigation by implementing the 2015 IWUIC for new buildings (by county).

Mitigation Saves:
At the WUI, Federal Grants for Mitigation of Fire Provide a $3 Benefit for Each $1 Invested

RESULTS OF FEDERAL GRANTS FOR FIRE MITIGATION

With a total project cost of approximately $56 million (inflated to 2016 USD), federally supported mitigation of fire at the wildland-urban interface (WUI) will save society an estimated $173 million in avoided future losses. For the 25 grants with sufficient data, the analysis produced an average benefit-cost ratio (BCR) of approximately 3:1.

For WUI fire resistance the mitigation measures examined include replacing roofs, managing vegetation to reduce fuels, and replacing wooden water tanks. Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the benefits specifically attributable to federal wildland fire mitigation grants. The national-level BCRs aggregate study findings across natural hazards and across state and local BCRs.

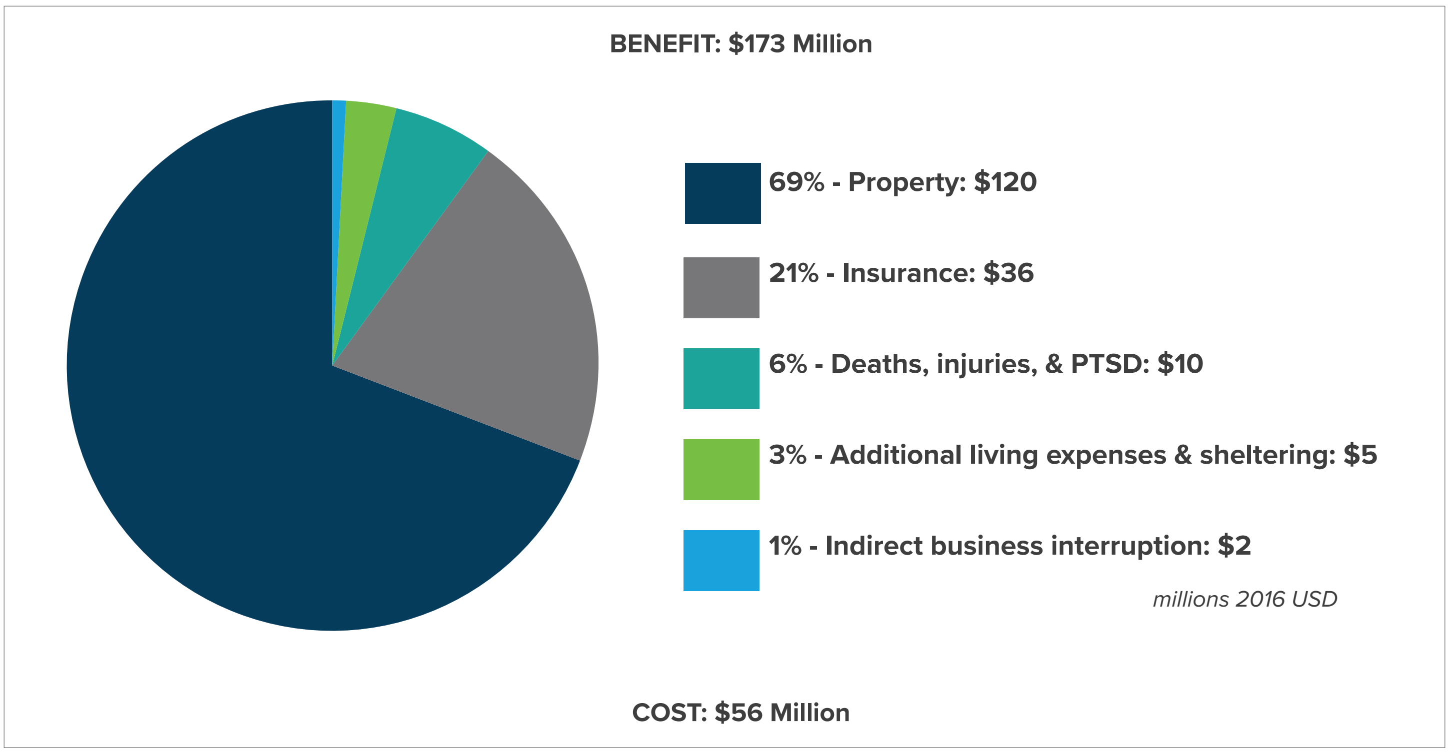

FIGURE 1. Contribution to benefit from federally funded WUI fire mitigation grants.

Mitigation Saves:
Retrofitting Buildings in the WUI Saves $2 for Each $1 Invested

RETROFITTING WILDLAND-URBAN INTERFACE BUILDINGS COULD SAVE $430 BILLION

Approximately 2.5 million homes have been built in the wildland-urban interface (WUI) and are so vulnerable to WUI fire that it would be cost effective to retrofit them to comply with the 2018 International Wildland-Urban Interface Code. These homes, plus nearby businesses and contents, are valued at approximately $1.3 trillion. To retrofit the most fire-resistant of these could cost as little as $4,000 or as much as $80,000 for the least fire resistant. The mix is highly uncertain, but even taking a conservatively high estimate of $72,000 cost to make the exterior cladding fire resistant, replace windows with double-paned glass, and clear a defensible space of excess fuel, the average benefit of $130,000 still would exceed the cost. In aggregate and using a conservatively high cost estimate, retrofitting all buildings in the WUI would cost $240 billion, but save society $430 billion, a benefit-cost ratio of 2:1. Using a lower, but still realistic, average retrofit cost of $16,000, the benefit is still $430 billion at a cost of $53 billion, meaning $8 of avoided future losses per $1 invested.

Figure 1 shows the sources of these benefits. The benefit-cost ratios are greatest for buildings in the most fire-prone locations—where climate, slope, and fuel produce the highest probability of fire. In those locations, the benefit-cost ratio can exceed 6:1 even with the more conservative estimate of retrofit cost.

