Natural Hazard Mitigation Saves: 2018 Interim Report

Summary of Findings

BCRs for Mitigation Strategies Studied
(from Highest to Lowest)

- Adopting Model Codes Saves $11 per $1 Spent
- Federal Mitigation Grants Save $6 per $1 Spent
- Exceeding Codes Saves $4 per $1 Spent
- Mitigating Infrastructure Saves $4 per $1 Spent

Natural hazards present significant risks to many communities across the United States. Fortunately, there are measures governments, building owners, developers, tenants, and others can take to reduce the impacts of such events. These measures—commonly called mitigation—can result in significant savings in terms of safety, and preventing property loss and disruption of day-to-day life.

Given the rising frequency of disaster events and the increasing cost of disaster recovery across the nation, mitigation actions are crucial for saving money, property, and, most importantly, lives. Activities designed to reduce disaster losses also may spur job growth and other forms of economic development.

Mitigation represents a sound financial investment. This Interim Study examined four sets of mitigation strategies and found that society saves a benefit-cost ratio (BCR) of 4:1 for investments to exceed select provisions of the *2015 International Residential Code* (IRC) and *International Building Code (IBC)*, the model building codes developed by the International Code Council (also known as the I-Codes); a BCR of 11:1 for adopting the 2018 IRC and IBC, versus codes represented by 1990-era design; a BCR of 4:1 for a select number of utilities and transportation infrastructure study cases; and a BCR of $6 for every $1 spent through mitigation grants funded through select federal agencies.

Just implementing the first and the last sets of mitigation strategies would prevent 600 deaths, 1 million nonfatal injuries, and 4,000 cases of post-traumatic stress disorder (PTSD) in the long term. In addition, designing new buildings to exceed the 2015 IRC and IBC would result in 87,000 new, long-term jobs, and an approximate 1% increase in utilization of domestically

produced construction materials.[1] Communities that consistently meet the latest editions of commonly adopted code requirements, culminating in the 2018 IRC and IBC, have added 30,000 new jobs to the construction-materials industry and an approximate .3% increase in utilization of domestically produced construction materials for each year of new construction over what it would have been if buildings were designed as they were in 1990.

The Interim Study examined four specific natural hazards: riverine and coastal flooding, hurricanes, earthquakes, and fires at the wildland-urban interface (WUI). The national-level BCRs aggregate the study findings across these natural hazards and across state and local BCRs. Table 1 provides BCRs for each natural hazard the project team examined.

National Benefit-Cost Ratio Per Peril *BCR numbers in this study have been rounded	Exceed common code requirements	Meet common code requirements	Utilities and transportation	Federally funded
Overall Hazard Benefit-Cost Ratio	4:1	11:1	4:1	6:1
Riverine Flood	5:1	6:1	8:1	7:1
Hurricane Surge	7:1	Not applicable	Not applicable	Too few grants
Wind	5:1	10:1	7:1	5:1
Earthquake	4:1	12:1	3:1	3:1
Wildland-Urban Interface Fire	4:1	Not applicable	Not applicable	3:1

Table 1. Benefit-Cost Ratio by Hazard and Mitigation Measure.

The Interim Study quantifies many, but not all, of the important benefits of mitigation. Mitigation activities save more than what is estimated in this report. Disasters disconnect people from friends, schools, work, and familiar places. They ruin family photos and heirlooms and alter relationships. Large disasters may cause permanent harm to one's culture and way of life, and greatly impact the most socially and financially marginal people. Disasters may have long-term consequences to the health and collective well-being of those affected. Such events often hurt or kill pets and destroy natural ecosystems that are integral parts of communities. Disasters clearly disrupt populations in ways that are difficult to articulate, let alone assign monetary worth.

This Interim Study updates and expands a 2005 study conducted by the National Institute of Building Sciences (Institute) Multihazard Mitigation Council (MMC), at the direction of the U.S. Congress, entitled *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities* (the 2005 study), which found, among other things, that every

[1] Higher construction costs might also cost jobs if they make new homes less affordable, unless the higher cost of homes is offset by incentives as described in the section, "Incentivization Can Facilitate Ideal Levels of Investment."

$1 of natural hazard mitigation funded by the Federal Emergency Management Agency (FEMA) between 1993 and 2003 saved the American people an average of $4 in avoided future losses.[2]

The Interim Study provides an updated examination of the benefits of federal agency grant programs. It utilizes a more-realistic economic life span for buildings (75 versus 50 years) and takes advantage of a more advanced Hazus-MH flood model and improvements in FEMA's Benefit-Cost Analysis Tool, which, among other things, allows quantification of the benefit associated with enhanced service to the community provided by fire stations, hospitals, and other public-sector facilities. The 2005 study did not estimate the economic costs associated with PTSD. The 2005 study also did not calculate avoided insurance administrative costs, overhead, and profit, the reduction of which can add significant benefit in some situations. The ability to estimate urban search and rescue costs is introduced here.

Mitigation Strategies Studied

The Institute's MMC undertook a study to update and expand upon the findings of its *2005 Mitigation Saves* study on the value of mitigation. The Interim Study analyzes four sets of mitigation strategies:

Beyond code requirements: The costs and benefits of designing all new construction to exceed select provisions in the 2015 IBC and the 2015 IRC and the implementation of the *2015 International Wildland-Urban Interface Code* (IWUIC). This results in a national benefit of $4 for every $1 invested.

Adopting I-Code Requirements: Design based on meeting the 2018 IRC and IBC versus codes represented by 1990-era design and National Flood Insurance Program (NFIP) requirements—results in a national benefit of $11 for every $1 invested.

Infrastructure: Case studies for utility and transportation infrastructure based on Economic Development Administration (EDA) grants and California projects result in a national benefit of $4 for every $1 invested.

Federal grants: The impacts of 23 years of federal mitigation grants provided by FEMA, EDA, and the Department of Housing and Urban Development (HUD), result in a national benefit of $6 for every $1 invested.

