

# Resilience Incentivization Roadmap 2.0

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A report by

Committee on Finance, Insurance and Real Estate  
Multi-Hazard Mitigation Council  
National Institute of Building Sciences

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Sponsored by:

Fannie Mae,  
represented by Tim Judge, Head of Modeling and Chief Climate  
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While this was a collaborative effort, it is important to recognize each of the authors.

Keith Porter, Chief Engineer with the Institute for Catastrophic Loss Reduction, led the development of the core concept, technical and business cases, real estate, benefit cost analysis, mitigation technical guides, and emotional incentives.

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Sean Kevelighan and Jeff Dunsavage, Chief Executive Officer and Senior Research Analyst with the Insurance Information Institute, led the development of the insurance Chapter. Dunsavage also served as the technical editor of the report.

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Special thanks to Mira Papinova with NIBS, who served as Project Manager.

## Sponsor and Project Team

Fannie Mae sponsored this work because it is aware that climate resilience will be key to sustainable homeownership as the impacts of climate change increase.

The National Institute of Building Sciences led this work and provided the thought leadership through its Multi-Hazard Mitigation Council (MMC) Committee on Finance, Insurance, and Real Estate (CFIRE). NIBS is an independent non-profit, non-governmental organization that was chartered by the U.S Congress to convene industry and government, bringing together experts from throughout the built environment in planning, design, construction, supply, technology, and government. NIBS leads efforts to ensure our buildings and communities remain safe and resilient by seeking consensus solutions to mutual problems of concern.

The project team (from the Western University Institute for Catastrophic Loss Reduction, the Insurance Information Institute, and Elliott Bay Analytics) participated because our missions align with the present project. We aim to make North America's buildings, utilities, and transportation infrastructure more resilient to natural disasters.

The team relied heavily on representatives of organizations (see page x) from across all stakeholder categories, without whose support the project would not have been possible.

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## Foreword

With increasingly frequent and severe disasters, the nation is struggling to cope. Governments are allocating an increasing share of their budgets to disaster response and recovery, communities are looking for long-term solutions, and all the while, businesses, citizens, and society writ large are feeling the impacts of hurricanes, wildfires, and the most common and costly disaster: flooding.

The difference between the status quo—a nation vulnerable to disasters—and a future where disasters have no economic, physical, or human consequences is what I call the “resilience gap.” While this future state might feel utopian, it should not deter us from making it our goal. Indeed, I believe resilience should be our North Star.

However, as I saw firsthand during my time at FEMA, the government alone cannot address the resilience gap. It will take public and private stakeholders, each working to leverage their unique capabilities, resources, and programs for the greater good. While they may lack direct authorities (the “sticks”), many of these stakeholders hold the carrots that could prove pivotal in closing the resilience gap.

As chair of the Committee on Finance, Insurance, and Real Estate, I’m delighted to share this report, which further advances the notion that private sector stakeholders can incentivize resilience actions in a way that governments alone cannot. Given the enormous potential scope of incentives, we opted to focus specifically on the most applicable industries and most prevalent hazard. We will continue to expand upon these efforts in the future and hope others similarly follow suit.

I credit the National Institute of Building Sciences for leading, and Fannie Mae for supporting, what I hope will become a national movement toward incentivizing resilience. Only through sustained efforts like this and actions by all stakeholders will we reach our goal of a more resilient nation.

Daniel Kaniewski, Ph.D.

Chair, Committee on Finance, Insurance, and Real Estate

Multi-Hazard Mitigation Council

## Executive Summary

In prior work, the [National Institute of Building Sciences](#) (NIBS) showed that investing in disaster resilience makes financial sense. That report – [Natural Hazard Mitigation Saves](#), published in 2019 – shows that spending money to improve one’s disaster resilience makes financial sense at the societal level. On a national average, natural hazard mitigation saves \$4-\$11 in avoided future losses for each \$1 invested, depending on the peril and mitigation measures. In its first edition of the present [“Roadmap to Resilience Incentivization.”](#) NIBS speculated that resilience incentives could lead to more people investing in disaster resilience and thereby reduce the human and financial cost of natural disasters.

The following paper – a product of collaboration across business and academic disciplines and incorporating input from a range of stakeholder groups – offers a roadmap toward implementing such incentives. It focuses on the peril of urban pluvial flooding and offers three major findings and several recommendations.

### Core concept: Co-beneficiaries help pay for mitigation

Resilience incentivization is about creating a set of mutually reinforcing contracts, grants, and other mechanisms for co-beneficiaries to help pay for resilience. Doing so better aligns everybody’s interests.

Figure ES-1A shows how resilience provides value to governments, insurers, real estate agents and brokers, and other co-beneficiaries. Figure ES-1B suggests how co-beneficiaries can help pay for resilience: through government grants and tax incentives, insurance premium incentives that reflect lower risk, consumer advice, higher resale value, lower loan points and rates, and lease premiums.

This roadmap explains how NIBS proposes turning these ideas into boilerplate contract language, consumer advice, and other incentive documents, and encourage people to use them in practice.

#### Intended Audience

*Owners and tenants.* Resilience costs and benefits these groups. Owners pay for retrofits and may pass cost to tenants. But both enjoy greater safety and lower property losses.

*Local, state, tribal, and federal government agencies* that provide or receive disaster aid, repair disaster damage, collect taxes that can drop because of disasters, or provide or receive disaster mitigation or development grants. Resilience benefits them through stable tax revenues and lower disaster expenses.

*Developers and Home Builders.* Resilience mostly costs this group, since they only briefly own resilient property. This work aims to change that.

*Financial services,* including portfolio lenders, securitizing lenders, securitizers, and investors, and government-sponsored enterprises, such as Fannie Mae. Resilience benefits them through lower default risk and higher property value in the event of a default.

*Insurers,* including primary insurers, reinsurers, and intermediaries. Resilience benefits them through lower claims and expenses.

*Real estate professionals.* Resilience benefits them through faster leasing and longer tenure. Growing evidence suggests resilient buildings have higher resale values.

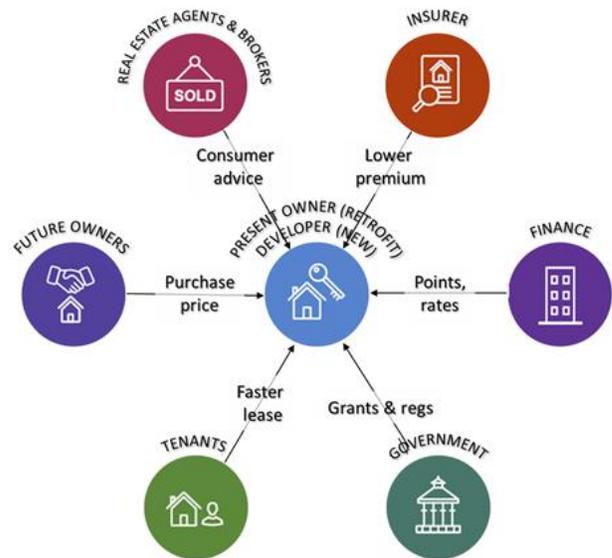
*Design and earth sciences professionals.* This includes engineers, architects, climate scientists, and seismologists who can provide technical information needed to make resilience incentives work.

Note that the figure emphasizes the relationships between co-beneficiaries and the present owner, but some co-beneficiaries also interact with others. For example, real estate professionals interact with future owners and tenants.

Figure ES-1A – How Resilience Provides Value



Figure ES-1B – How Co-Beneficiaries Can Help Pay



## Why Focus Initially on Pluvial Flooding?

About 90% of all U.S. natural disasters involve flooding. Whether related to coastal and inland inundation due to hurricanes, extreme rainfall, snowmelt, mudflows, or other events, floods cause billions of dollars in losses each year.

Pluvial urban flooding refers to rainwater that cannot flow downhill fast enough to reach streams and stormwater systems and therefore backs up through basement windows and into garages. Or, the rainwater flows into buildings due to improper grading. Or, it backs up through sewer laterals into buildings from overwhelmed combined sewer and stormwater system.

Wing et al. (2018) estimate that 70% of Americans who face at least a 1-in-100 annual chance of flooding (28 million of 41 million total) live outside special flood hazard areas (SFHA) designated by the Federal Emergency Management Agency (FEMA). Many of these 28 million are subject to pluvial flood risk. Much of the inland flooding caused by Hurricane Ida (2021), Hurricane Ian (2022), and more recent flooding in California due to “atmospheric rivers” and in the Northeast would fall under this category.

Common low-cost measures exist to protect buildings from pluvial urban flooding, including sewer backflow valves, battery backup sump pumps, and proper grading that slopes away from buildings.

The relative ease and affordability of such mitigations – compared to the major structural modifications often required to address coastal or riverine flooding – made pluvial urban flooding an appropriate initial target for this project.

Disaster mitigation is a complicated subject. Cost-effective approaches vary by peril, asset class, location, and other factors. This work does not attempt to provide a complete roadmap to incentivizing all mitigation for all situations. But it can provide a starting point. We believe our concept and findings can be applied to other types of flooding and other non-flood perils.

## Findings

1. ***Mitigation saves, but it doesn't do so in proportion to individual stakeholder investments.*** Investment in disaster resilience makes great financial sense for society – but for individual stakeholders the cost can seem to exceed the benefits. For example, the \$5,000 it might cost to retrofit an existing house benefits the current owner, future owners, insurers (by limiting the risk of flood-related claims, assuming the property is insured against flood), financial institutions holding the property owner's mortgage, and so forth. The retrofit saves society more than it costs in places with at least a 1 in 100 chance of basement flooding per year. It saves up to 13 times the cost in the highest hazard locations. But, to the homeowner paying the entire cost, the investment can seem hard to justify. (Building for flood resilience at the time of initial construction is less expensive and more cost effective, and it makes sense even when flooding occurs less frequently.)
2. ***Co-beneficiaries can share the cost of such investments – but they face similar challenges to those of the property owner.*** In the \$5,000 basement-flood retrofit example, mortgage holders and governments would save in the long run by offering a total of \$3,300 in incentives anywhere with at least a 1-in-100 chance of basement flooding per year. Homeowners would end up paying only \$1,700 and saving more than they pay in both moderate- as well as high-hazard locations. Why don't co-beneficiaries provide these incentives? Because stakeholders' interests are intertwined but are not aligned.
3. ***Public-private coordination is essential.*** In developing this roadmap, we engaged with scores of professionals across all the stakeholder groups. The stakeholders' interest in addressing this misalignment of incentives has been as evident as the complexity of the challenge itself. It's clear that research and work are being done by many, but these efforts require coordination to bear fruit.

With support from [Fannie Mae](#), NIBS developed this roadmap toward creating and implementing these incentives, including a conceptual flood resilience certification program and three possible pilot studies.