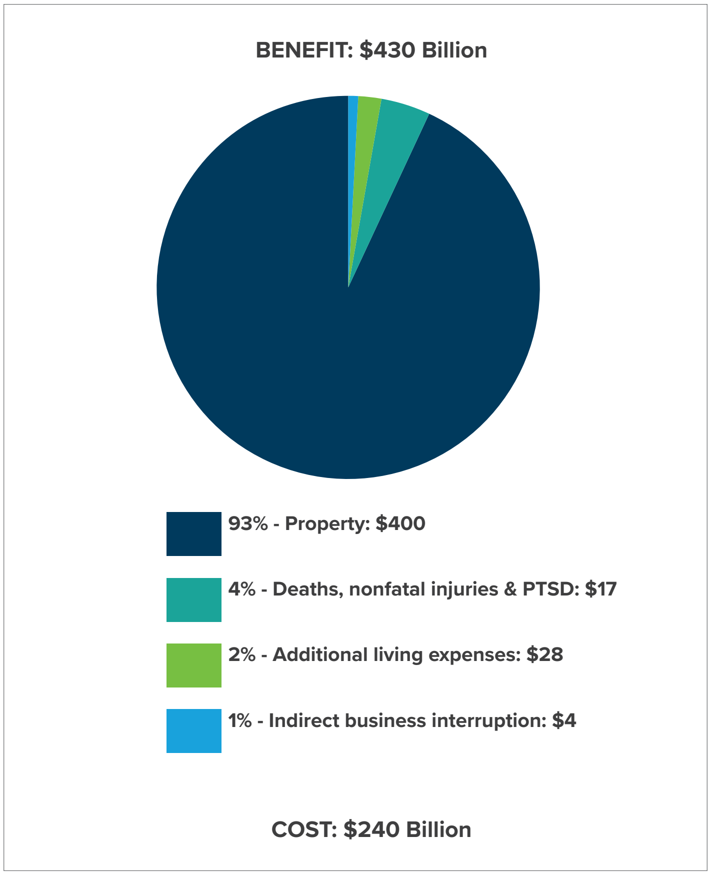

FIGURE 1. Total costs and benefits of private-sector WUI retrofit, using a conservatively high cost estimate.considered here.retrofit.

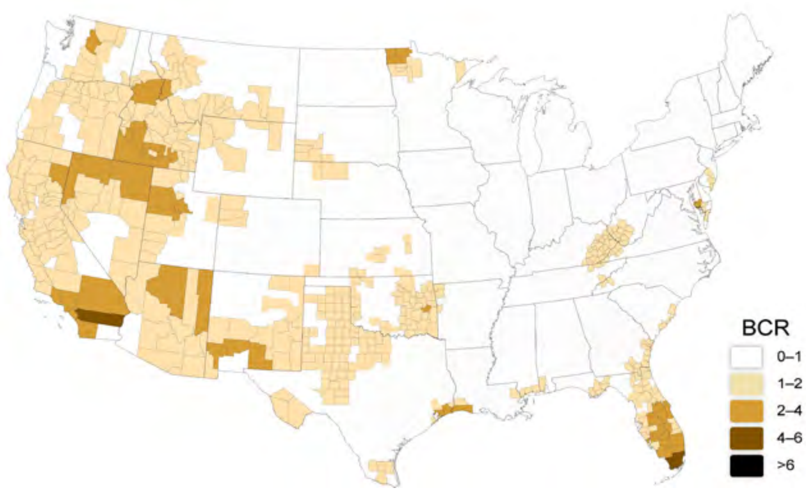

FIGURE 2. Benefit-cost ratios of retrofitting private-sector buildings to better resist fire in the wildland-urban interface. The map is shaded by county for simplicity, but typically only part of each county stands in the WUI. The shading reflects the location for the part of the county with the highest BCR. considered here.retrofit.

UTILITIES & TRANSPORTATION FACT SHEETS

National Institute of
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UTILITY AND TRANSPORTATION INFRASTRUCTURE MITIGATION

The project team sought to use Economic Development Administration (EDA) grants to look at how the agency's mitigation efforts to address four potential perils and four categories of utilities and infrastructure might benefit communities. Of the 859 EDA grants the project team reviewed, only 16 related to natural-hazard mitigation of utilities and transportation lifelines. Of these, the team acquired sufficient data to estimate benefit cost ratios (BCRs) for 12 mitigation investments.

Because too few EDA grants were available to provide statistical value, the project team modified its objectives to analyze the grants as case studies. Since the grants did not represent all common retrofit measures (particularly in regard to earthquakes), the project team also analyzed potential mitigation measures to address the gaps.

The EDA grants studied by the project team included:

- Flood mitigation for roads and railroads (five grants), with BCRs ranging between 2.0 and 11.0 for four grants, and one grant exhibiting a BCR of 0.2.
- Flood mitigation for water and wastewater facilities (four grants), which produced BCRs between 1.3 and 31.0.
- Wind mitigation for electric and telecommunications (two grants). These grants were estimated to produce BCRs of approximately 8.5.
- Flood mitigation for electric and telecommunications (one grant). This grant produced an estimated BCR of 9.4.

Note: While not statistically valid, these grants, when viewed as case studies, offer anecdotal evidence of the potential value of such types of mitigation.

In light of the unexpectedly limited grant data, the project team supplemented the analysis of grants by studying a few leading options for natural-hazard mitigation of utilities and transportation infrastructure. These included:

- Replace specific water supply pipeline segments to create a "resilient water-supply grid" that better resists earthquakes. (At least two West Coast water utilities are designing a resilient grid.) The project team estimated this measure would save up to $8 per $1 spent, depending on local seismic hazard.
- Strengthen electric substation equipment to better resist earthquake loads and to create a "resilient electric grid." (At least three West Coast electric utilities have been developing a resilient electric grid.) The project team estimated this measure would save up to $8 per $1 spent, depending on local seismic hazard.
- Strengthen highway bridges to better resist earthquake loads. The project team estimated this measure would produce a benefit of $3 per $1 spent.
- Perform prescribed burns in the watershed of water utilities to reduce wildfire and inhibit soil-carrying runoff that can cause turbidity in reservoirs. The project team found that this measure is unlikely to be cost effective, and that water utilities have less-expensive options available to address turbidity resulting from runoff after wildfires.

In addition to the specific projects examined, the study provides new analysis methods that can be readily applied to other projects to support consistent means for determining BCRs.

Mitigation Saves:
Utilities and Transportation Infrastructure Investments Can Provide Significant Returns

HAZARD	PROJECT DESCRIPTION	BCR
FLOOD (from actual EDA grants)	Elevate rail, Iowa	2:1
	Elevate rail, Missouri	2:1
	Elevate road, Nebraska	7:1
	Elevate road and reconstruct bridge, Iowa	11:1
	Reconstruct bridge, New Mexico	0.2:1
	Elevate water treatment plant equipment, Virginia	10:1
	Relocate water treatment plant, Iowa	1:1
	Relocate wastewater treatment plant, Iowa	4:1
	Protect water and wastewater treatment plants, North Carolina	31:1
	Mitigate electric and telecommunications substation, Wisconsin	9:1
WIND (from actual EDA grants)	Replace aboveground power lines, Vermont	6:1
	Improve electric power lines, Texas	6:1
EARTHQUAKE (based on project team analysis))	Implement resilient water distribution grid, San Francisco, CA	8:1
	Implement resilient water distribution grid, Los Angeles, CA	6:1
	Implement resilient water distribution grid, Portland, OR	0.6:1
	Implement resilient water distribution grid, Seattle, WA	2:1
	Retrofit Electric substations, San Francisco, CA	8:1
	Retrofit Electric substations, Los Angeles, CA	8:1
	Retrofit Electric substations, Portland, OR	6:1
	Retrofit Electric substations, Seattle, WA	2:1
	Improve columns and footings of highway bridges, California	3:1

TABLE 1. BCRs for select infrastructure mitigation measures (based on actual EDA grants and project team analysis forpotential resilience initiatives).