BCRs in Greater Depth

The Interim Study examines the savings (benefit) associated with an identified level of investment (cost). The ratio of the former to the latter is the BCR, which is one of many measures that decision-makers can use to judge the desirability of an investment. Here, "cost" means the up-front construction cost and long-term maintenance costs to improve existing

[2] National Institute of Building Sciences. *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities* (2005). http://www.nibs.org/mmc_projects#nhms

facilities or the additional up-front cost to build new ones better. "Benefit" refers to the present value of the reduction in future losses that mitigation provides. For the results presented in this report, a discount rate of 2.2% is used. At higher discount rates, including those used by the Office of Management and Budget (OMB), such measures remain cost effective.[3]

All mitigation produces benefits, so BCR is always greater than 0; there are no negative BCRs. A BCR over 1.0 signifies that the mitigation measure has an up-front cost, but after accounting for the time value of money and inflation, the future societal losses are reduced more than they cost on average. Thus, the return on investment (ROI), calculated by subtracting 1 from the BCR, is positive at the societal level. This means that the long-term cost of ownership at the societal level is lower with the mitigation than without it. The higher the BCR, the more cost effective is the measure.

The Interim Study includes the benefits associated with avoided cases of PTSD. The project team considered the cost of mental health impacts similarly to costs related to injuries as a whole; that is, as an acceptable cost to avoid a future statistical injury, as opposed to the expense associated with a particular injury. The costs consider direct treatment costs where treatment is about 10% of the overall costs of the incidence, and the other costs include things like lost wages, lost household productivity, and pain and suffering. Because few benefit-cost analyses (BCAs) even attempt to include these costs, the additional of acceptable costs to avoid a statistical instance of PTSD is a conservative but innovative addition to the 2005 *Mitigation Saves* study.[4]

[3] Consult Section 2.11 in the full report for an in-depth discussion on discount rates.

[4] See Sections 3.10 and 4.18 of the Technical Documentation for an in-depth discussion on the calculation of PTSD.

Why Four BCRs?

The *2018 Interim Report* of results features four high-level BCRs representing the benefits of mitigation achievable through exceeding code provisions, meeting the latest editions of commonly adopted code requirements, select utility and transportation infrastructure mitigation strategies, and federal grant programs. While the project team recognized the desire to have a single BCR that would facilitate widespread dissemination of the project results, providing such an aggregate number will be more useful when other parts of the Interim Study are completed.

The 2005 study produced the widely cited results that showed a $4 benefit for every $1 invested in mitigation. Despite the specific guidance that the result represented only a single, very narrow set of mitigation strategies, specifically those funded through FEMA mitigation grants, the BCR has been used to justify all types of mitigation strategies.

The *2018 Interim Report* includes the results from the examination of a new set of mitigation measures: exceeding the 2015 IBC and IRC and implementing the 2015 IWUIC that provides an aggregate benefit of 4:1; meeting the 2018 IRC and IBC that provides an aggregate benefit of 11:1; and utility and transportation infrastructure case studies that provide an aggregate benefit of 4:1. While these mitigation measures are an important addition to the dialogue around mitigation, they still only represent a subset of many practical strategies.

The *2018 Interim Report* also provides an updated examination of the benefits of federal agency grant programs (including the addition of EDA and HUD grants), resulting in a $6 benefit for every $1 invested. While not a direct replacement, when used to describe federal grant programs, the 6:1 BCR can be used in place of the original 4:1.

In lieu of providing a result based on a limited set of mitigation measures, with the result likely to change as new mitigation strategies are studied and added to the aggregate number, the project team elected to provide BCRs for each strategy individually. Once the project team has identified BCRs for a sufficient number of mitigation strategies, it will provide an aggregated number representing the overall benefit of mitigation.

Figure 1 shows the overall ratio of benefits to costs of designing new buildings to exceed the select 2015 I-Code requirements that the project team studied and meeting the 2015 IWUIC. The costs reflect only the added cost relative to the 2015 IBC and IRC, or the adoption of the 2015 IWUIC. Where communities have an older code or no code in place, additional costs and benefits will accrue. Figure 2 shows the overall ratio of costs to benefits for adopting the 2018 IRC and IBC as compared to 1990 design. Figure 3 shows the overall ratio of costs to benefits for implementing select utility and transportation infrastructure mitigation strategies. Figure 4 shows the overall ratio of costs to benefits for identified federal agency mitigation programs.

Figures 1, 2, 3 and 4 show that benefits extend beyond the property lines of the mitigated buildings and the lives of occupants. Mitigation frees up resources that would otherwise be spent on insurance claims and administrative fees. Mitigation helps to assure critical post-disaster

services to the community (e.g., fire stations and hospitals). Benefits and costs are rounded to no more than two significant figures to reduce the appearance of excessive accuracy.

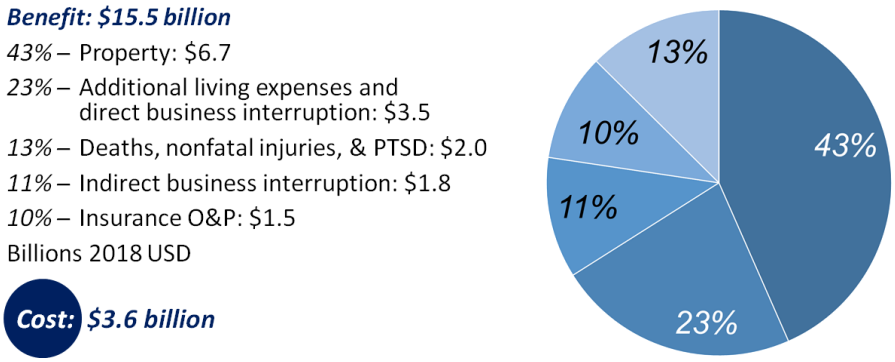

Figure 1. Total costs and benefits of new design to exceed select 2015 I-Code requirements and meet the 2015 IWUIC.

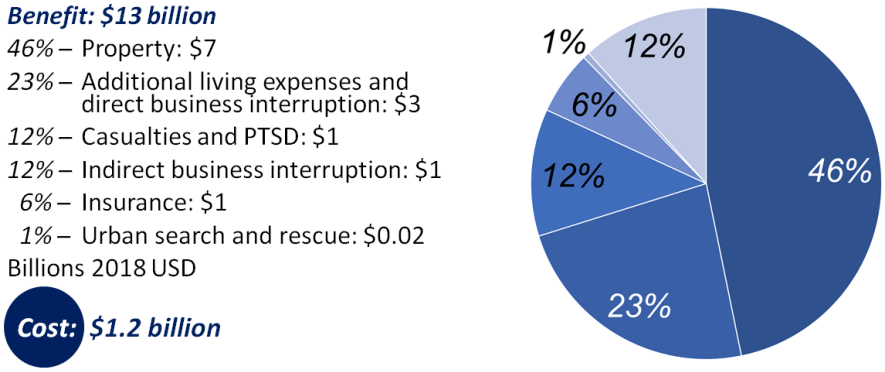

Figure 2. Total costs and benefits of meeting the 2018 IRC and IBC.