This roadmap provides a framework for aligning the interests and incentives of these stakeholders. It focuses on pluvial urban flood resilience for illustration, but many of the principles can be applied to riverine and coastal flooding, as well as non-flood perils. In fact, the roadmap draws heavily from

voluntary programs that have seen success in other contexts – such as those associated with the [Insurance Institute for Business & Home Safety \(IBHS\) FORTIFIED Home™ Standard](#) and the [California Earthquake Authority's Earthquake Brace + Bolt](#) retrofit program.

## Recommendations

This roadmap was developed by a multi-disciplinary team that received input from organizations representing a cross-section of stakeholder groups. The team recommends the following:

- 1. *Develop a flood resilience building certification program.*** Mitigation would provide clearer, more verifiable benefits if they met a predefined standard to which stakeholders could refer, incorporating technical guides, a training program, and a system to record compliance. Several organizations have developed rating systems for other perils, especially earthquake and wind, but not yet flood. A flood resilience certification program could be created in partnership with these other organizations and patterned on successful programs like the U.S. Green Building Council's [Leadership in Energy and Environmental Design \(LEED\)](#) certification. The program developers will decide costs and who pays.
- 2. *Pilot test an incentive program.*** A pilot program needs to be carried out to test whether a network of mutually reinforcing incentives would work. The pilot program could be built upon the knowledge collected in this report and aim at investing in pluvial flood risk mitigation, possibly including a certification program for measures such as the basement flood protection actions detailed in this report. The concept and feasibility could also be explored in other natural hazards and building sectors.

The pilot study would include as many co-beneficiaries as are willing to participate.

- a) Governments offer grants to help pay for mitigation. Numerous examples exist of local, state, and federal governments supporting a variety of resilience measures including basement flood protection.
- b) Mortgage holders choose among several options. They could reduce some loan origination fees. If the mortgage holder is a bank or credit union, they might offer discounts on other services or products they offer. Or, the mortgage holder may offer a slightly lower interest rate on the mortgage.
- c) Insurers price coverage to reflect the risk reduction produced by the certified mitigation measures or incorporate other risk-specific products, such as [parametric insurance](#) to provide liquidity required for homeowner resilience or [community-based catastrophe insurance](#) programs.

- d) Real estate agents and brokers offer potential buyers and tenants plain-language literature that explains the risk-reduction benefit of the mitigation measure.
- e) Recognizing that sometimes money matters less than other emotional considerations, we also propose various appeals to psychology and behavioral economics.

The more of these incentives that can be offered in a pilot study, the better. If several competing options present themselves, the choice could be informed by the one with the greatest monetary value, emotional appeal, breadth of incentives, or likelihood of success. A pilot should resemble a sound, diversified investment portfolio, with many small bets that include existing incentives, rather than relying on one big new one.

Here are some new options, or new bets, to add to the incentive portfolio for the pilot test:

- a) Cities reduce development impact fees for developers who build new houses to include certain mitigation measures;
  - b) Government-sponsored enterprises (entities like Fannie Mae that purchase loans in secondary markets) arrange for lenders to offer home equity loans (HELoans) expressly to pay to retrofit homes for greater resilience; and
  - c) Federal government offers tax relief to homeowners who retrofit their homes for greater resilience or to developers who build new homes to exceed building-code minimum requirements.
3. ***Test the conjecture that flood resilience has a market value.*** When selling existing homes, some real estate agents advertise that the home has some resilience feature: a tornado shelter, various wind-resistance features, or seismic retrofit. A growing body of research shows that when they offer that market signal, buyers pay more for the house – in some cases, far more than what it costs the seller to add the resilience feature. If the same proved true for flood resilience, greater resale value would represent a powerful incentive. The pilot program could provide a mechanism for testing this hypothesis.
4. ***Engage private insurers to help them build on their existing individual efforts to promote resilience-focused investments.*** Operational and regulatory constraints make developing insurance discount programs a challenge. It has been done, however, as part of state-specific approaches to perils other than flood. Premiums must reflect actual risk factors – therefore, any discounts would have to be based on measurable reduction of the likelihood and potential cost of damage from the risk being covered.

Knowing this, and consistent with all federal and state antitrust laws, we propose a three-step approach to engaging private insurers and state insurance regulators on pluvial flooding, risk-reducing mitigation actions, and their relevance to private flood insurance:

- a) Form a panel of actuaries, underwriters, claims professionals, and product developers representing a cross-section of U.S. homeowners insurance exposure and of reinsurers who provide capacity to assess pluvial flooding risk and the effect of various mitigation actions on risk reduction.
- b) Hold a conference at which the panel's findings are presented to insurers who currently offer residential flood insurance and representatives from the National Association of Insurance Supervisors and state insurance regulators.
- c) In coordination with relevant state regulators, individual insurers incorporate information about pluvial flooding and risk-reducing mitigation actions into pricing and underwriting in the state in which the pilot occurs.

Taken together, these recommendations would form the basis for the pilot program (or series of pilot projects) to create value for all stakeholders while generating useful learnings toward future resilience incentive efforts.

## Preface and Acknowledgements

The National Institute of Building Sciences and Fannie Mae prepared this document: A roadmap toward a collaborative mitigation investment strategy that will help Americans make buildings and other infrastructure more resistant to climate change and earthquakes.

Stemming from prior mitigation research - *Natural Hazard Mitigation Saves* and *Roadmap to Resilience Incentivization*, NIBS aimed to develop this roadmap with recommendations on private and public incentives for owners of buildings and other infrastructure to facilitate the upgrade of existing infrastructure and better design of new infrastructure.

For this purpose, the study sought collaboration with all stakeholders of the built environment - lenders, developers, insurers, engineers, agencies, and policymakers - with the goal to support communities to develop layered mitigation investment packages. We would like to acknowledge the many subject matter experts from the Multi-Hazard Mitigation Council (MMC) and its Committee on Finance, Insurance, and Real Estate (CFIRE), who supported this important initiative.

Specifically, for this roadmap development, appreciation is due to Tim Judge, Fannie Mae's Chief Climate Officer, who supported this study, collaborated with the team, and provided invaluable input on the discussed topics. We would also like to recognize CFIRE Chair Daniel Kaniewski from Marsh McLennan, who worked tirelessly behind the scenes, reviewed the drafts reports, and connected the authors of the study with subject matter experts from all fields in the industry, so we could gather a variety of perspectives. We are grateful for the extensive review and comments provided by Stuart Adams with Stantec, Lindsay Brugger with the Urban Land Institute Americas, Anne Cope and Michael Newman with Insurance Institute for Business & Home Safety, Ryan Colker with the International Code Council, Jason Fraley with The Huntington National Bank, Thomas Hughes with Pennsylvania Emergency Management Agency, John Ingargiola with Federal Emergency Management Agency, Jack Krolkowski with American Flood Coalition, Carolina Thompson with Freddie Mac, and Kathryn Thurston with PGIM Real Estate.

We hope to lay out a potential path to increase mitigation investment and wish to collaborate with existing programs in other organizations for potential pilot projects. We strongly believe that real progress on resilience incentives will require collaboration across the building sciences, marrying the efforts of both the private sector and government. Individuals and organizations who have contributed to the project include:

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 Federal Housing Finance Agency  
 Fifth Third Bank  
  
 Freddie Mac  
  
 Guy Carpenter  
 The Huntington National Bank  
  
 Insurance Institute for Business & Home Safety  
 Institute for Catastrophic Loss Reduction  
 International Code Council  
 Lennar Mortgage  
 Mitigation Framework Leadership Group (MitFLG), FEMA  
 Mortgage Bankers Association  
 Munich Re  
 National Association of Home Builders  
 National Association of Insurance Commissioners (NAIC)  
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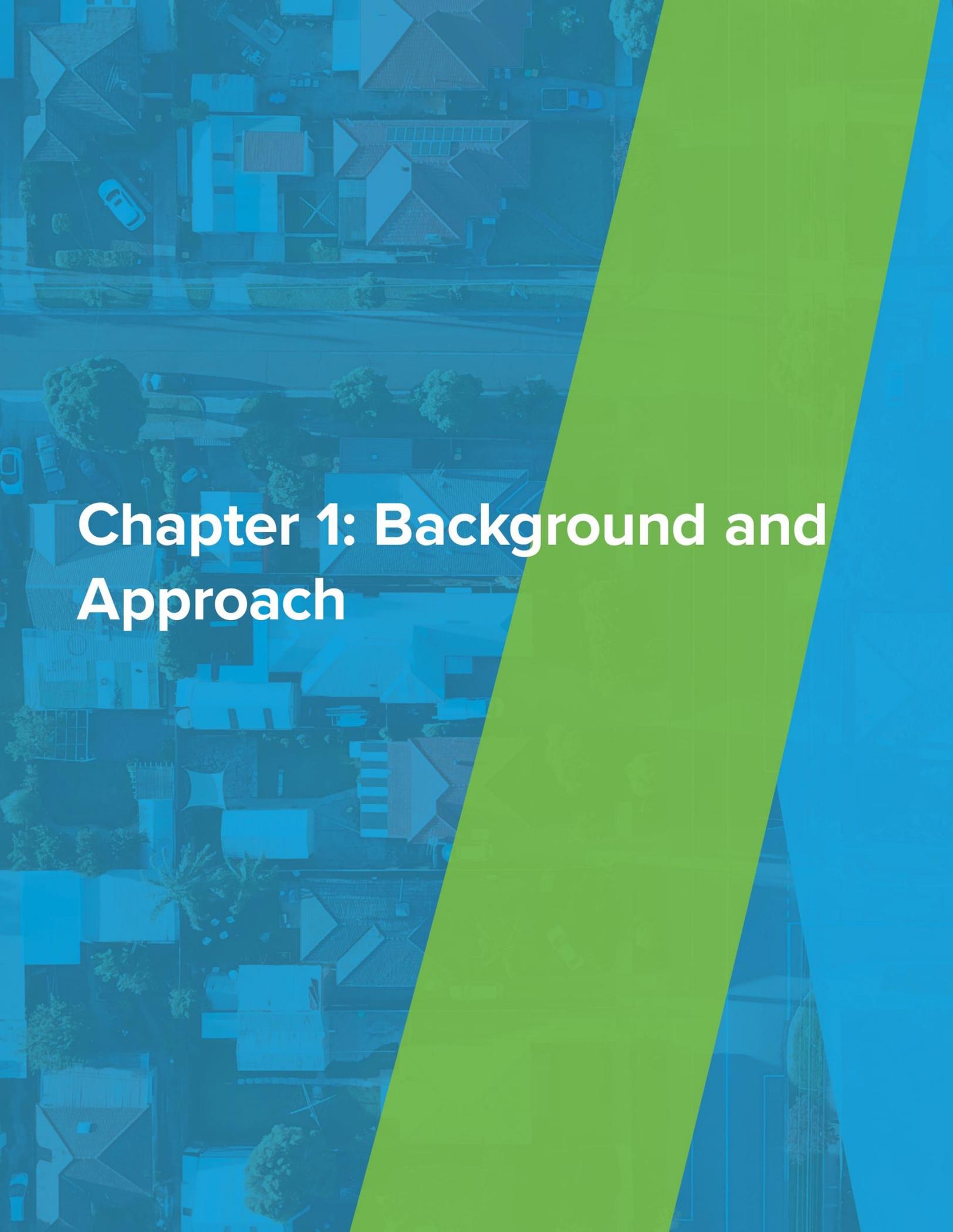
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## Glossary