SOCIETY FACT SHEETS

National Institute of BUILDING SCIENCES™

Innovative Solutions for the Built Environment

Mitigation Saves:
Designing to Exceed 2015 Codes Provides $4 Benefit for Each $1 Invested

RESULTS OF EXCEEDING CODE

If all new buildings were built to the incrementally efficient maximum (IEMax) design to exceed select requirements of the 2015 IBC and IRC and compliance with the 2015 IWUIC for one year, new construction would save approximately $4 in avoided future losses for every $1 spent on additional, up-front construction cost. Such measures are estimated to prevent approximately 32,000 nonfatal injuries, 20 deaths and 100 cases of PTSD.

Table 1 provides BCRs for each natural hazard the project team examined. Figure 1 shows the overall ratio of costs to benefits for the design of new buildings to exceed the select I-Code requirements that the project team studied. The costs reflect only the added cost relative to the 2015 IBC and IRC. Where communities have an older code or no code in place, additional costs and benefits will accrue. If all new buildings built the year after were also designed to exceed select I-Code requirements, the benefits would be that much greater, in proportion to the quantity of new buildings.

The stringency of codes adopted at the state and local level varies widely. The project team used the unamended 2015 IBC and IRC as the baseline minimum codes for this study. Minimum codes provide a significant level of safety, however, society can save more by designing some new buildings to exceed minimum requirements of the 2015 Codes. Strategies to exceed minimum requirements of the 2015 Codes studied here include:

- For flood resistance (to address riverine flooding and hurricane surge), build new homes higher abovebase flood elevation (BFE) than required by the 2015 IBC.
- For resistance to hurricane winds, build new homes to comply with the Insurance Institute for Business & Home Safety (IBHS) FORTIFIED Home Hurricane standards.
- For resistance to earthquakes, build new buildings stronger and stiffer than required by the 2015 IBC.
- For fire resistance in the wildland-urban interface, build new buildings to comply with the 2015 IWUIC.

The national-level BCRs aggregate study findings across natural hazards and across state and local BCRs. The Interim Study examined four specific natural hazards: riverine and coastal flooding, hurricanes, earthquakes and fires at the wildland-urban interface (WUI). Discussion of each hazard and the associated BCRs are provided in separate summaries.

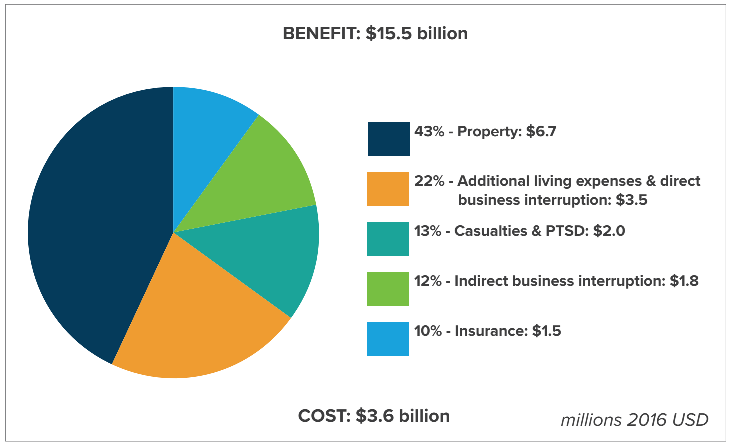


FIGURE 1. Total costs and benefits of new design to exceed 2015 I-Code requirements.

ALL STAKEHOLDERS BENEFIT FROM MITIGATION INVESTMENTS

All major stakeholder groups, including developers, title holders, lenders, tenants and the community, enjoy net benefits from new design to exceed the code requirements studied. See Figure 2. All of society wins when builders make new buildings meet an IEMax level of design exceeding 2015 I-Code requirements where it makes financial sense, on a societal level, to do so. The benefits to tenants and owners only accrue to those who own or occupy buildings designed to exceed 2015 I-Code requirements, not for example to the people who live or work in buildings not designed to exceed I-Code requirements. However, even those who do not own or occupy those buildings enjoy a share of the community benefits.

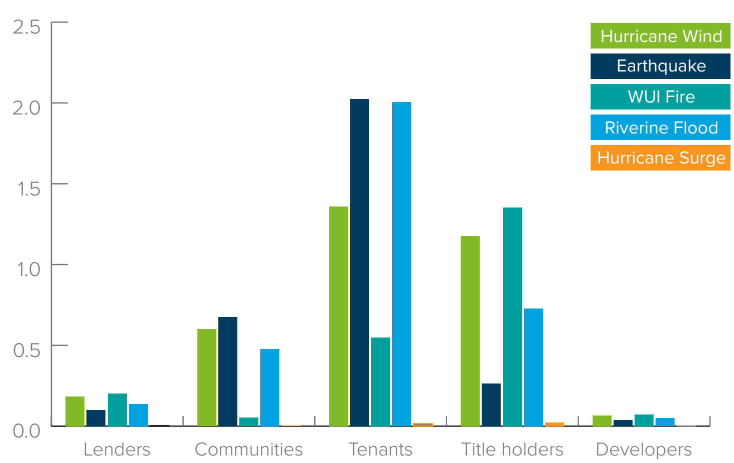
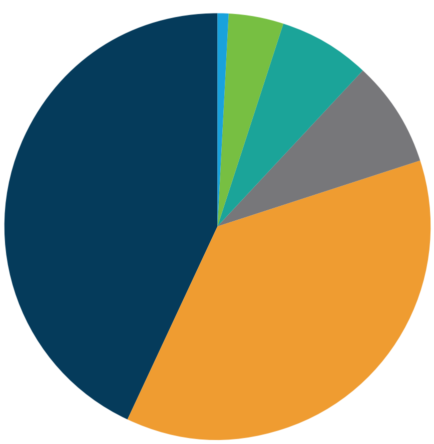


FIGURE 2. Stakeholder net benefits resulting from one year of constructing all new buildings to exceed select 2015 IBC and IRC requirements or to comply with 2015 IWUIC.

RESULTS OF FEDERAL GRANT PROGRAMS

Considering the subtotal for the past 23 years of federally funded natural hazard mitigation, at the cost-of-borrowing discount rate, the analysis suggests that society will ultimately save $6 for every $1 spent on up-front mitigation cost. The past 23 years of federally funded natural hazard mitigation is estimated to prevent deaths, nonfatal injuries and PTSD worth $68 billion, equivalent to approximately 1 million nonfatal injuries, 600 deaths and 4,000 cases of PTSD. Table 1 provides benefit-cost ratios (BCRs) for each natural hazard the project team examined. Figure 1 shows the contributions to the calculation of these benefits.