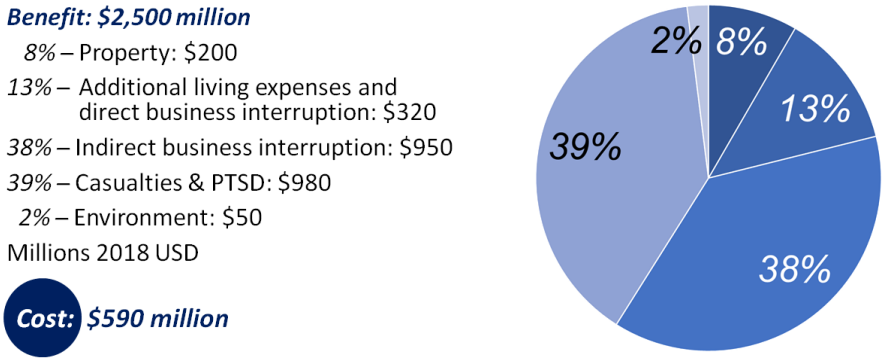

Figure 3. Total costs and benefits resulting from select utility and transportation lifeline mitigation efforts.

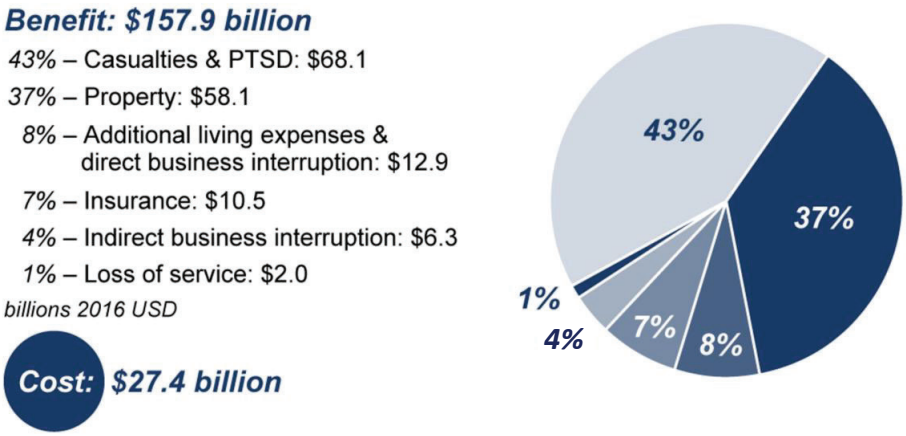

Figure 4. Total costs and benefits of 23 years of federal mitigation grants.

Tables 2, 3 and 4 provide details on the costs and benefits. The costs would be experienced mostly at the time of construction.

Mitigation Category	Cost	Benefit	BCR
Riverine Flood	$0.91	$4.30	**5:1**
Hurricane Surge	$0.01	$0.07	**7:1**
Hurricane Wind	$0.72	$3.80	**5:1**
Earthquake	$1.16	$4.30	**4:1**
Wildland-Urban Interface Fire	$0.80	$3.03	**4:1**
Total for select measures to exceed code requirements	**$3.60**	**$15.50**	**4:1**

Table 2. Costs and benefits associated with constructing new buildings in one year to exceed select 2015 I-Code requirements or adopt the 2015 IWUIC (in $ billions).

Mitigation Category	Cost	Benefit	BCR
Riverine Flood	$0.09	$0.55	**6:1**
Hurricane Wind	$0.53	$5.55	**10:1**
Earthquake	$0.58	$6.90	**12:1**
Total for adopting 2018 I-Codes	**$1.20**	**$13.00**	**11:1**

Table 3. Costs and benefits associated with constructing new buildings to meet the 2018 IRC and IBC (in $ billions).

Mitigation Category	Cost	Benefit	BCR
Riverine Flood	$11.54	$82.00	**7:1**
Wind	$13.60	$70.00	**5:1**
Earthquake	$2.20	$5.73	**3:1**
Wildland-Urban Interface Fire	$0.06	$0.17	**3:1**
Total for federal grants	**$27.40**	**$157.90**	**6:1**

Table 4. Costs and benefits associated with 23 years of federal grants (in $ billions).

Mitigation Benefits at the State and Local Level

Just as the vulnerability to specific natural hazards varies geographically, so too does the BCR for specific mitigation measures to resist those natural hazards. Figures 5 through 10 identify the state- or county-specific BCRs for designing to exceed select 2015 I-Code requirements, meeting the 2015 IWUIC, and meeting the 2018 IRC and IBC.

Considering the past 23 years of federally-funded mitigation grants, every state in the contiguous United States is estimated to realize at least $10 million in benefits, with the majority of states exceeding $1 billion in benefits. Four states: Louisiana, New Jersey, New York, and Texas, will save at least $10 billion (See Figure 11).

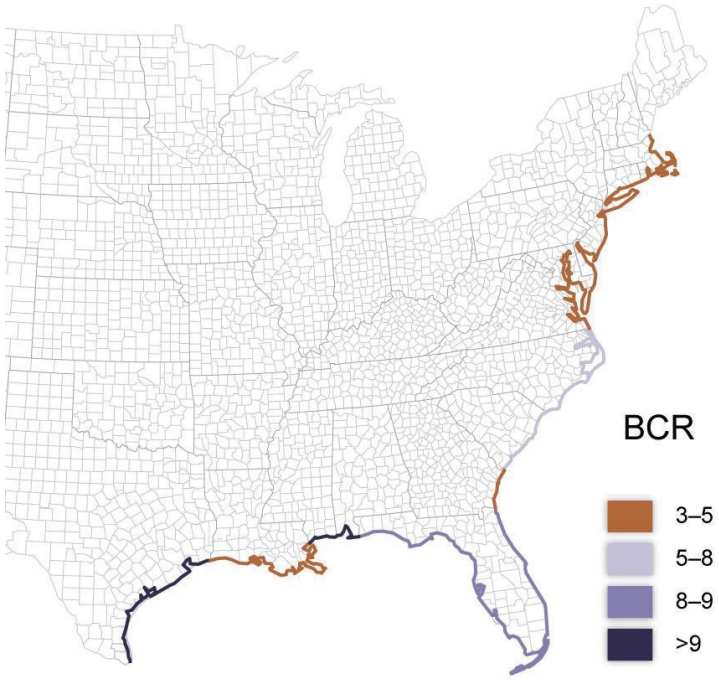

Figure 5. BCR of coastal flooding mitigation by elevating new homes above 2015 IRC requirements (by state).