ASME	American Society of Mechanical Engineers
BCR	Benefit-cost ratio
CBCI	Community-based catastrophe insurance
CEA	California Earthquake Authority
CRS	Community Rating System
CRT	Credit-risk transfer security
CSA	Canadian Standards Association
DIY	Do it yourself
DOE	US Department of Energy
DOT	US Department of Transportation
DRRA	Disaster Recovery Reform Act
EAL	Expected annualized loss
EDA	Economic Development Administration
EMS	Emergency medical service
EPA	US Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHFA	Federal Housing Finance Agency
FHA	Federal Housing Administration
FIA	Federal Insurance Administration
FIRM	Flood insurance rate map
Fluvial flooding	Flooding from a nearby water body such as a river overflowing its banks
GDP	Gross domestic product
GSE	Government-sponsored entity
HEloan	Home equity loan

HUD	US Department of Housing and Urban Development
IBHS	Insurance Institute for Business & Home Safety
IPCC	Intergovernmental Panel on Climate Change
LTV	Loan-to-value ratio
MBS	Mortgage-backed security
MLS	Multiple Listing Service
NAHB	National Association of Home Builders
NAIC	National Association of Insurance Commissioners
ND	No date
NFIP	National Flood Insurance Program
NIBS	National Institute of Building Sciences
Pluvial flooding	Flooding caused by rain that cannot drain away fast enough into the stormwater system or nearby waterways
PSA	Public service announcement
SBA	Small Business Administration
SFHA	Special Flood Hazard Area
USD	United States dollars
USACE	US Army Corps of Engineers
VA	Veterans Administration
Vulnerability	Here, the degree of loss experienced as a function of the degree of environmental excitation, such as repair cost as a function of flood depth.

An aerial photograph of a residential neighborhood, showing houses, streets, and trees, overlaid with a semi-transparent blue filter. A large, bright green diagonal stripe runs from the top right towards the bottom left, partially obscuring the text.

# Chapter 1: Background and Approach

## Chapter 1: Background and Approach

U.S. natural disaster losses currently cost \$120 billion annually (see Figure 1-1, developed for the present work) – about 8% of the private construction completed per year (U.S. Census Bureau 2023). That means disasters wipe out the equivalent of one month of construction investment per year on average. In 2017, the loss exceeded \$300 billion, equivalent to three months of construction value put in place (National Oceanic and Atmospheric Administration National Centers for Environmental Information 2023).

One might expect or hope that, as more resilient construction replaces more vulnerable buildings, the nation’s disaster losses would decline relative to population. But, contrary to expectation, U.S. disaster losses are growing 6% per year, 10 times faster than population, twice as fast as gross domestic product. (See Changon et al. 2000 for some causes of the growth.)

On our current trajectory, natural disaster losses will eat up a greater and greater share of construction expenditures, with repairs displacing investment. This trajectory is unsustainable.

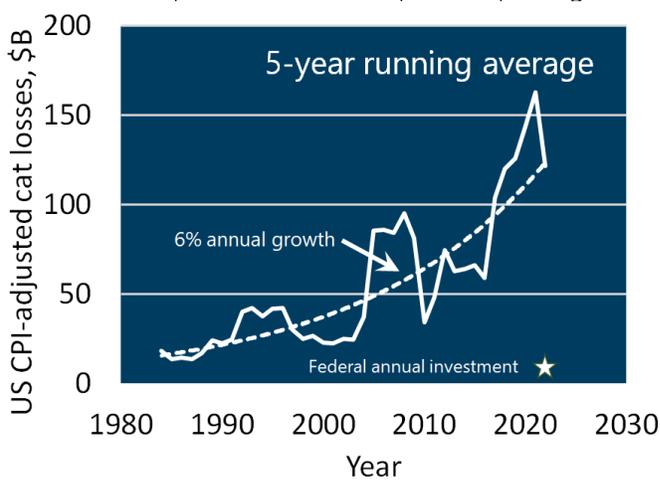


Figure 1-1. U.S. catastrophe losses are growing at an unsustainable clip

(Data from National Oceanic and Atmospheric Administration National Centers for Environmental Information 2023)

The American Society of Civil Engineers has consistently estimated that the U.S. has deferred trillions of dollars of maintenance on its utilities, transportation infrastructure, and other lifelines. In 2022, that figure was \$2.9 trillion. The *Natural Hazard Mitigation Saves* study (Multi-Hazard Mitigation Council 2019) quantified a few ways in which the country could cost effectively close its resilience investment gap. An estimated \$500 billion could be invested in 15 projects to retrofit private-sector buildings and \$4 billion per year on better-built new construction. The \$500 billion retrofit figure omits several important categories of fragile buildings, such as older steel and concrete buildings in seismically active parts of the country. In light of the climate crisis, this may underestimate the cost effectiveness of investment in wildfire and flood retrofitting.

Given the deferred maintenance costs, the investment needs identified in *Natural Hazard Mitigation Saves*, and the omitted categories of vulnerable buildings, the nation's resilience investment gap seems likely to exceed \$5 trillion. The federal government has allocated a few billion per year to the problem – orders of magnitude too small to substantially solve it.

In this work, we address the question: How can we mobilize private-sector investment to significantly address the problem?

*Natural Hazard Mitigation Saves* and other studies show that mitigation makes financial sense:

- Code improvements would save \$4 per \$1 of added cost, as would retrofits to buildings, utilities, and transportation infrastructure.
- Public-sector retrofits have been shown to save an estimated \$6 per \$1 of cost.

So why aren't we already making these investments?

The reason has to do with the notion of "we." We are not building better because **we** don't build. Developers and owners build and bear the initial expense. While they enjoy some of the benefits of resilience, others go to a variety of stakeholders. The more that costs are carried by one group while others enjoy the benefits, the more the groups' interests fail to align. Such misaligned interests seldom lead to positive societal outcomes.

The National Institutes of Building Sciences (NIBS) [Multi-Hazard Mitigation Council](#) has conceived of public-private incentivization mechanisms to better align those competing interests. In our concept of resilience incentivization, co-beneficiaries share some of their co-benefits with owners and developers in reasonable fair proportion to both offset the developer or owner resilience cost and to increase their resilience investment. (See [white papers and roadmap 1.0.](#))

This work aims to show in greater detail how the incentives would work, outline some of them, and gather evidence of how people would use them. To limit our scope and make practical recommendations, this work focuses on incentivization for one class of property owners and a group of retrofit measures for one peril and one building type. However, the methodology should be applicable to many kinds of decision-makers, perils, and building or other asset types.

## Homeowners bear the greatest exposure

Homeowners bear more exposure to flood risk than other stakeholders. Yet, as a group, they underinvest in features that would make their homes more resilient to floods.

Disasters kill or injure residents. Owners pay for the uninsured portion of the costs of repairing any damage to the home. If damage is severe, residents may need to find alternative shelter, perhaps for an extended period. The location, condition, and cost of the alternative living arrangement may hamper the residents' ability to maintain their employment and schooling commitments.

For homeowners, financial incentives may take the form of government grants or tax credits and discounts for different types of loans, insurance, and real estate services. It may be difficult for homeowners to perceive the combined subsidy of financial incentives offered by multiple stakeholders. This lack of awareness makes it even more difficult for homeowners to fully appreciate the financial value of such support.

Ultimately, homeowners are the gatekeepers for resilience investment. In the absence of building-code requirements or other mandates, such investments occur only when homeowners choose to pay for them. For existing homes, owners must be willing to pay to retrofit. For new construction, prospective buyers must be willing to defray the increased costs borne by the builders. The entire scope for increasing the resilience of homes to flood risk lies with current and prospective homeowners.

## Why homeowners underinvest in resilience

Three factors may discourage a homeowner from investing in resilience:

- Cost of investment.
- Inability of the homeowner to capture all the benefits of a resilience investment, despite bearing the entire cost; and
- Uncertainties surrounding flood risk, appropriate investments, and length of homeownership.

To understand how these factors may lead homeowners to underinvest in resilience, it is useful to contrast an energy-saving investment, such as installing solar panels, with a resilience investment of similar cost:

- The federal government and some state governments offer significant tax credits to subsidize the purchase and installation of solar panels. Resilience investments are rarely subsidized<sup>1</sup>.

<sup>1</sup> The wind-risk-related FORTIFIED™ designation created by the Insurance Institute for Business & Home Safety (IBHS) is an exception. In some states, discounted insurance premiums are available to homeowners who achieve a FORTIFIED designation, and some states have offered grants to homeowners to undertake the investments required to achieve a FORTIFIED designation.

- The up-front cost of both solar panel installation and resilience investments can be financed. Many lenders, both bank and non-bank, have programs specifically for financing solar panels. Loans for resilience investments are evaluated as generic home improvement loans.
- The financial benefits of solar panels are immediate, certain, and tangible. The benefits of the resilience investment accrue in the future—if at all—and are difficult to measure. The impact of solar panels on the resale value of a home can be gauged by showing the most recent year of electric bills to prospective buyers

A resilience feature's potential value in avoided future repair costs depends on the probability of the occurrence of a flood. Unfortunately, human beings are notoriously poor judges of probability. To make matters worse, the probability of a damaging flood differs from house to house. Damage from a flood can differ even for next-door neighbors.

The plethora of estimates available to homeowners makes clear the uncertainty surrounding the risk of a flood at a specific location. An important source of information about this risk is the portfolio of Flood Insurance Rate Maps (FIRMs) maintained by the Federal Emergency Management Agency (FEMA). These maps partition areas into zones of higher or lower risk of any type of flood, but gradations of likelihood are coarse—from lowest to highest. They are (1) less than a 0.2 % annual chance of a flood, (2) at least a 0.2 % annual chance but less than a 1 % annual chance of a flood (the 500-year floodplain), (3) at least a 1 % annual chance of a flood (the 100-year floodplain). Category (3) is defined as high risk by FEMA.

A host of other sources on location-specific flood risk are available online. Some are free and provide site-specific maps of the depth and likelihood of flooding today and in future decades for any location in the conterminous U.S., under a variety of future climate policies. Others charge a small fee for a report on an individual property. Like the FEMA FIRMs, some sources report ranges of risk, often at a more granular level than that of FIRMs. Other sources provide point estimates of the annual probability of a flood, often along with an estimate of the average annual loss (property damage) due to flood. Some provide information about the method they use to estimate the risk of a flood, while others maintain their formulas are proprietary knowledge. Given the profusion of available estimates, it is no surprise that homeowners are uncertain about the risk they face.