BENEFIT: $157.9 Billion



43% - Casualties & PTSD: $68.1%

37% - Property: $58.1

12% - Additional living expenses & direct business interruption: $12.9

6% - Insurance: $10.5

6% - Indirect business interruption: $6.3

1% - Loss of service: $2.0

COST: $27.4 Billion

FIGURE 1. Total costs and benefits of 23 years of federal mitigation grants. measures: (left) soft-story retrofit, and (right) strap water heaters.

The federal agency strategies consider 23 years of public sector mitigation of buildings funded through FEMA programs including the Flood Mitigation Assistance Grant Program (FMA), Hazard Mitigation Grant Program (HMGP), Public Assistance Program (PA) and Pre-Disaster Mitigation Grant Program (PDM), plus the HUD Community Development Block Grant Program (CDBG) and several programs of the EDA. Barring identification of additional federal data sets or sources of federal mitigation grant and loan funding, these analyses represent essentially the complete picture of such mitigation measures. In the future, the project team might also look at mitigation measures directly implemented by federal agencies.1 Results represent an enhanced and updated analysis of the mitigation measures covered in the 2005 study. Public-sector mitigation strategies include:

- For flood resistance, acquire or demolish flood-prone buildings, especially single-family dwellings,manufactured homes and 2- to 4-family dwellings.
- For wind resistance, add shutters, safe rooms and other common measures.
- For earthquake resistance, strengthen various structural and nonstructural components.
- For fire resistance, replace roofs, manage vegetation to reduce fuels and replace wooden water tanks.

The national-level BCRs aggregate study findings across natural hazards and across state and local BCRs. The Interim Study examined four specific natural hazards: riverine and coastal flooding, hurricanes, earthquakes and fires at the wildland-urban interface (WUI). Discussion of each hazard and the associated BCRs are provided in separate summaries.

NATURAL HAZARD MITIGATION SAVES IN EVERY STATE

Every state in the contiguous United States is estimated to experience at least $10 million in benefits from federal grants to mitigate flood, wind, earthquake, or fire at the wildland-urban interface. The majority of states enjoy at least $1 billion in benefits. Four states—Louisiana, New Jersey, New York and Texas—enjoy at least $10 billion in benefits. See Figure 2.

Mitigation Saves:
Federal Grants Provide a $6 Benefit for Each $1 Invested

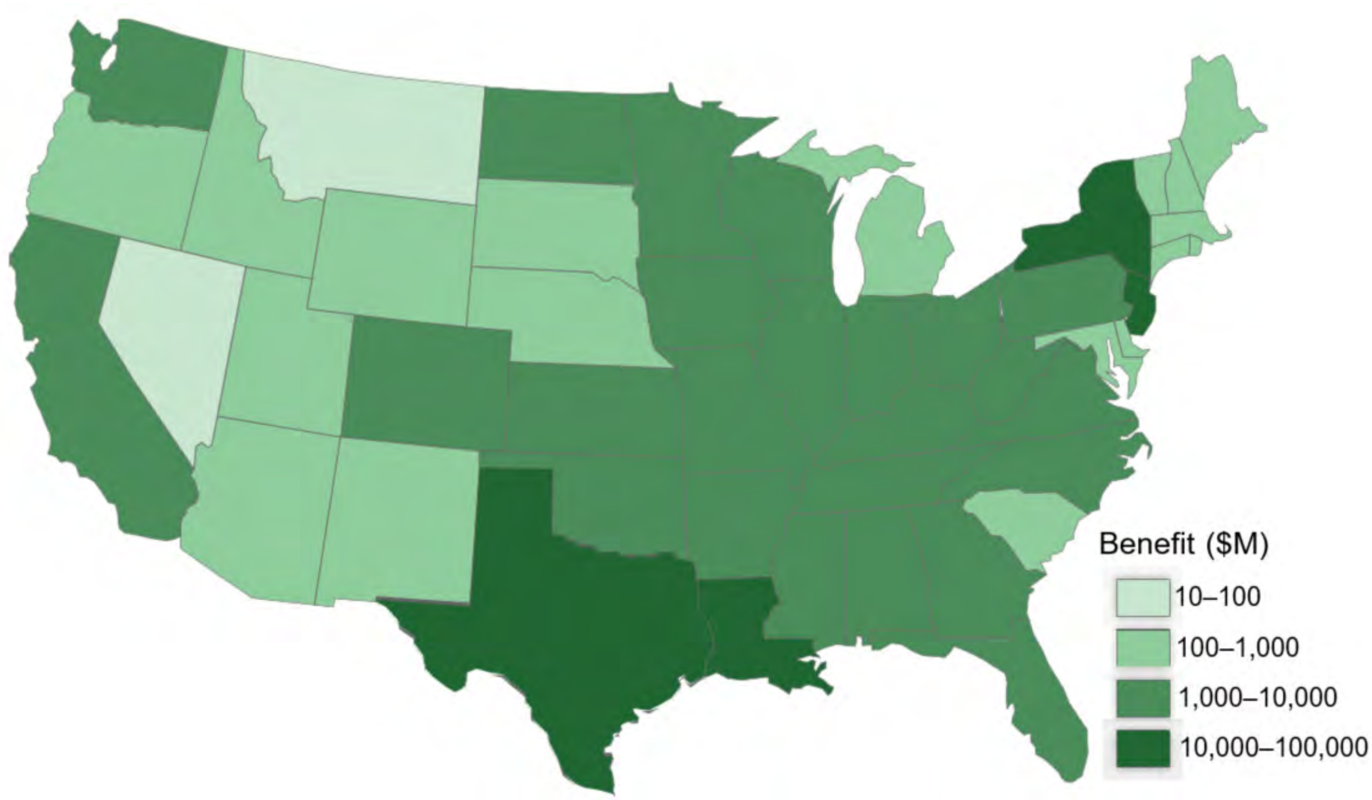


FIGURE 2. Aggregate benefit by state from federal grants for flood, wind, earthquake, and fire mitigation.

Mitigation Saves:
Private-Sector Retrofit Saves $4 for Each $1 Invested

RETROFITTING PRIVATE-SECTOR BUILDINGS COULD SAVE SOCIETY OVER $2 TRILLION

Codes and standards have improved over time, but that means older buildings embody numerous weaknesses that could be fixed through retrofit. More than 1 million houses currently stand in the 100-year floodplain, and are more likely than not to be flooded during their economic life. A variety of retrofit measures could make these buildings safer and more efficient to own. A combination of buyouts, elevation projects, and less-expensive modifications to basements and heating and air conditioning equipment could save society almost $1.3 trillion, albeit at a cost of $225 billion—a benefit-cost ratio of $6 saved per $1 invested.