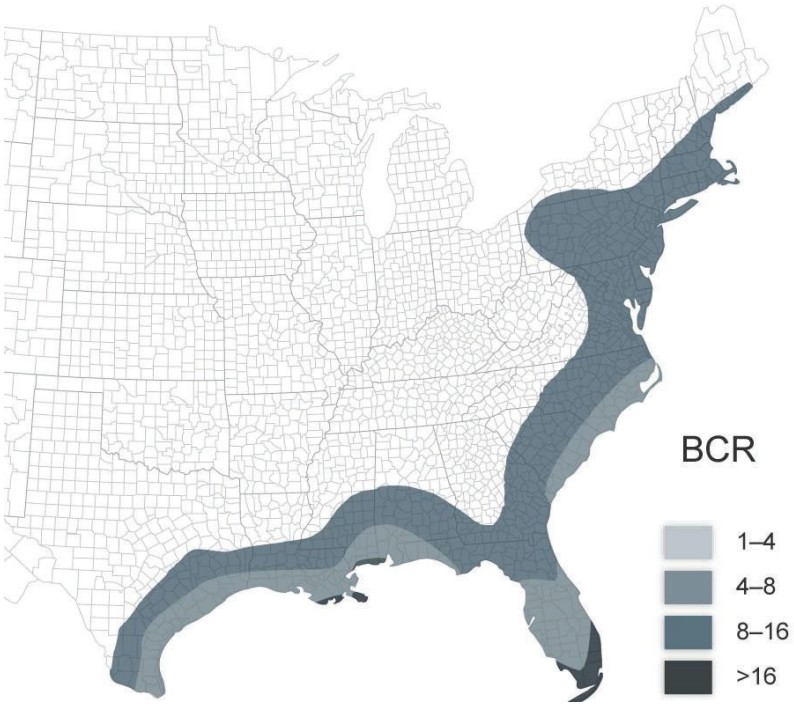

Figure 6. BCR of hurricane wind mitigation by building new homes under the FORTIFIED Home Hurricane Program above 2015 IRC requirements (by wind band).

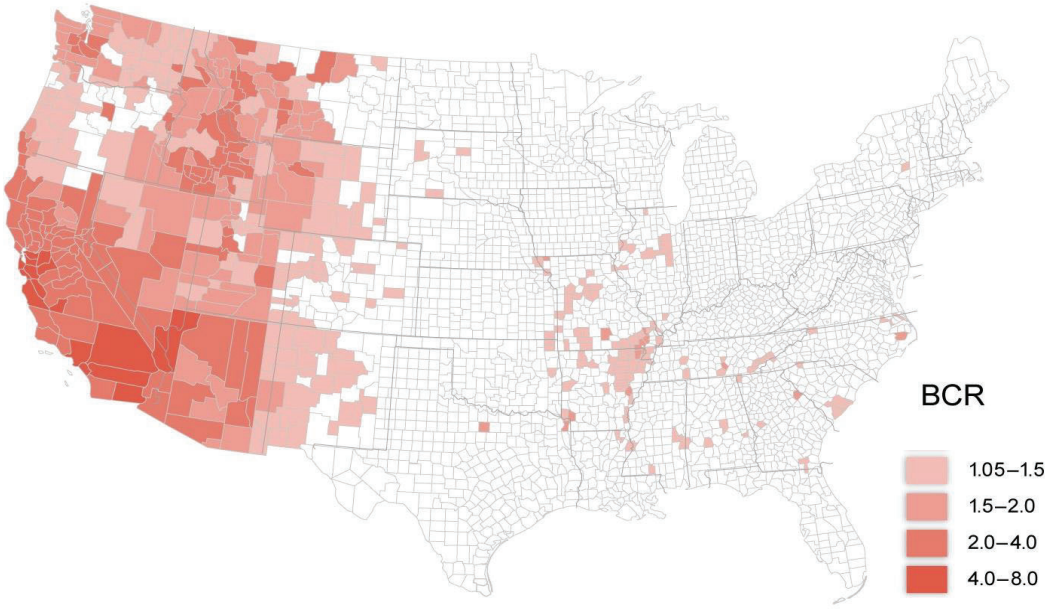

Figure 7. BCR of earthquake mitigation by increasing strength and stiffness in new buildings above the 2015 IRC and IBC requirements (by county).

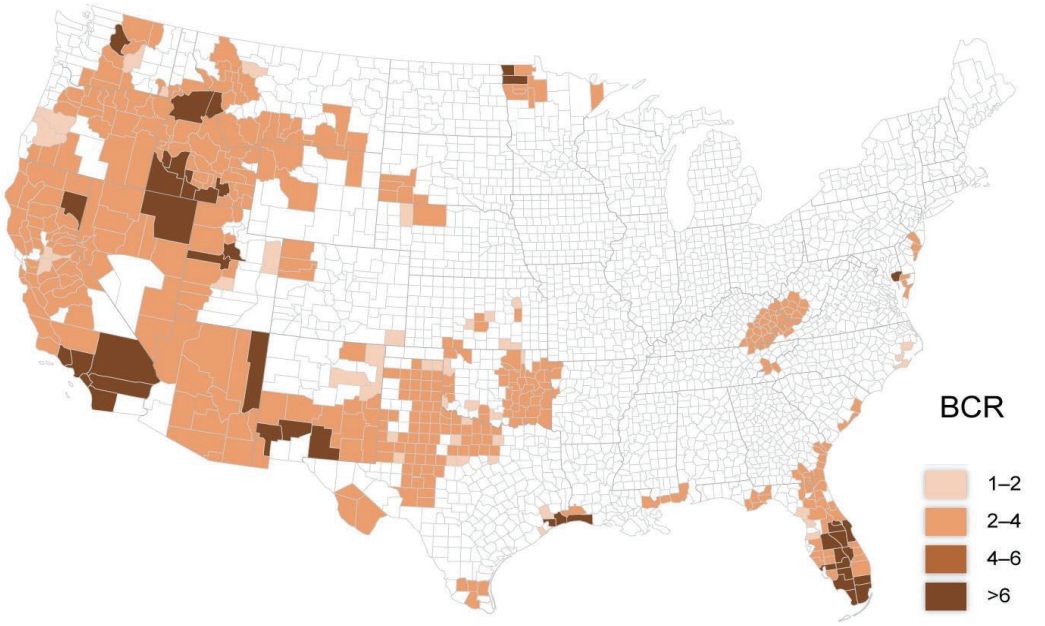

Figure 8. BCR of WUI fire mitigation by implementing the 2015 IWUIC for new buildings (by county).