In addition, homeowners are not cold-blooded calculating machines. Some studies suggest homeowners' estimates of flood risk can be unduly influenced by emotional reactions to recent events. While it makes sense to update estimates of flood risk, the tendency to overreact to a recent event is well documented in the literature on behavioral economics<sup>2 3</sup>.

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<sup>2</sup> Recency bias is just one of the many tendencies that can lead people to misjudge the objective probability of risk. The opposite of recency bias is primacy bias, the tendency to overweight the earliest events or facts. And normalcy bias is a tendency to disbelieve or minimize threat warnings. All these biases, and more, can make it difficult for homeowners to accurately assess the flood risk of their home

<sup>3</sup> In *The Maltese Falcon*, Dashiell Hammet presents an example of the tendency to overreact to recent information. Private detective Sam Spade tells the story of a missing person case he was assigned. A married

Even if it was possible to provide precise information about the probability of a flood to every homeowner, people differ in their willingness to bear risk. Some homeowners are very risk averse, while others are willing to roll the dice and avoid the cost of resilience investments, even when the probability of a future flood is significant.

The limited length of homeownership<sup>4</sup> creates an additional disincentive to investing in resilience. With proper maintenance, a well-built house can easily last significantly longer than 50 years. In areas with elevated flood risk, the risk of a damaging flood is quite high over that span. However, the average duration of homeownership in the U.S. is just eight years<sup>5</sup>, meaning the probability of a damaging flood is much less.

For instance, if the annual probability of a flood at a particular property is 1% (the so-called 100-year flood plain), the probability of a flood in 50 years is 39%. The probability of a flood in eight years is 8%. Thus, the average homeowner bears 100% of the cost of a resilience investment but has only an 8% chance of receiving the benefits in terms of avoiding repair costs. (Higher resale value is a different matter.)

An additional kind of uncertainty afflicts resilience investments—uncertainty about the appropriateness and quality of the investment and, hence, of its benefits. There are many types of investments that may increase a home's resilience to flooding. It would be unreasonable to attempt to undertake all these investments and some of them might not make sense for certain homes. How should the homeowner decide which are the most important types of investment for her or his home? Even if the homeowner has decided which types of investments to make, it can be difficult to choose among the competitors in a product category. Which products are likely to be more effective and more reliable? For instance, should the homeowner automatically choose a high-end sump pump with battery backup or would a less-expensive alternative work as well? In addition, some investments require professional installation and the often-onerous task of gauging and finding a quality installer. Over time, the condition of the investment must be monitored to ensure its optimal performance.

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business executive in Seattle, WA disappeared without a clue one day. Some years later, Spade finds the executive in Portland, OR with a new business and a new family, both remarkably similar to the ones he left in Seattle. Spade learns that, as the executive walked to work in Seattle one day, he was narrowly missed by a falling safe when the winch lifting it to a high floor failed. As the executive reflected on the fragility of his existence, he decided to walk away from his life in Seattle at once. Over time, though, he drifted back to his familiar business and personal life in a city not too distant from Seattle. As Spade summarized it, the falling safe convinced the executive that his life was likely to be snuffed out in a meaningless accident at any moment, and he changed his behavior as a result of that insight. When safes failed to fall in the future, the executive slowly adjusted his estimate of the probability of a random accident and drifted back to the type of life he had enjoyed previously.

<sup>4</sup> And uncertainty about the length of homeownership.

<sup>5</sup> The median is slightly over 13 years. The average person will own at least three houses in their lifetime. <https://www.thezebra.com/resources/home/average-length-of-homeownership/#average-length-of-homeownership-in-the-us>

For homeowners, these choices will likely be made no more than a few times in their lives. They are unlikely ever to become well versed in these issues. These variables raise the degree of uncertainty significantly and may discourage homeowners from undertaking costly resilience investments.

## Incentives for homeowners

Both financial and behavioral incentives can increase homeowners' willingness to invest in resilience. Financial incentives reduce the up-front cost of resilience investments. Behavioral incentives reduce the various types of uncertainty faced by a homeowner trying to decide if resilience investments are worth it. Both may be necessary to generate an effective level of buy-in.

Financial incentives work in three ways:

- Lowers the cost of investment – especially the more expensive ones.
- Allows homeowners to capture some of the benefits of resilience investments currently enjoyed by co-beneficiaries; and
- Benefits the greater community, in addition to the single homeowner, thereby helping to persuade homeowners to invest more than they would for their sole benefit.

Government-sponsored financial incentives — in the form of tax credits or government-funded discounts — have a long history. For example, a 2018 study reviewed data on nearly 200 incentive programs for electric-vehicle purchases offered by federal and state governments, electric utilities, and other entities<sup>6</sup>. This study concluded that every \$1,000 offered as a rebate or tax credit increases average sales of electric vehicles by 2.6%<sup>7</sup>.

Critics of government-sponsored financial incentives for electric vehicles have argued that the inducements largely benefit more affluent consumers, many of whom would have purchased an electric vehicle regardless. It is true that at least some portion of any incentive program structured similarly to the electric vehicle incentive programs will end up delivering benefits to those who'd done the incentivized action anyway. It's also true that even generous incentives for expensive items may not be sufficient to trigger their purchase by less affluent households.

### Equity considerations

It is well known that less affluent communities are disproportionately exposed to flood risk and may find the cost of resilience investment daunting. Even with financial incentives, they may find it beyond their means to make these investments.

Furthermore, if resilience features increase resale value, poorer people may be crowded out of resilient homes — especially if the addition of these features leads to increased property taxes.

Thus, as an unintended consequence, some financial incentives may primarily benefit more affluent homeowners and harm less affluent ones.

<sup>6</sup> Alan Jenin, Katalin Springel and Anand R. Gopal. "Effectiveness of Electrical Vehicle Incentives in the United States" (2018). <https://www.sciencedirect.com/science/article/abs/pii/S0301421518302891>

<sup>7</sup> The study found that offering HOV lane access to electric vehicles also was a significant incentive.

Homeowners typically share some of the benefits of a resilience investment with co-beneficiaries, other entities with some stake in the resilience of the house. For instance, if the homeowner has flood insurance, the insurer may enjoy fewer and smaller future claims. Similarly, a portfolio lender is likely to suffer fewer defaults on mortgages when the houses include effective resilience investments<sup>8</sup>. This leakage of benefits to co-beneficiaries reduces the Benefit/Cost Ratio (BCR) of an investment for the homeowner.

The benefit of a flood mitigation measure depends on the location of the house and the mitigation performed. On a nationwide average level, retrofitting a house to reduce its flood risk can save \$6 in avoided future losses for every \$1 spent<sup>9</sup>. The homeowner's incentive to invest in resilience depends on how much of that avoided loss accrues to the homeowner, as opposed to other stakeholders.

Using the 6:1 BCR as an example, if half the benefits accrue to others, the homeowner retains a 300% return on an investment in flood resilience. The reduction in this example does not eliminate the homeowner's incentive to undertake the investment. A BCR of 3:1 still represents an attractive return on investment. However, the return would be even more attractive if the homeowner captured at least some part of the benefits that accrue to others<sup>10</sup>.

Resilience investments, like many other home investments, often provide benefits to the neighborhood and community. These ancillary benefits are unlikely to be enjoyed directly by the homeowner. Maintaining the appearance of the house and its landscaping has a positive impact on home values in the immediate neighborhood. Moreover, maintaining an attractive home may also stimulate neighbors to maintain the appearance of their homes. As a result, the neighborhood participates in a virtuous circle; one homeowner's positive behavior spills over into the behavior of other neighbors. This effect also works in reverse; neglect by one neighbor may lower the attractiveness of neighboring houses, turning the virtuous circle into a vicious one.

Investments in flood resilience may have similar neighborhood effects. Flood damage to a home can lead to long periods of vacancy, neglect, and vandalism. Resilience investments protect against these outcomes, providing some amount of financial protection for neighboring houses by reducing the risk of an eyesore property. For this reason, some types of community support for resilience investments in individual homes may represent an appropriate community investment.

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<sup>8</sup> See Kousky, Palim and Pan (2020).

<sup>9</sup> Natural Hazard Mitigation Saves, Multi-Hazard Mitigation Council (2019). These avoided losses include both financial losses such as property damage and non-financial losses such as impact on the homeowner's physical and mental health.

<sup>10</sup> The Department of Energy offers financing programs for clean energy upgrades that tie the repayment obligation to the property rather than to the homeowner. Depending on the specific program, repayments are included either in the homeowner's utility bill or property tax bill. If the home is sold before the debt is fully repaid, the subsequent homeowner(s) are responsible for the remaining payments. If similar programs could be offered, they would allow the current homeowner potentially to share some part of the expense of a resilience investment with future beneficiaries.

We noted above that uncertainty – about the likelihood of a damaging flood, length of homeownership, most appropriate resilience investments, and the best devices and materials and most competent installers – may discourage homeowners from investing in resilience. This collective uncertainty can be overcome by a collection of public awareness campaigns, certifications, and easier access to more information.

Public awareness programs can help homeowners assess their flood risk and choose among the available resilience investments those that are likely to be the most effective for their specific properties. Certification of products and installers can give homeowners confidence that their investments can provide the advertised resilience.

Public Service Announcements (PSAs) have long been effectively employed to inform the public about issues of general social importance and to persuade people to take appropriate actions. PSAs have warned about the dangers of smoking and drug misuse (“This is your brain on drugs”); the damaging impact of littering and other types of pollution (“Give a hoot; don’t pollute”); and the importance of citizen involvement in reducing crime (“Take a bite out of crime”). During World War II, a variety of PSAs cautioned the public to guard sensitive information (“Loose lips sink ships”); reminded them of the need to conserve scarce materials needed for the war effort (“Is this trip necessary?”); and paraded celebrities to sell war bonds (“Bonds buy bullets”). Future PSAs can increase homeowner awareness of the flood risk they may face (“I thought my family was protected from floods. I was wrong.”).

To maximize the impact of PSAs and other awareness programs, it is important to highlight the aspects of an issue around which there is likely the most agreement. Common ground provides a much-needed foundation for changing opinion and habits. We often see the inverse of this: For example, discussions of flood risk often highlight related concerns about climate change. As climate change remains a contentious and divisive political topic, PSAs that emphasize a link between the two are more likely to be dismissed by some portion of the public.

Fortunately, facts about flood risk can be presented without taking a position on climate change. Natural disaster risk of all kinds is a present danger, regardless of your position on climate change. In this context, using the FEMA FIRMs – rather than competing indicators of flood risk – may be helpful as FEMA’s data does not incorporate assumptions about future climate change.

A more targeted kind of public awareness program may reduce homeowners’ uncertainties about both their personal exposure to flood risk and the necessary steps to increase their home’s resilience. A perennially popular article in media is a type of decision tree. The reader answers a sequence of questions to determine their personality type, if they are at risk for Alzheimer’s, the best time to retire, the retirement location that might suit them, and a host of other burning questions. Each question is a node in a decision tree; each answer directs them to another node in the tree. The result: a personalized answer to the question.