Almost 3 million older homes along the Gulf and Atlantic coasts lack modern resilience features like strong roofs that could make ordinary houses more resistant to hurricanes, or engineered tie-down systems for manufactured homes that could make them more resistant to strong winds. Efficient retrofit of these homes could save $140 billion at a cost of $24 billion—again, $6 saved per $1 invested.

Millions of homes in high-seismic areas across the U.S. have weak ground stories, freestanding furnishings, water heaters that could fall over, and other deficiencies that, if strengthened, could save $330 billion at a cost of $25 billion, for a benefit-cost ratio of $13:1, the highest considered here.

Finally, 2.5 million homes stand in a part of the wildland-urban interface, where the risk of fire is so high that it would be cost effective to provide a defensible space, replace cladding, and make other changes that would save them $430 billion, at a cost of $240 billion, for a benefit-cost ratio of 2:1.

Considering just these retrofit options, America has a $520 billion private-sector retrofit investment gap that, if closed, would save society $2.2 trillion, for a benefit-cost ratio of 4:1. Figure 1 shows the sources of these benefits, totaling over the four perils and numerous private-sector retrofit options considered here.

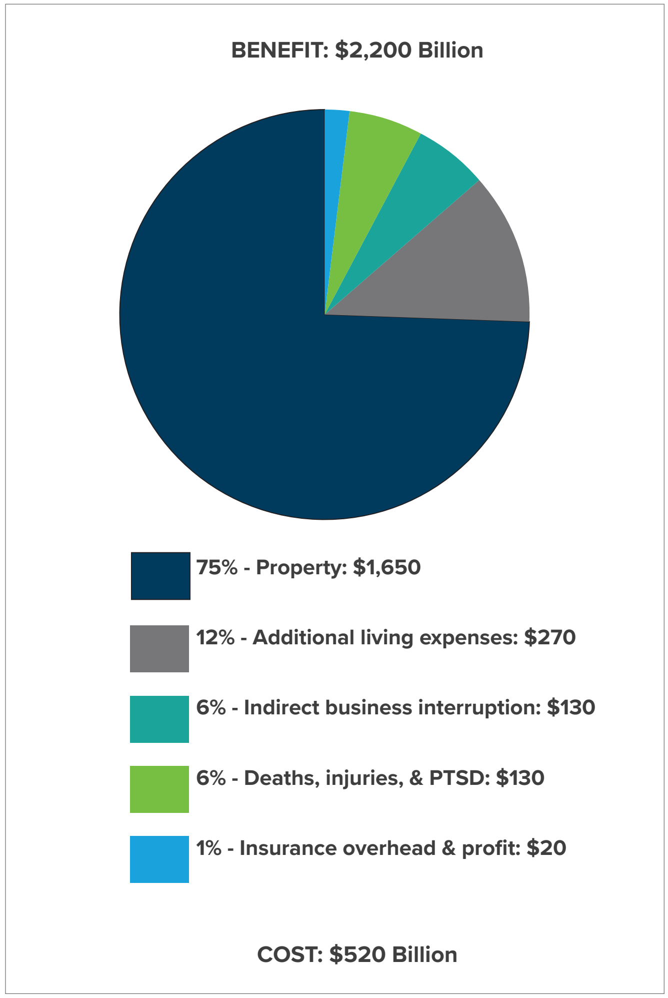


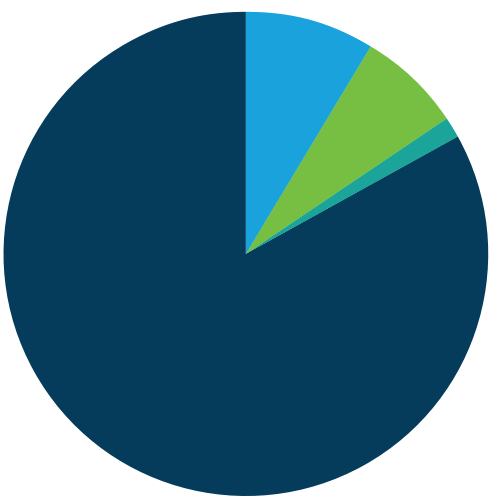
FIGURE 1. Total costs and benefits of private-sector retrofit options considered here.

Mitigation Saves:
Saving the Federal Treasury $930 Million Per Year

SAVINGS TO THE FEDERAL TREASURY

The study estimated that the federal government spends an annual average of $10 billion on disasters through public assistance, individual assistance, and other costs. Natural hazard mitigation reduces those outlays by the federal government. The mitigation measures examined in the study are estimated to reduce annual federal expenditures by approximately 8%, meaning that natural hazard mitigation reduces federal outlays from the treasury by approximately $800 million per year. In addition, natural hazard mitigation increases federal tax revenues by approximately $130 annually because of fewer tax deductions for disaster losses. Thus, the mitigation measures examined here provide an annual benefit to the federal treasury of approximately $930 million, as detailed in Figure 1.

BENEFIT: $930 Million



82%: Federally Funded
$772

1%: Utilities and Transporation
$12

7%: Meet common code requirements
$64

9%: Exceed common code requirements
$82

FIGURE 1. Annual savings to the federal treasury resulting from natural hazard mitigation.

MULTIPLE STAKEHOLDERS BENEFIT FROM ADOPTING OR EXCEEDING I-CODE REQUIREMENTS

Designing new buildings to exceed select 2015 IBC and IRC requirements (where it is cost effective to do so) for flood, hurricane wind and earthquake; designing new buildings in parts of the WUI to meet the 2015 IWUIC to better resist fire; and meeting the 2018 I-Code requirements for flood, hurricane wind and earthquake affect various stakeholder groups differently. The project team considered how each of five stakeholder groups bears the costs and enjoys the benefits of mitigation for the natural hazards under consideration. Stakeholders include:

- Developers: Corporations that invest in and build new buildings, and usually sell the new buildings once they are completed, owning them only for months or a few years.
- Title holders: People or corporations, who own existing buildings, generally buying them from developers or from prior owners.
- Lenders: People or corporations that lend a title holder the money to buy a building. Loans are typically secured by the property, meaning that if the title holder defaults on loan payments, the lender can take ownership.
- Tenants: People or corporations who occupy the building, whether they own it or not. This study uses the term "tenant" loosely, and includes visitors.
- Community: People, corporations, local government, emergency service providers, and everyone else associated with the building or who does business with the tenants.

When one subtracts the costs each group bears from the benefits it enjoys, the difference—called the net benefit—is positive in each category. Figures 2 and 3 reflect long-term averages to broad groups, so it only speaks to the group as a whole, on average, rather than to the experience of each individual member of the group.