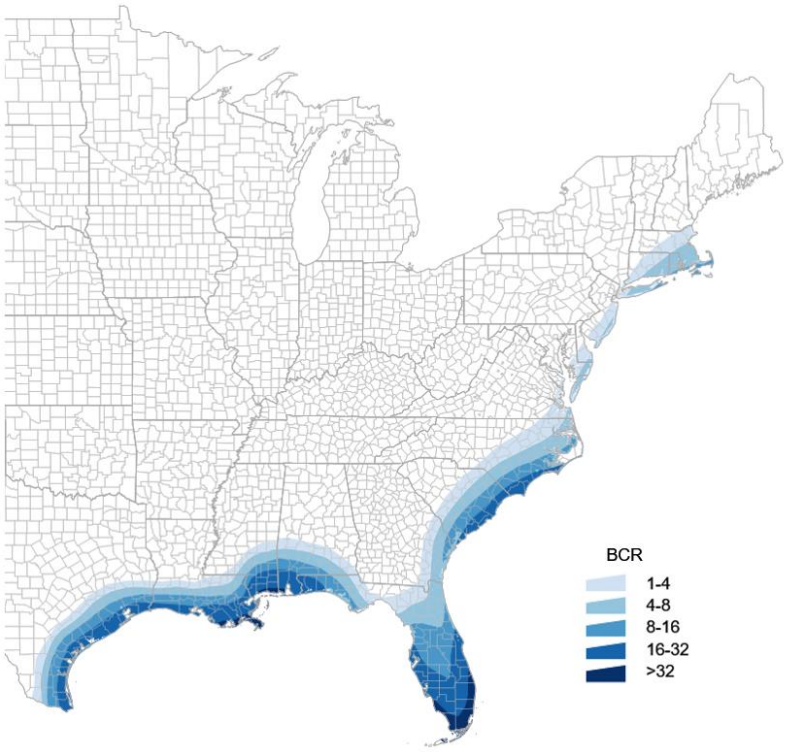

Figure 9. BCR of hurricane wind mitigation by increasing roof strength in new buildings to meet the 2018 IRC and IBC (by wind band).

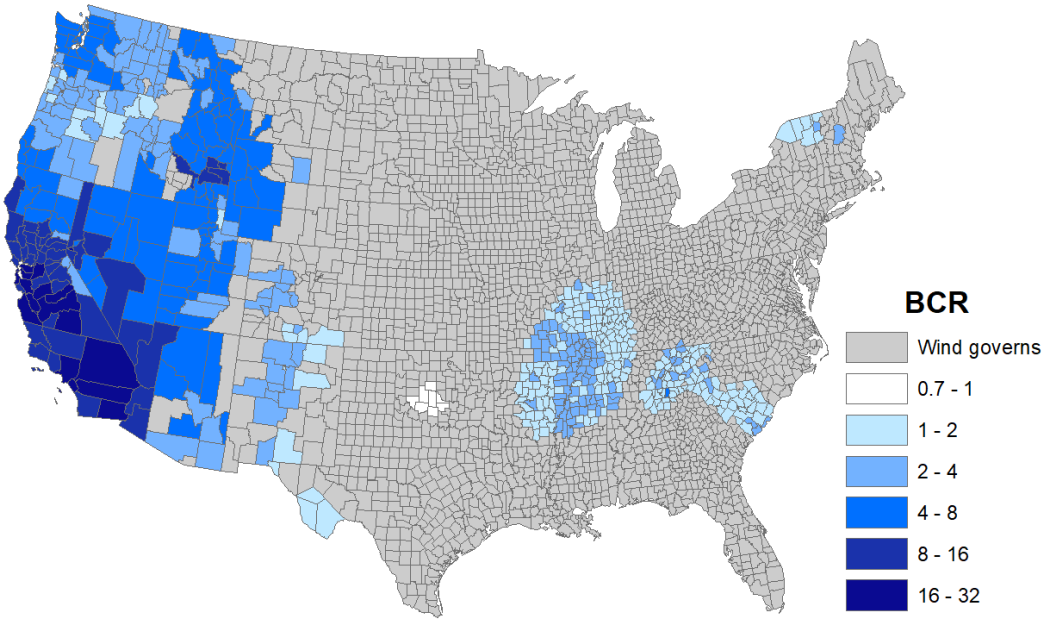

Figure 10. BCR of earthquake mitigation by increasing strength and stiffness in new buildings (by county) to meet the 2018 IRC and IBC.

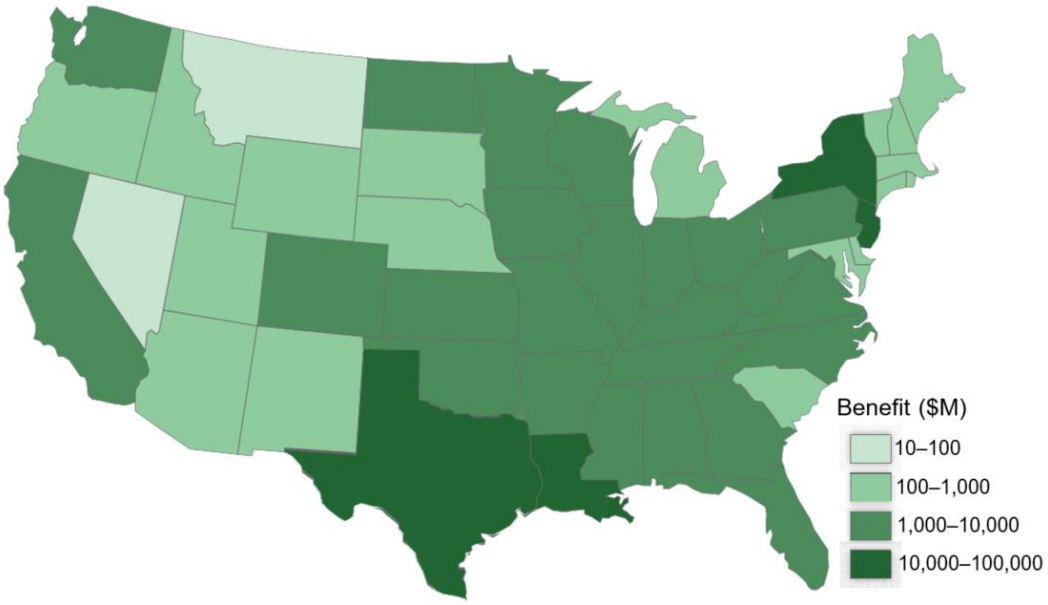

Figure 11. Aggregate benefit by state from federal grants for flood, wind, earthquake, and fire mitigation.