One can imagine a decision tree to help homeowners assess flood risk<sup>11</sup>. The initial question may ask for information about location, followed by one or more questions about the structure of the house, its placement on the lot, its age, etc. The payoff is an informed indication of the level of flood risk to which the homeowner is exposed. Another type of decision tree would help guide the choice of potential resilience investments, tailored to the risk at the homeowner's location and to the type of house.

For homeowners, this type of decision tree is designed to cut through layers of confusion about the most effective resilience strategy. The terminal point may include referrals to additional sources of information, such as certified installers.

Certifications can be a powerful tool, both for reducing uncertainty and for credibly communicating resilience benefits to home buyers. Many of the more widely known certifications focus on green building techniques and energy efficiency, but certifications for resilience features do exist. The FORTIFIED™ designation created by the Insurance Institute for Business & Home Safety provides information about wind risk.

With so many kinds of certifications, provided by just as many accrediting bodies, it's no wonder homeowners and home buyers become overwhelmed. There is no single "Good Housekeeping Seal of Approval" for flood resilience. And not all certifications offer the same assurances. Are they guarantees or warranties of some type? Is there any recourse if the resilience investments don't function as advertised?

To make a certification of flood resilience features more effective, consider creating one that combines the best features of existing certifications, and then encourage industry stakeholders to rely on this new certification *and* communicate its value to consumers. The new certification should clarify the benefits and limitations of resilience features. To the extent this type of certification gains market acceptance, it might enhance home resale value, which may encourage homeowners who anticipate a relatively short period of ownership to invest in resilience.

This suggestion of a more effective certification program is an ambitious one, dependent upon cooperation of multiple industry stakeholders. But it could be an effective tool to reduce consumer uncertainty, confusion, and skepticism.

### Core concept: Co-beneficiaries help pay for mitigation

Resilience incentivization is about creating contracts and other mechanisms for co-beneficiaries to share in the cost of resilience. Doing so better aligns the interests of all involved.

Figure 1-2A shows how resilience provides value to insurers, lenders, and other co-beneficiaries. Figure 1-2B suggests methods for co-beneficiaries to help pay for resilience: insurance premium

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<sup>11</sup> The pluvial flooding technical guidelines in Appendix C provide this type of information.

reductions; lower loan points and rates; government grant and tax incentives; lease premiums, higher purchase price, and consumer information.

This roadmap outlines how NIBS proposes turning these ideas into boilerplate contract language, consumer advice, and other incentive documents -- and how it expects to encourage shareholders to put them in practice. Note that the figure emphasizes the relationships between co-beneficiaries and the present owner, but co-beneficiaries often interact with others. For example, real estate agents and brokers interact with future owners and tenants.

Figure 1-2A – How Resilience Provides Value

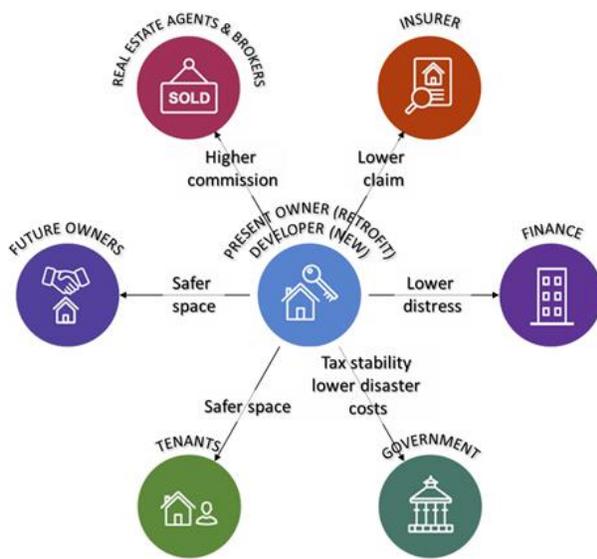
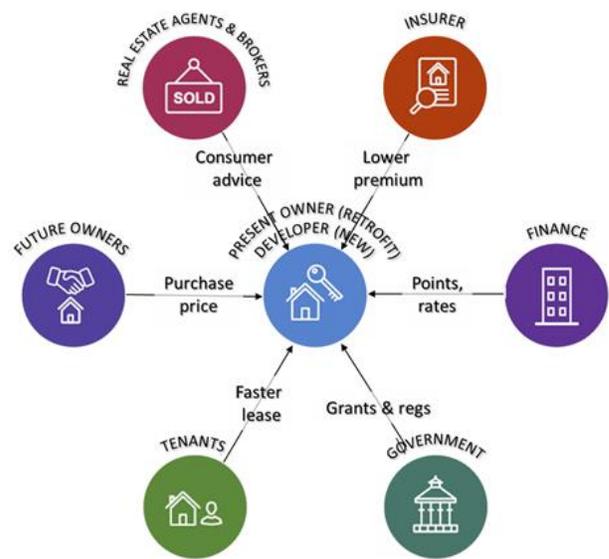
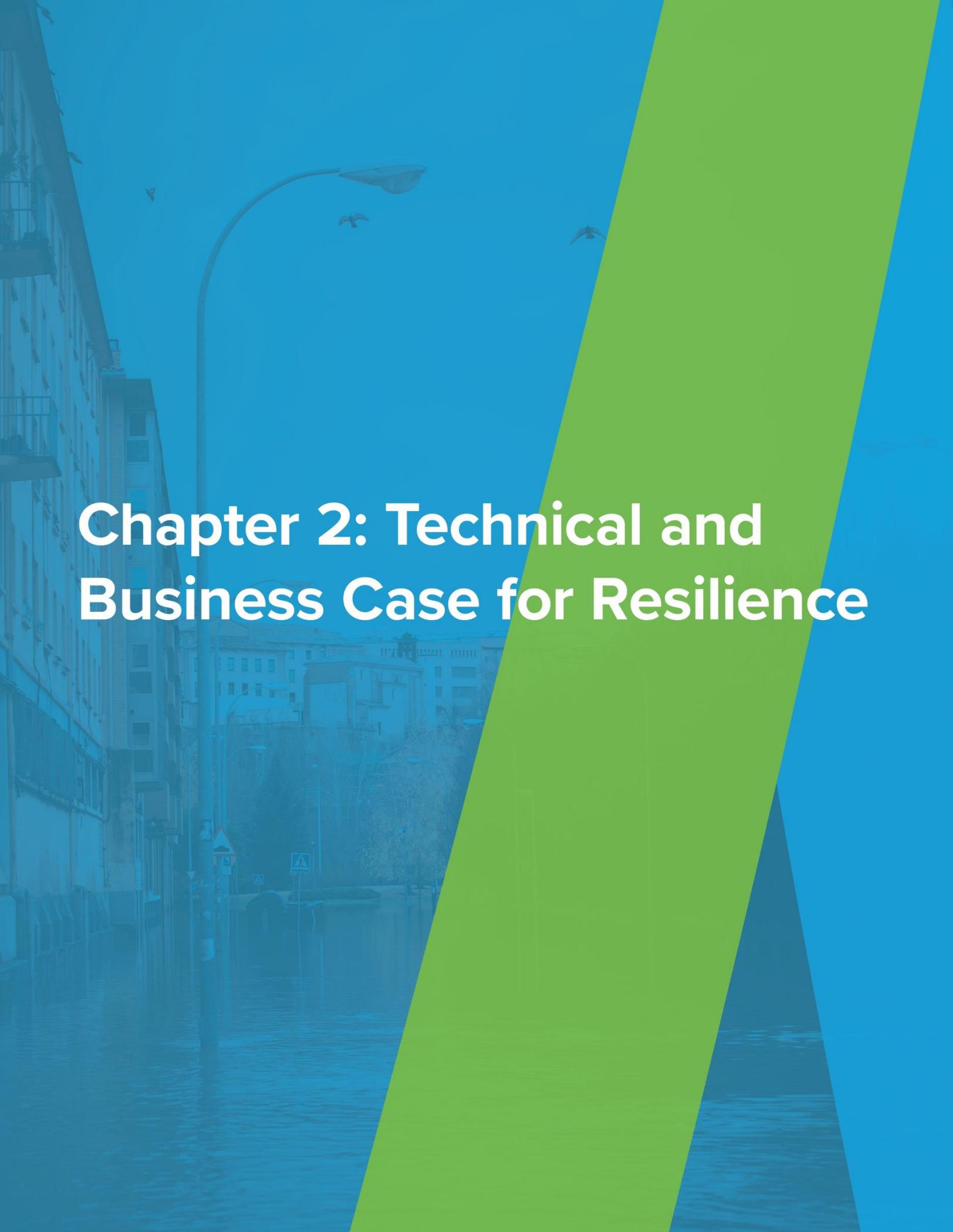


Figure 1-2B – How Co-Beneficiaries Can Help Pay





# Chapter 2: Technical and Business Case for Resilience

## Chapter 2: Technical and Business Case for Resilience

Any decision about investing in resilience requires information many decision makers lack. What is the nature of the hazard? What is the chance that one's property will be affected? And if so, how severely? What options exist to reduce the risk? What do they cost? How likely are they to work? How can one best ensure that the work is done the way it ought to be done?

These crucial questions demand clear, easy-to-access information sources and consistent standards for mitigating the risk.

This roadmap uses pluvial flood resilience to illustrate incentivization. Pluvial flooding refers to what occurs when rainwater cannot flow downhill fast enough to reach streams and stormwater systems and backs up through basement windows and into garages, flows into buildings from improper grading, or backs up through sewer laterals into buildings from overwhelmed combined sewer and stormwater system. Wing et al. (2018) estimate that 70% of Americans who face at least a 1% annual chance of flooding live outside special flood hazard areas (28 million of 41 million total). Many of these 28 million are subject to pluvial flood risk.

Common, low-cost measures to protect buildings from pluvial flooding include sewer backflow valves, battery-backup sump pumps, and proper grading that slopes away from buildings.

Multi-Hazard Mitigation Council (2019) offers benefit-cost analysis for new construction to exceed building-code requirements, retrofitting existing buildings, and improving existing utilities and transportation infrastructure. It offers evidence of the cost-effectiveness of resilience against riverine and coastal floods, severe winds, fire, and earthquakes, with some benefit-cost ratios exceeding 10:1.

Our searches for benefit-cost analyses of measures for pluvial flooding proved unsuccessful, so we estimated costs and benefits for the present project. **See Appendix A for the benefit-cost analysis and results.**

### Market value of flood resilience

The benefits discussed above focus on avoiding future losses but ignore the possibility that flood resilience has a market value – by increasing the resale value and partly or fully offsetting its cost.

#### Beyond Pluvial Flooding

This roadmap uses pluvial flood resilience to illustrate incentivization, but many of principles developed here can apply to riverine and coastal flooding – as well as other perils, including fire, wind, hail, temperature extremes, earthquake, and others. Not all aspects of this roadmap apply universally. To apply incentivization to other mitigation measures, perils, and places will require adaptations.