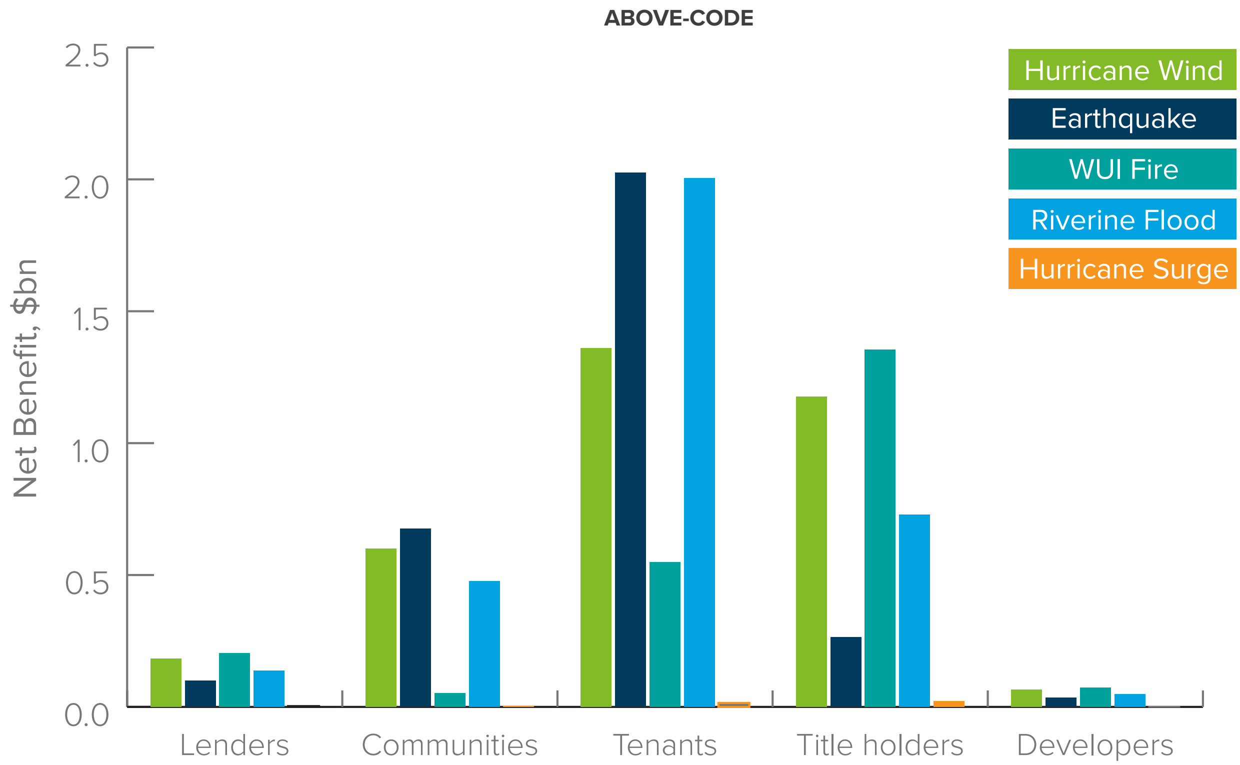


FIGURE 2. Stakeholder net benefits resulting from one year of constructing all new buildings to exceed select 2015 IBC and IRC requirements or to comply with 2015 IWUIC.

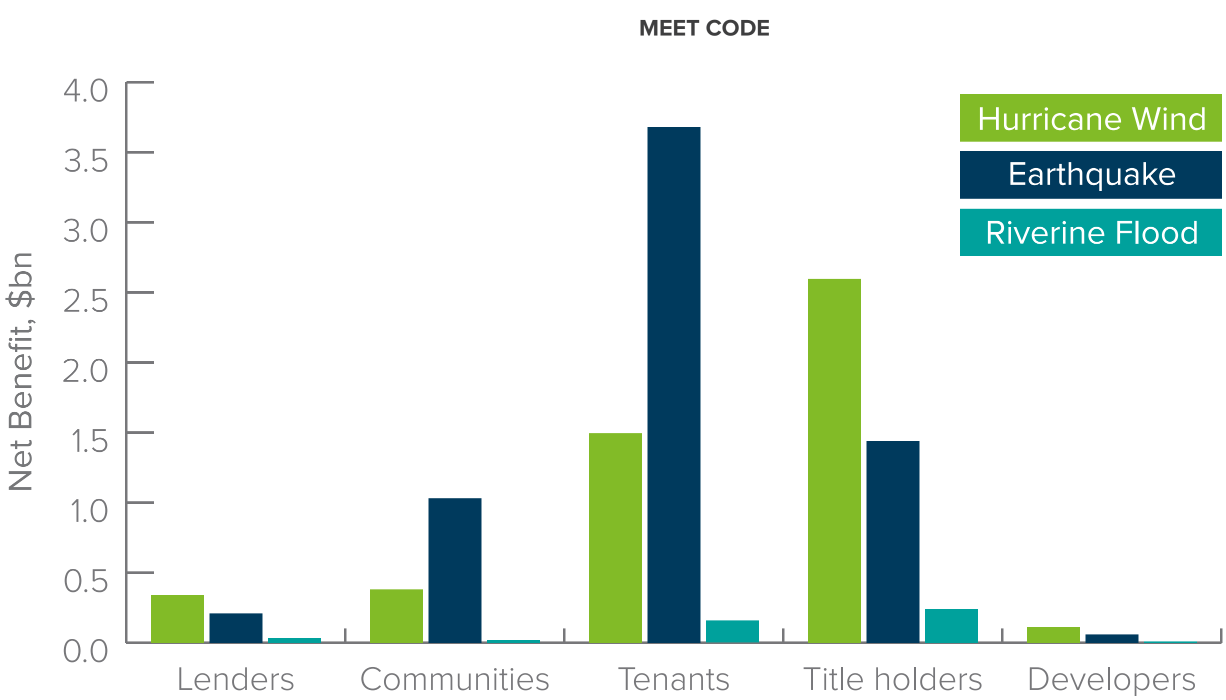
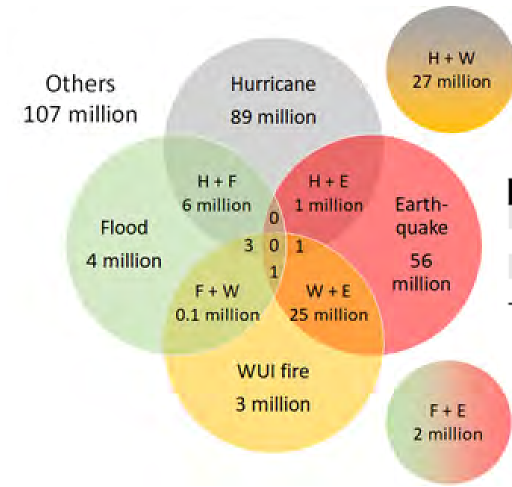


FIGURE 3. Stakeholder net benefits per year of new construction resulting from meeting the 2018 IRC and IBC.