Building on the 2005 Mitigation Saves Study

In recent years, with the growing interest in the concept of resilience and the rising costs of disaster recovery, the MMC and industry stakeholders contemplated updating and expanding the 2005 study to address hazard-mitigation investments made by additional federal agencies, examine fire at the WUI, and examine mitigation measures undertaken by the private sector.

In 2017, the Institute, through a team of researchers, began a new, multi-year effort to develop an updated and expanded look at the benefits of hazard mitigation. The 2018 *Interim Report* includes the results from the study of four sets of mitigation measures. This *Summary of Findings* is the second edition of multiple documents that will ultimately examine the value of many kinds of natural hazard mitigation at the national level. The mitigation measures discussed are described in detail in the *Technical Documentation.*

Mitigation Measures Studied

The Interim Study uses the same independent, transparent, peer-reviewed methods from the 2005 study. Where practical, the study advances the prior work utilizing newer or more effective techniques.

What Benefits are Counted?

The 2018 Interim Report quantifies a number of benefits from mitigation, including reductions in:

- Future deaths, nonfatal injuries, and PTSD.
- Repair costs for damaged buildings and contents.
- Sheltering costs for displaced households.
- Loss of revenue and other business-interruption costs to businesses whose property is damaged.
- Loss of economic activity in the broader community.
- Loss of service to the community when fire stations, hospitals, and other public buildings are damaged.
- Insurance costs other than insurance claims.
- Costs for urban search and rescue.

The project team considered the benefits that would result if all new buildings built in one year were designed to exceed select I-Code requirements where it is cost effective to do so. If accomplished, the benefits would be that much greater in proportion to this quantity of new buildings. The stringency of codes adopted at the state and local level varies widely. To set a consistent starting point, the project team used the 2015 IRC and IBC as the baseline minimum codes. 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 IRC and IBC and to comply with the 2015 IWUIC in others. Strategies to exceed minimum requirements of the 2015 I-Codes studied here include:

- For flood resistance (to address riverine flooding and hurricane surge), build new homes higher 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 Hurricane standards.
- For resistance to earthquakes, build new buildings stronger and stiffer than required by the 2015 IBC.
- For fire resistance in the WUI, build new buildings to comply with the 2015 IWUIC.

The project team also considered the benefits that would result if all new buildings built in one year were designed to meet 2018 IRC and IBC versus codes represented by 1990 design and NFIP requirements. Across the country, code adoption is not uniform—the code editions in place vary widely from jurisdiction to jurisdiction. Some jurisdictions adopt new editions on a regular cycle, while others remain on older editions. With each new edition, additional benefits accrue. Some jurisdictions may capture these benefits in incremental pieces with each adoption, while others update their codes less frequently, during which time the benefits from more recent codes are not realized. Code-based mitigation strategies include:

- For flood resistance, incorporate at least one foot of freeboard into the elevation requirements to comply with the 2018 I-Codes.

- For resistance to hurricane winds, build new roofs to comply with the 2018 I-Codes and comply with a variety of openings and connection detailing requirements added since 1990.
- For resistance to earthquakes, build new buildings stronger and stiffer relative to 1990 construction to comply with the 2018 I-Codes.

The project team used 12 EDA grants and additional mitigation measures as case studies to show the degree to which mitigation of utilities and transportation lifelines can be cost effective. The project team estimated BCRs for several categories of infrastructure: water, wastewater, electricity, telecommunications, roads, and railroads. The measures studied include:

- Elevating roads and railroads; elevating water treatment plant electrical equipment; and relocating to higher ground electrical substations, telephone substations, water treatment plants, and wastewater treatment plants to better resist flood.
- Protecting water and wastewater treatment plants with berms.
- Moving electrical transmission lines underground to better resist wind loads.
- Strengthening bridge structures to better resist earthquake forces.
- Strengthening substation buildings and equipment to create a more earthquake-resilient electric grid.
- Hardening selected water pipelines to create a more earthquake-resilient water-supply grid.

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), as well as 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 a comprehensive picture of such mitigation measures. In the future, the project team might also look at mitigation measures directly implemented by federal agencies.[5] Results represent an enhanced and updated analysis of the mitigation measures covered in the 2005 study. Public-sector mitigation strategies based on federal grants include:

- For flood resistance, acquire or demolish flood-prone buildings, especially single-family homes, manufactured homes, and 2- to 4-family dwellings.
- For wind resistance, add hurricane shutters, tornado 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.

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

[5] Such measures include U.S. Army Corp of Engineers levees and other water management programs; National Oceanic and Atmospheric Administration early warning systems for weather; and U.S. Department of Agriculture (USDA) Forest Service prescribed burns

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 12 and 13 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.

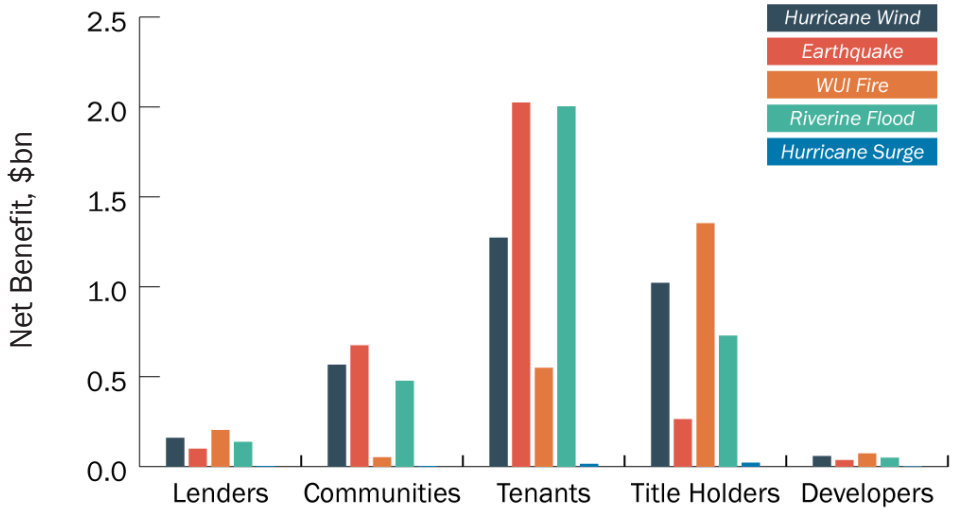

Figure 12. Stakeholder net benefits resulting from one year of constructing all new buildings to exceed select 2015 IBC and IRC requirements or to comply with 2015 IWUIC.