Several studies suggest some buyers value resilience. At least four research teams collected real estate sales data and performed multivariate regression analysis of home sale prices. These included the usual measures of value, but added a resilience feature for tornado, hurricane, and earthquake. The authors detected an increase in resale value that cannot be attributed to location, house size, community attributes, and in the case of Porter et al. (2022), other improvements and renovations ([Figure 2-1](#)):

- **Tornado shelters in Oklahoma City: \$12,000.** Simmons and Sutter (2007) found that Oklahoma City homes with tornado shelters sold for about 4% more than those without. With median sale prices currently around \$300,000, 4% amounts to \$12,000.
- **IBHS FORTIFIED Home hurricane certification in Coastal Alabama: \$70,000.** Awondo et al. (2019) found that coastal Alabama homes with IBHS FORTIFIED Home Hurricane ratings sold for about 15% more than those without. The median home listing price is Gulf Shores, Ala., is currently \$450,000; 15% of that is \$70,000.
- **Storm blinds in a Gulf of Mexico beachfront community: \$70,000.** Simmons and Kruse (2000) found a similar increase (16%) for beachfront Gulf of Mexico homes with storm blinds.
- **Seismic retrofit in California: \$100,000.** Pre-1940 California homes with seismic retrofit resold for about 17% more than those that lacked the retrofit feature, or those whose listing did not mention the feature (Porter et al. 2022). This can amount to \$100,000 for a median-price home.

### Mandeville, La., sees flood mitigation benefits

The studies summarized here use sales data and regression analysis to estimate what people paid for tornado, hurricane, and earthquake resilience features. Nobody seems to have performed a similar analysis for flood mitigation, but the [example of Mandeville, La.](#), emphasizes the value of flood resilience investment.

After Hurricane Katrina, the community enacted a local ordinance to require new construction to exceed the International Residential Code's elevation requirements by one foot. In the neighborhood nearest Lake Pontchartrain, residents are voluntarily building new buildings and retrofitting existing ones to exceed code-required elevation by seven feet (Roderick Scott, Flood Mitigation Industry Association, oral communication, May 19, 2023). Elevations can cost as much as \$100,000, and average \$22,000 (Homeguide 2023) – considerably more than adding sump pumps and backflow valves.

Mandeville's aggressive approach appears to have borne results. Like Katrina, Hurricanes Isaac and Ida brought nine-foot storm surges, but the results were very different:

- Katrina (2005) – 750 NFIP claims for \$25 million;
- Isaac (2012) – 250 NFIP claims for \$7.5 million;
- Ida (2021) – no NFIP claim data yet, but only 59 documented occupied flooded buildings.

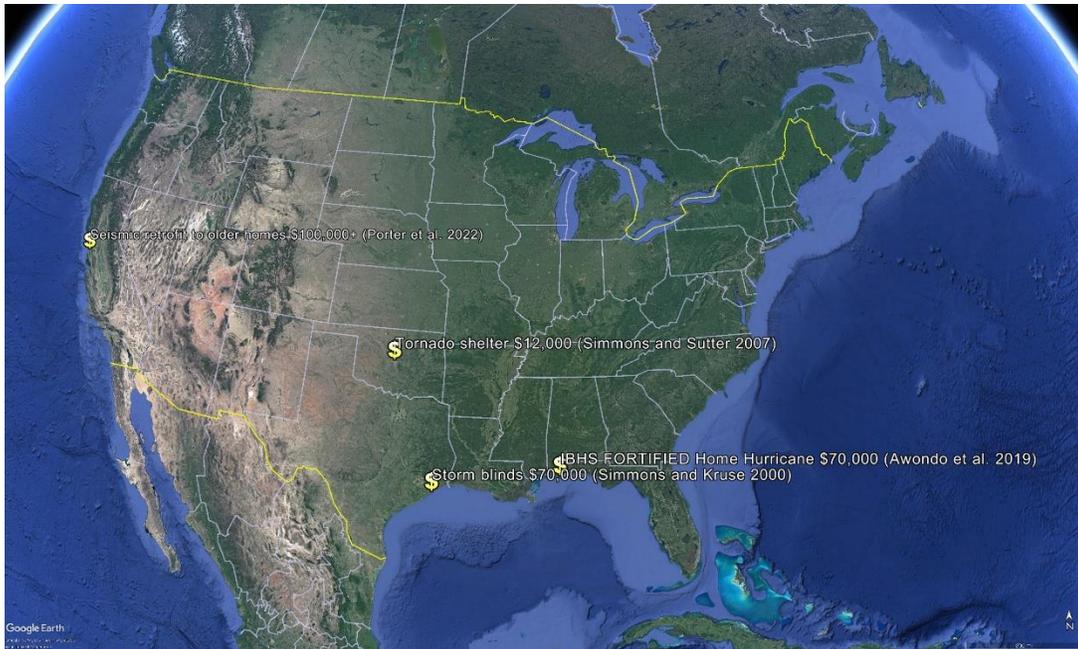


Figure 2-1. Observed market value of some resilience measures

Resilience features may have a market value only under the conditions where these studies took place:

- Tornado shelters where tornadoes had recently occurred (Simmons and Sutter 2007);
- Earthquake retrofits in earthquake country (Porter et al. 2022);
- Hurricane storm shutters and hurricane-resistant design near coastlines where damaging hurricanes had recently struck (Awondo et al. 2019), and
- Flood elevations in a community with repetitive flooding.

Residents of areas not considered highly hazardous may forgo taking action that would protect their property, potentially putting them at a market disadvantage relative to owners who have invested in resilience.

## Surveys of willingness to pay

The National Association of Home Builders (NAHB) sponsored nationwide surveys of prospective home buyers (Home Innovation Research Labs 2019a, 2019b) about their willingness to pay more to minimize damage from natural disasters for new, code-compliant homes. Home Innovation Research Labs (2019a, pp.10-12) found that in locations with “high” or “severe” risk potential buyers of homes who perceived that risk expressed a willingness to pay more for a new house that exceeds code requirements.

- **Flood:** \$5,000 median, with 44% willing to pay more than \$7,500, and 23% willing to pay more than \$25,000;
  - 30% said they would pay more than \$7,500 to minimize flood risk; and

- 15% would pay more than \$25,000 extra.
- **Hurricane:** \$5,000 median, 48% above \$7,500, and 21% over \$25,000;
- **Tornado:** \$5,000 median, 45% above \$7,500, and 22% over \$25,000;
- **Earthquake:** \$10,000 median, 52 % above \$7,500, and 32% over \$25,000;
- **Wildfire:** \$3,500 median, 40% above \$7,500, and 26% over \$25,000;
- **Hail:** \$1,000 median, 26 % above \$7,500, and 12 % over \$25,000; and
- **Snow:** \$500 median, 29 % above \$7,500, and 11 % over \$25,000.

Buyers were less willing to pay for above-code resistance in areas where the perceived hazard is *not* high. However, even in those places, a substantial fraction of respondents expressed a willingness to pay more to minimize damage.

Figure 2-2 illustrates these values for flood mitigation. The survey did not ask owners of older existing houses with higher risk about their willingness to pay for upgrades, nor did it ask about respondents’ knowledge of risk or experience of past disasters.

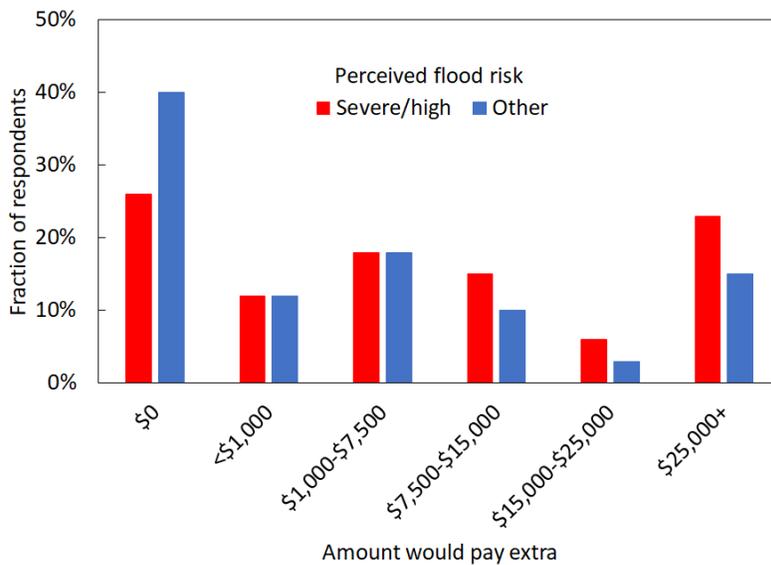


Figure 2-2. Home buyer willingness to pay for above-code flood resilience (after Home Innovation Research Labs 2019a)

The NAHB survey echoes the findings of 2016 Davis and Porter survey that found a median willingness to pay about \$7,500 for above-code earthquake resistance.

## Reconciling sale price studies and willingness-to-pay survey

The NAHB median figures are lower than market analyses:

- Half the value for tornado shelters (inferred value of \$12,000 from market prices versus \$5,000 median surveyed willingness-to-pay value in high-hazard locations);
- One quarter for flood (\$22,000 market-price value versus \$5,000 median survey response in high-hazard locations); and
- 1/14 for storm shutters and FORTIFIED Home Hurricane designation (\$70,000 versus \$5,000), and 1/10 for earthquake (\$100,000 versus \$10,000).

Market value might differ from the median survey responses because of several factors:

1. **Hypothetical bias: a factor between 0.1x and 100x.** What people say they would pay and what they actually pay are not the same. Economists call this difference hypothetical bias, and sometimes refer to the difference as the calibration factor. It can be high (people actually pay less than they say they are willing to pay) or low (people actually pay more). The calibration factor can range between 0.1 and 10 (Loomis 2011, Murphy et al. 2005, Hensher 2010).