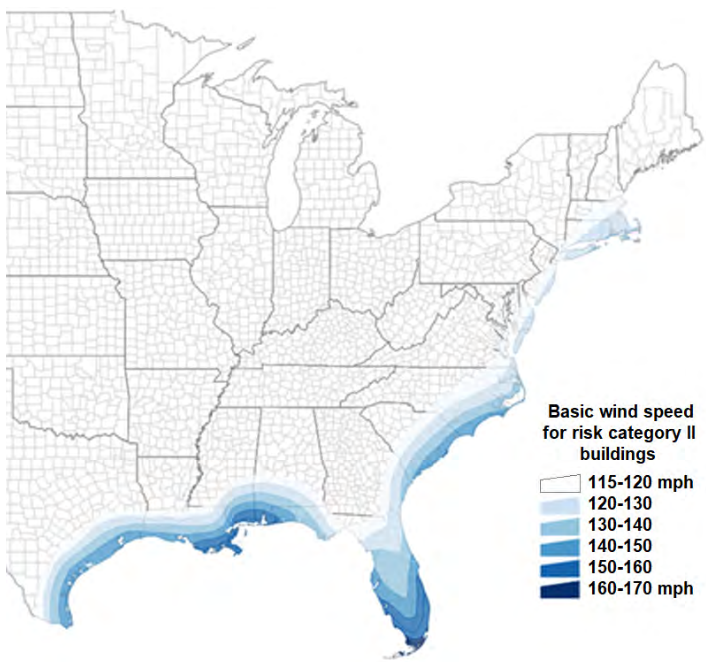
Mitigation Saves:
Most Americans are Exposed to Natural Hazards

Every state in the nation is at risk to more than one kind of natural hazard. Figure 1 shows where flooding, hurricanes, earthquakes, and wildfire threaten the conterminous 48 states. Figure 2 shows quantities: approximately 89 million people are exposed to hurricanes, 56 million to earthquakes, 4 million to flood, and 3 million to fire at the wildland-urban interface (WUI). Many are exposed to multiple perils: 27 million to hurricane and WUI fire (H + W = 27 million), 25 million to WUI fire and earthquake (W + E = 25 million), etc.

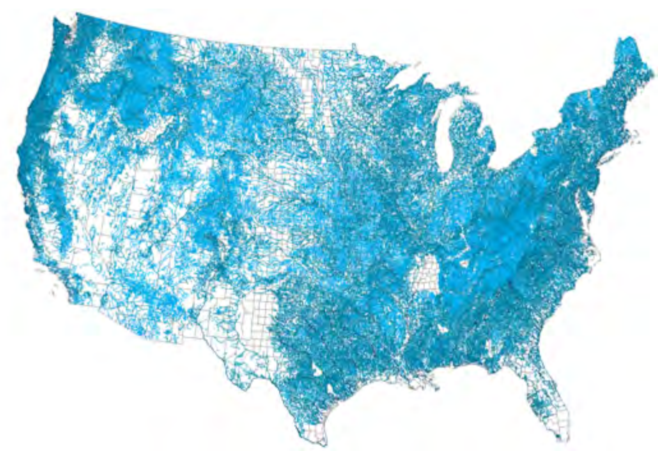


Peril	Sum
Hurricane	127 million
Earthquake	85 million
WUI fire	59 million
Flood	42 million

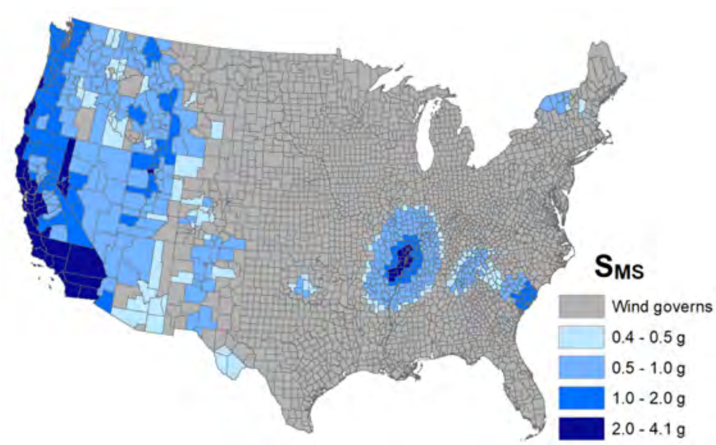
FIGURE 2. The diagram shows how many Americans in the conterminous states are exposed to these natural hazards.



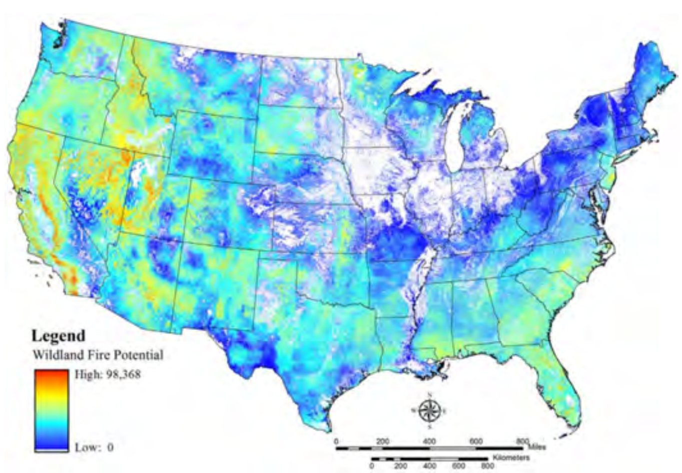
HURRICANE



FLOOD



EARTHQUAKE



WUI FIRE

FIGURE 1. Locations where Americans are exposed to flooding, hurricane, earthquake, and fire at the wildland-urban interface.

Mitigation Saves:
Saving the Federal Treasury $930 Million Per Year

SAVINGS TO THE FEDERAL TREASURY

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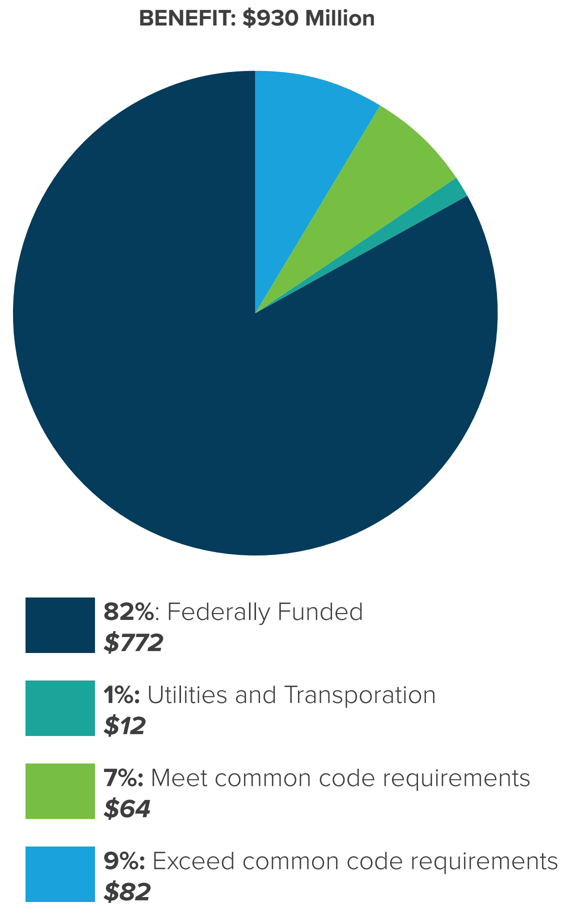

FIGURE 1. Annual savings to the federal treasury resulting from natural hazard mitigation.