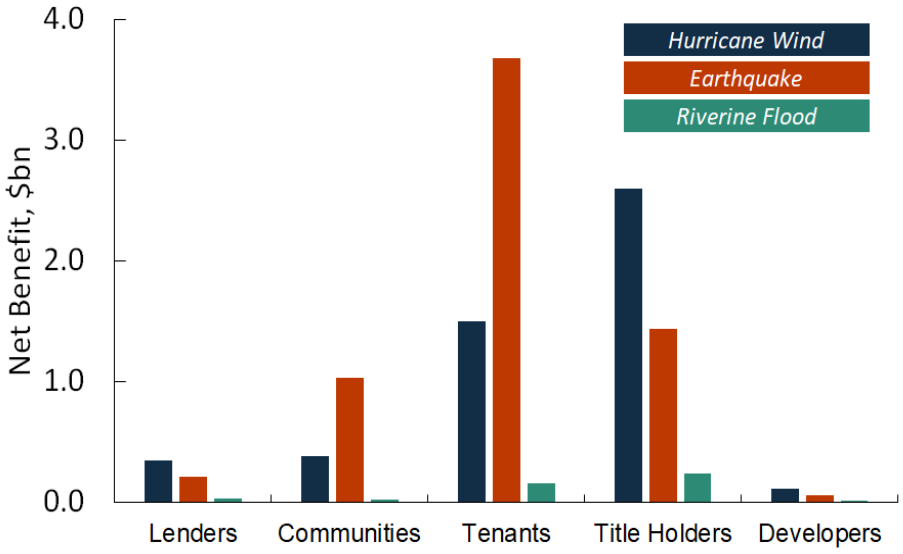

Figure 13. Stakeholder net benefits per year of new construction resulting from meeting the 2018 IRC and IBC.

Additional Mitigation Measures

The project team analyzed a number of mitigation measures, yet they do not represent all of the measures that could ultimately be applied to address the natural hazards studied. Recognizing the current limited applicability of the data provided, the project team identified additional mitigation measures to be studied. For example, in 2019 the project team will evaluate mitigation of existing buildings, while other measures have been identified but their analysis remains unfunded.

Existing buildings represent the vast majority of the building stock in the United States. While codes are generally applicable to new construction and to major renovations, some mitigation measures might be cost effective for existing buildings that are not otherwise part of a major renovation. The project team will research the BCRs for various measures that can improve the resilience of existing buildings to the identified perils.

Benefits Accrue Across a Spectrum of Design Options

The selected options to exceed 2015 I-Code requirements for flood, wind, and earthquake offer a range of design levels. The project team, as an example, analyzed these ranges, which include different elevations above base flood elevation (BFE), different IBHS FORTIFIED Home Hurricane design levels (Silver, Bronze, and Gold), and different strength and stiffness factor I_e for seismic design. The project team identified the point on a geographic and mathematical basis where the last incremental improvement in the design cost effectively captures the last incremental benefit, here called the incrementally efficient maximum or IEMax. In all cases, significant benefits can be achieved cost effectively at various levels of design up to this identified point, meaning that one can enjoy cost-effective improvement without designing all the way up to the IEMax. The ideal level of mitigation for a specific project will vary. The benefits and costs of mitigation measures at the project level should be evaluated based on the

specific characteristics of the project and the needs of the owner and users. This study does not address project-level conditions or the decision-making required at an individual project level.

Table 5 provides BCRs at the state level that correspond to a range of elevations above BFE. Figures 14 and 15 illustrate where the two IBHS FORTIFIED Home Hurricane and High Wind programs and the range of earthquake strength and stiffness factors result in cost-effective design.

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 Jersey	+2 to 6	**6.7** to **3.8**
New York	+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 5. BCRs for various heights above BFE for new coastal V-zone buildings.

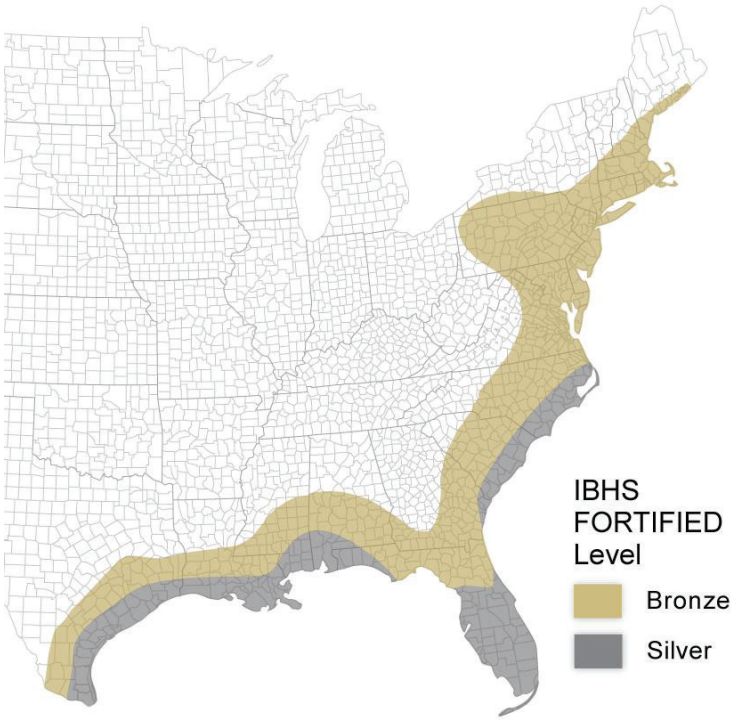

Figure 14. Maximum level of the IBHS FORTIFIED Home Hurricane design for new construction where the incremental benefit remains cost effective.