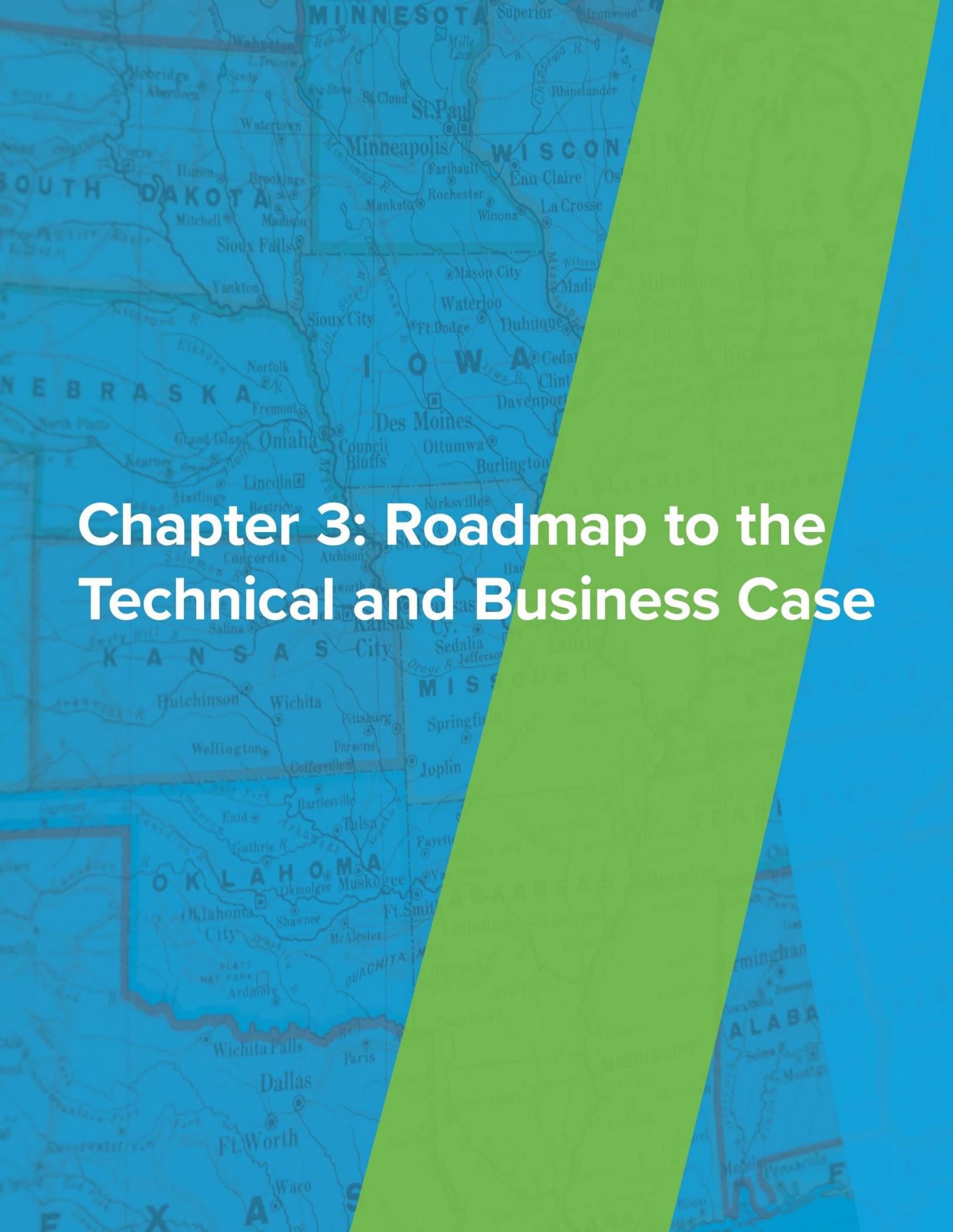
The fact that the survey places the value of hurricane resistance at a median of \$600, while actual sales prices in coastal Alabama and another Gulf Coast community suggest a value 100 times larger, shows how substantial a hypothetical bias may be. (To avoid confusion, the economists' calibration factor is the ratio of survey responses, i.e., hypothetical willingness to pay, to actual price. We are concerned with the inverse: the ratio of actual price to survey response. So a calibration factor of 0.1 means that the real price is 1/0.1, or 10 times the survey.)

2. **New homes versus existing homes: a factor of 10x.** New homes represent 10 % of sales; resilience features matter more in older ones. Both NAHB and Davis and Porter asked about the perceived value of resilience features in new, code-compliant buildings, which represent about one in 10 home sales. The present project is concerned with existing homes, as well as new ones. Resilience features likely matter more to buyers of older, more-vulnerable homes. Porter et al. (2022) found that seismic retrofitting of pre-1940 California houses added 17% to resale value, while retrofitting houses built between 1940 and 1959 added about 1%, suggesting a factor of 10x or more for age and degree of perceived risk in that situation.
3. **Local hazard matters: a factor of 1x to 5x.** We suspect a greater market value exists for resilience in places where buyers are keenly more aware of the hazard and where buyers believe older homes on the market are less resilient than new code-compliant ones. Awondo et al. (2019) observed the market value of FORTIFIED Home Hurricane certification to be three times greater for houses within 0.5 miles of the coast versus the average of 4.5 miles. NAHB observed similar factors, e.g., comparing willingness to pay in high-flood hazard areas to average conditions (\$5,000 and \$1,000, respectively).

4. *The winning competitive bid exceeds the median: a small factor.* The median bid only wins in a competitive bid when there is only one bidder (23% of sales in 2022; Berchick 2023). Where there are two or more participants in a competitive bid (as in 75% of bids in 2022), the increase in sale price will exceed the median value placed on the feature. The more bids, the greater the difference. And the more rounds of bidding, the higher the increase in sale price. Survey responses reflect neither increase. Berchick's data match a lognormal distribution of bids with a median 2.4 bids per house in 2022 and a logarithmic standard deviation of 0.6. Assuming normally distributed bids with a realistic coefficient of variation of 0.1 and only one round of bidding, the high bid averages 1.05 times the median, a slight change compared with other factors.

Let's ignore the local-hazard factor (number 3 above) so we may compare the survey results in high-hazard areas with the market-value studies. What is being compared? The product of factors 1, 2, and 4 ranges between 1x and 1,000x, widely bracketing the 2x to 14x difference between observed and survey prices for tornado, flood, hurricane, and earthquake resilience in high-hazard locations. The range suggests that the NAHB's \$5,000 median figure for market value of flood resilience may be low by a factor of 2 or more.

Should we include the \$5,000 figure (or higher) as an incentive to promote basement flood mitigation? The \$5,000 figure reflects above-code flood resilience of new buildings, intended "to exceed current building codes, to further minimize the likelihood of your home being flooded as a result of a significant rainfall or hurricane." It does not speak to the particular flood mitigation measures or to the broader class of homes addressed here. While the market value could exceed \$5,000, the issue is uncertain enough to avoid until future studies analyze actual sales data for basement flood resilience features in new and existing homes.

A map of the central United States, showing states from Minnesota to Texas and Wisconsin to Oklahoma. Major cities like St. Paul, Minneapolis, St. Louis, Kansas City, and Dallas are labeled. A large green diagonal shape is overlaid on the right side of the map.

# Chapter 3: Roadmap to the Technical and Business Case

## Chapter 3: Roadmap to the Technical and Business Case

### Roadmap the science, engineering, and evaluation tools

To implement the science, engineering, and evaluation tools offered here in a long-term resilience incentivization program, organizational leaders should:

1. ***Provide benefit-cost data, like that in Table A-2, for all locations and stakeholders.*** The table provides benefit and cost information for four scalar hazard levels. Until a government agency offers free, location-specific information about basement-flood hazards, we propose to measure hazard using Flood Factor, which has 10 levels. In a pilot, the authors can apply the equations offered here to all 10 levels and tabulate benefits and costs for all relevant stakeholders. (If the pilot study were to focus on the mitigation measures examined in Appendix A, the pilot community would have to be one where those mitigation measures make sense. For example, one with many homes facing pluvial flooding that rarely exceeds three to six inches. We will review key parameter values, such as retention rate and weighted average life of a mortgage, with stakeholder representatives to ensure that most stakeholders have the risk information they need to assign parameter values to their incentives. We will document the benefit-cost analysis in a report or manuscript suitable for publication in an archival journal, to ensure transparency. The full benefit and cost data table will accompany the report or manuscript.
2. ***Test the market value of flood resilience and certification.*** We conjecture (with evidence) that people value disaster resilience and are willing to pay more for homes with resilience features, at least in locations with an awareness of risk. Research by three teams of independent scholars has shown increased market value where homes have features to better resist tornadoes, hurricanes, or earthquakes. Builders who already exceed the code use resilience as a marketing feature. Real estate agents who recognize that value could advertise resilience features in market listings, use resilience-certification information to price homes and distribute literature about resilience features during open houses. We will carry out research similar to that of Porter et al. (2022), but for basement flood mitigation. We will engage the real estate and appraisal industries to enhance our proposed educational and training materials.
3. ***Develop checklists and technical guides, like those in Appendix C.*** Technical guides and checklists need to be developed to address the owner's information needs.
4. ***Engage engineers to act as independent evaluators.*** To roll out flood certification, the lead organization could host a workshop at the beginning of the pilot test, inviting engineers from the American Society of Civil Engineers committee ASCE/SEI 24, new members' forums, and/or other committees with an interest in basement-flood resilience. The workshop

provides the perfect opportunity to recruit these experts to become independent evaluators who can pilot test training materials and review the certification program. Opportunities to institutionalize recruitment of independent evaluators demand further exploration with related industry leaders, building upon lessons learned from LEED, Earthquake Brace+Bolt, FORTIFIED Homes, and other successful programs.

5. ***Engage plumbers, landscape architects, roofers, and construction contractors to carry out the mitigation.*** The lead organization could hold a rollout workshop at the beginning of the pilot test at which it convenes professional societies for these groups to recruit professionals to pilot test the mitigation construction work. Relevant professional societies include the American Society of Plumbing Engineers, American Society of Landscape Architects, National Association of Roofing Contractors, and Association of General Contractors.
6. ***Engage building officials to supervise the pilot test.*** The lead organization could hold a rollout workshop at the beginning of the pilot test at which it convenes local building officials and the International Code Council to monitor the pilot test, confirm that the work does not conflict with the work of building officials, to offer advice for adjustments.
7. ***Engage floodplain managers to supervise the pilot test.*** The lead organization could hold a rollout workshop at the beginning of the pilot test at which it convenes local floodplain managers from the Association of State Floodplain Managers to monitor the pilot test, to confirm that the work does not conflict with sound floodplain management, and to offer advice for adjustments.
8. ***Estimate other cost-and-benefit quantities.*** Use the following data to promote incentivization, such as:
  - Maps of benefit-cost ratio
  - Job-creation estimates
  - Nationwide resilience investment gap estimates
  - Potential estimated total dollar savings of mitigation
  - Potential estimated benefit by industry
9. ***Compile behavioral incentives to include in training materials and other collateral.*** This task implements the suggestions from Cialdini's Principles of Persuasion. Collect mitigations-encouraging quotes, via text and video, from trusted experts involved in developing the roadmap and the pilot test. Via real estate literature, advise the seller's agent to address mitigation and its value with potential buyers and sellers, making sure to highlight previous efforts and emphasize the importance of consistent mitigation and investment in resilient homes. Encourage agents to promote the scarcity of homes with the resilience feature. Recruit celebrities in science and architecture to record messages urging disaster risk reduction (liking). Search for existing video or statements by other science celebrities that do the same (same). In the pilot test, ask governments, lenders, insurers, and real estate agents and brokers to offer something, even of small value, and ask the decision-maker to do mitigation (reciprocity). In conversations with plumbers, landscape architects, roofing

contractors, general contractors, and others, tell stories or cite statistics about other efforts of disaster-risk reduction, or show that an increasing number of property owners are engaging in it (social proof).