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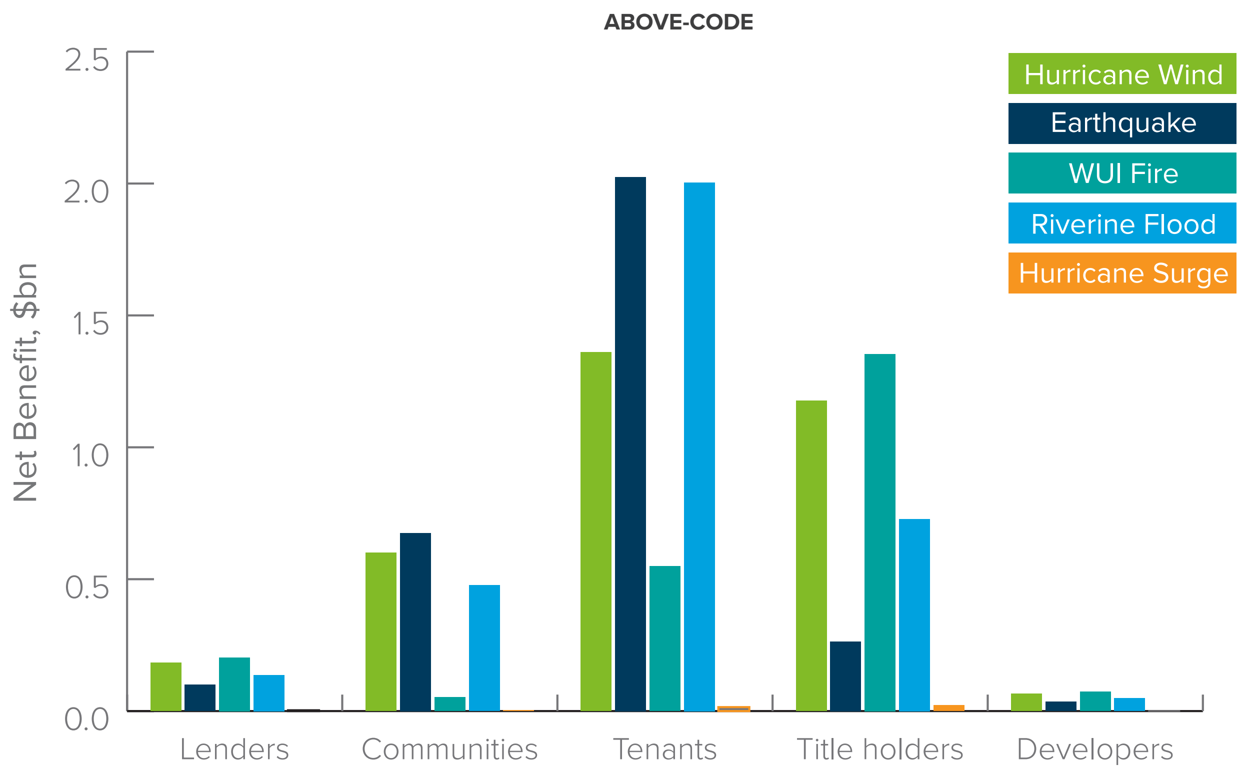

FIGURE 2. Stakeholder net benefits resulting from one year of constructing all new buildings to exceed select 2015 IBC and IRC requirements or to comply with 2015 IWUIC.

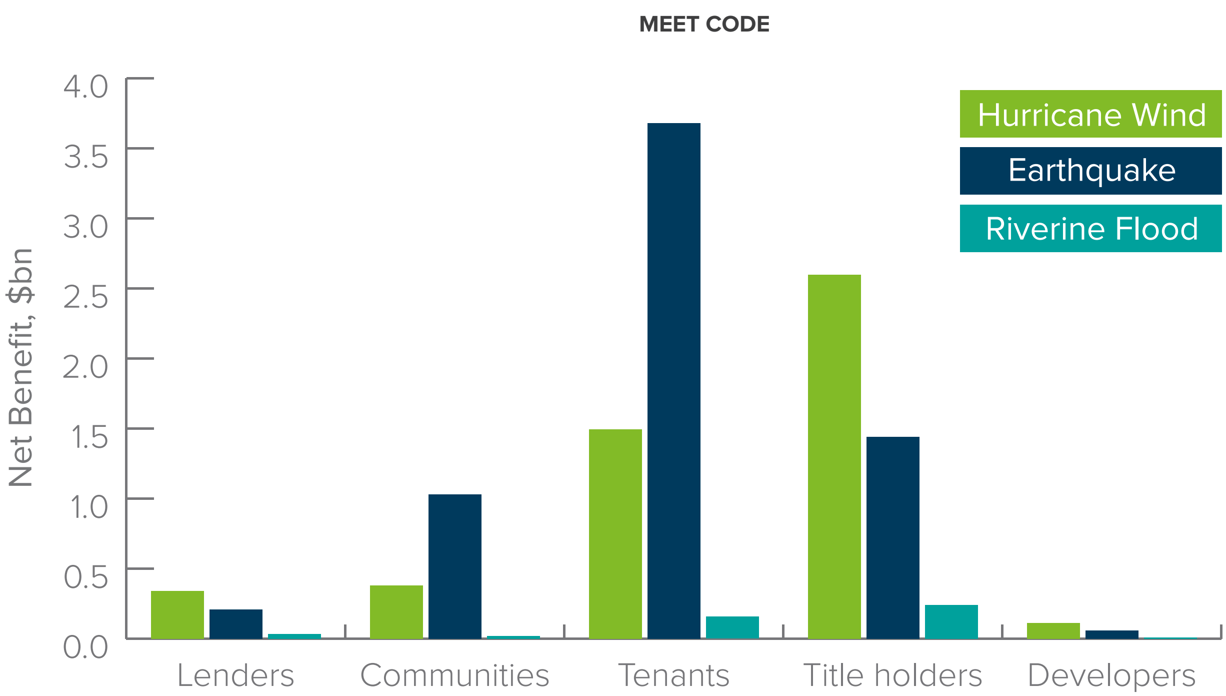

FIGURE 3. Stakeholder net benefits per year of new construction resulting from meeting the 2018 IRC and IBC.