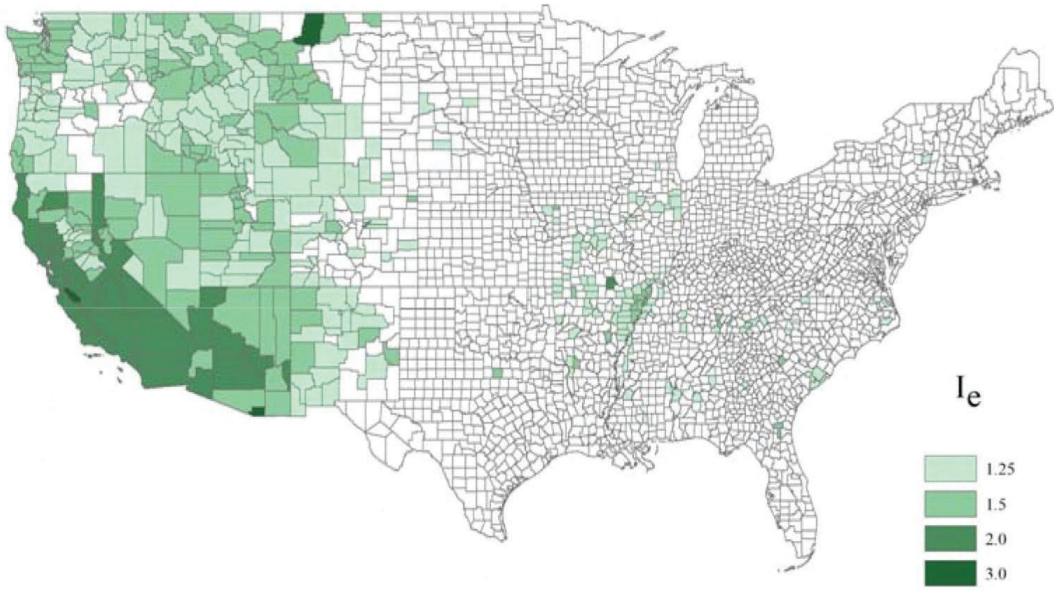

Figure 15. Maximum strength and stiffness factor Ie to exceed 2015 IBC and IRCseismic design requirements where the incremental benefit remains cost effective.

Utilizing the Best Available Science

To provide meaningful results within a reasonable timeframe and budget, the project team identified and used the best available, yet practical, science. For example, to estimate how earthquakes damage buildings, the project team used a 20-year-old method of structural analysis. Despite the existence of newer tools, this older approach was the only practical way to proceed given the enormous variety of building types, heights, occupancy classes, and design requirements that exist in the built environment.

Focusing on single mitigation strategies provides a means for understanding mitigation options, but does not capture the nuances of individual buildings and the hazards they may face. The *2018 Interim Report* examines the overall average cost effectiveness of mitigating broad classes of buildings, but does not address unique features of individual buildings. The details of a particular building can make a big difference in the cost effectiveness of mitigation. Elevating buildings reduces the chance that they will be flooded; however, people can still be stranded in elevated buildings. Designing new buildings to be stronger and stiffer in resisting earthquake loads reduces structural damage, but can increase the damage to acceleration-sensitive components such as furniture and other contents, unless one also takes care to properly install or secure those components, such as by strapping tall furniture to the building frame. Furthermore, using a simple factor for greater strength and stiffness may cost more or save less than a design that uses base isolation or another design technique. Each approach has its advantages and disadvantages.

Mitigation decisions take place in contexts that involve more than tangible costs and benefits. Other decision-maker preferences; available financial resources; legal and time constraints; justice and equity; and other variables also matter. The project team did not examine these other considerations, which could matter more than BCR. Furthermore, this study offers BCR estimates as one consideration for a wide variety of possibly complex decision situations that community leaders often face.

Incentivization Can Facilitate Ideal Levels of Investment

Not everyone is willing or able to bear the up-front construction costs for more resilient buildings, even if the long-term benefits exceed the up-front costs. Different stakeholders enjoy different parts of the costs and benefits, and the people who bear more of the costs may argue more urgently against mitigation than the people who enjoy more of the benefits. However, one set of stakeholders may be able to offer incentives to others to decrease the cost or increase the benefit, and better align the competing interests of different groups. The MMC and the Institute's Council on Finance, Insurance and Real Estate (CFIRE) have proposed a holistic approach to incentives that can drive coordinated mitigation investments, aligning the interests of multiple stakeholder groups so that they all benefit from a cooperative approach to natural hazard mitigation.[6]

Results Inform Mitigation Decision-Making

This *Summary of Findings* and the ongoing study add to the growing body of scientific evidence that demonstrates that mitigation lessens the financial impact of disasters on local businesses,

[6] National Institute of Building Sciences, *Developing Pre-Disaster Resilience Based on Public and Private Incentivization* (2015). http://www.nibs.org/resource/resmgr/MMC/MMC_ResilienceIncentivesWP.pdf

communities, and taxpayers and thus enables individuals and communities to recover more rapidly from these events when they do occur. Additionally, it affirms that decision-makers, including governments, building owners, developers, tenants, and others, should consider opportunities for implementing mitigation activities to reduce the threat to lives, homes, businesses, schools, and communities, while also reducing future repair and rebuilding costs.

Expert Contributions to the Interim Study

The Institute's project team, which consisted of eight authors and five leaders, developed the methodology with oversight by three committees, with a combined membership of 24 independent experts, who peer-reviewed the work and confirmed the results. Institute staff directed and managed the overall effort. FEMA provided additional review by 20 subject matter experts. Other agencies of the federal government, including EDA, HUD, and OMB, contributed a total of nine experts who provided input in developing the project, its methods, data, and products, or reviewed the study for reasonableness and usefulness. In particular, HUD, along with FEMA, provided economic input to the benefit-cost methodology. Four experts from ICC conducted several reviews. A total of 43 other representatives from 32 other organizations and stakeholder groups, including banking, insurance, government, construction, natural hazards, economic policy, environmental science, and structural engineering, provided oversight and peer review. The project team is well-known for expertise in earthquake engineering, fire, flood, and wind risk, as well as engineering economics and disaster sociology. Several of the authors participated in or helped lead the 2005 study. In total, the Interim Study represents the combined effort of over 100 experts in virtually all fields relevant to natural hazard mitigation in the United States.

Federal- and Private-Sector Support for the Interim Study

A number of public- and private-sector organizations interested in expanding the understanding of the benefits of hazard mitigation generously funded the research presented in the *2018 Interim Report*, as well as the project team's ongoing work. Funders to date are Premier Plus Sponsor FEMA; Premier Sponsors EDA and HUD; Lead Sponsor ICC; Sponsors IBHS and National Fire Protection Agency; and Supporter American Institute of Architects. While representatives from these organizations provided data and expertise to the project team, their input was largely informative, resulting in a truly independent study. The Institute seeks additional funders to support the study of additional mitigation measures.