## Roadmap the mitigation certification

What would be required to certify that a building meets certain flood-resilience requirements? Appendix B provides checklists and forms for homeowners and others to document the successful completion of a mitigation effort. Checklists and forms are necessary tools in a certification process, but they are not the whole process.

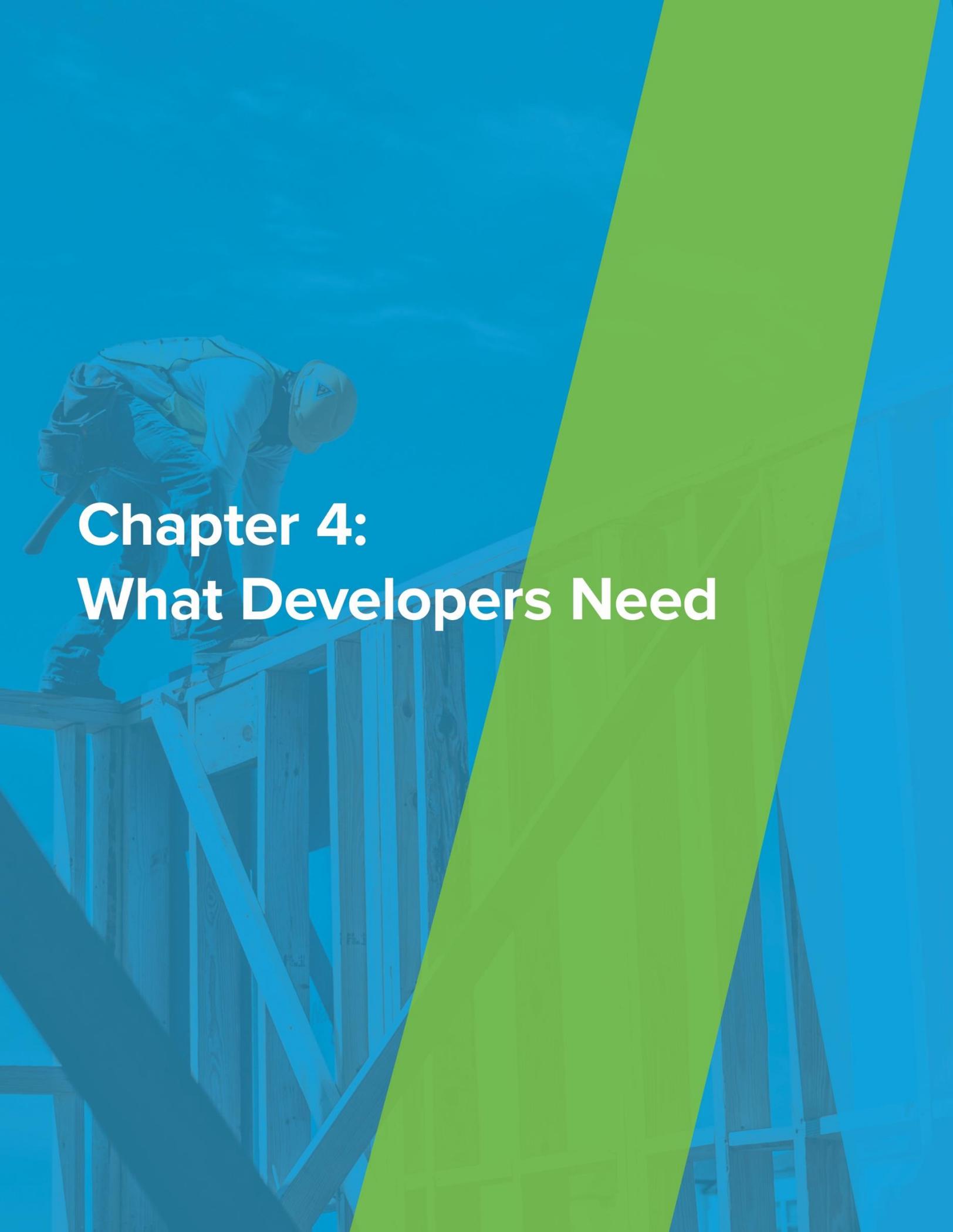
The Insurance Institute for Business & Home Safety (2022) offers the example of the FORTIFIED program, which focuses on wind and hail resilience of residential and commercial buildings. The US Resiliency Council (2023) offers a similar system to rate and certify the earthquake and wind resilience of buildings. The two cover the following:

1. **Construction.** In the case of FORTIFIED, contractors trained and certified by the Insurance Institute for Business & Home Safety work to bring the building into compliance. The U.S. Resiliency Council does not train or certify contractors.
2. **Documentation.** In the case of FORTIFIED, an independent evaluator, trained and certified by IBHS, examines the building and its documentation for compliance with the program. In the case of the US Resiliency Council, an independent evaluator, trained and certified by the organization, examines the building and its documentation, and proposes ratings of the building's resilience.
3. **Certification.** In both cases, workers employed by the certifying organization confirm the documentation and issue a certificate. The certifying organization maintains a database of certification for buyers and other stakeholders to check.

Using these two as guides, a certification program could be modeled by taking the following steps:

1. **Adapt technical guides.** Empanel basement-flood experts to check and adapt the mitigation technical guide checklists offered here as documentation for basement-flood certification. The panel could include:
  - Cleanup contractors experienced in basement flooding
  - Professional plumbers experienced in backup battery sump pumps and sewer backflow valves
  - Landscape architects experienced in inside grading
  - Gutter and eavestrough experts
  - Experts familiar with pluvial flood hazard modeling
  - Floodplain managers
  - Present authors

2. **Create training programs.** Create and maintain a training and testing program for contractors (if imitating FORTIFIED), independent evaluators (whether imitating FORTIFIED or the U.S. Resiliency Council), and its own employees, to act as certifying agents to confirm documentation. To do so, contract with a training developer, such as Spekit, to both convert technical guides into online content, knowledge, and training for on-demand online delivery and to maintain and serve the training program.
3. **Staff the program.** Employ or task current support staff to:
  - Monitor the training web infrastructure and instruct the contractor to make needed changes.
  - Recruit contractors and independent evaluators via professional societies or from members of the National Institute of Building Sciences.
  - Confirm documentation before issuing a certificate; and
  - Contract with a service provider to maintain an online database of certified buildings and provide on-demand confirmation of certification to third parties, such as buyers. The certifying contractor and training-program contractor can be the same person.



# Chapter 4: What Developers Need

## Chapter 4: What Developers Need

Developers – both national-level construction companies and local general contractors – play an essential role in increasing the resilience of houses to floods. Many resilience investments can be installed exclusively by building and construction professionals. While some investments, like battery backups for sump pumps, can be installed by handy homeowners, other projects require specialized skills, tools and equipment – requirements that rule out the owner. These more complex resilience features will be installed only if required by the building code or if developers are willing to include them voluntarily.

### Few builders see resilience as profitable

Developers are in business and must profit if they hope to survive. As a result, they incorporate features that buyers value in homes. If buyers value granite countertops, builders will install granite countertops. Similarly, if buyers value resilience features above what the building code requires, builders will include them.

However, as [we've pointed out](#), evidence suggests many homeowners do not consider resilience features when shopping for a home. Recall that the Home Innovation Research Labs (2019b) found many developers believe homeowners are reluctant to pay for items not required by the code and, are therefore hesitant to include such resilience features. (Important exceptions include roughly half of home builders voluntarily exceed code requirements for window and door flashing and sealing, wind-resistant siding, wind- hail- and fire-resistant roofing, and wind- earthquake- and flood-resistant water heaters and HVAC equipment. For these and other examples, see Home Innovation Research Labs 2019b p 11.)

Some of this reluctance may reflect, in part, the high cost of housing in recent years. Many buyers have had to stretch their budgets to – and beyond – their limits to purchase a home. As a result, buyers may shy away from houses that include optional features, such as additional resilience, that increase the cost.

Builders also face cost pressures likely to limit a willingness to add features. The cost of building materials has increased significantly in recent years. Many builders report difficulties finding and retaining workers. Communities often require developers to pay significant development-impact fees and include features, such as set-asides for parks and open space, roads and other non-house-specific features before granting approval for new subdivisions. All these costs squeeze builders' margins further and discourage adding resilience features that home buyers may not be willing to pay for.

As noted above, while some developers may not perceive a market value for resilience, some do. A particular example may be useful. In the planned 19,500-home community of Babcock Ranch, Fla., the developer added several non-mandatory green and hurricane-resilience features to the community's utility and transportation infrastructure and highlighted the features in their sales material: a solar

farm, underground power lines, porous pavements, and a community storm shelter (Neuman 2022), all of which involved extra cost. The developer has sold more than 3,000 homes in 2023 alone and points out that its annual home sales have increased every year since the development began in 2017 (Babcock Ranch 2023a). The developer was able to brag about how well the community weathered 2022 Hurricane Ian, with its 100-mph winds (Babcock Ranch 2023b).

## Type of project influences investment

Building projects can usefully be divided into three groups when considering the opportunity to increase the resilience of a house:

- Pre-construction sales include both purchases of yet-to-be-built houses in new subdivisions and bespoke construction where a home buyer engages a builder and architect to create a custom house.
- Spec construction takes place when developers either build an entirely new house or rehab an existing structure prior to finding a buyer.
- Retrofitting occurs when a homeowner engages a builder or handyman to install a resilience-improving feature or to correct an existing resilience vulnerability. They may also engage design professionals (e.g., architects or engineers).

**Pre-construction** sales offer the greatest flexibility for incorporating resilience features and the greatest opportunity for communication and negotiation between buyer and builder. When buyers commit to buying a house not yet built, they generally review various options. Some options (think higher-quality appliances, carpets, and finishes) can add to the quality of life in the house. But other options, such as higher-quality windows, roofing, and siding, can make the house more resilient to a variety of natural disasters<sup>12</sup>. In reviewing these options, the buyer may consider resilience investments that might not have occurred to them otherwise.

**Spec construction** focuses on features that either reduce cost or appeal to the majority of target buyers. While large, national building companies sometimes create subdivisions as spec projects, small companies and individual contractors account for a large volume of spec construction. The smaller participants may face financing constraints without the economies of scale larger developers enjoy. Consequently, they may find it uneconomic to include important resilience features that may be invisible to, or not wanted by, potential home buyers.

**Retrofitting** generally is performed by local firms that specialize in retrofitting and remodeling. Some types of resilience investments are more difficult and more expensive for existing houses, making such expenditures less compelling. Retrofitting firms are likely to find the most success in neighborhoods already clearly facing heightened risk of recurring floods. A few initial successful retrofits may

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<sup>12</sup> Even more ambitious resilience features, such as increased freeboard, are much easier and less expensive to incorporate in new construction than in an existing house.

encourage neighboring homeowners to investigate the same types of investments. As many retrofitting firms are small; financing remains a hurdle.

## Ways to increase resilience investment by builders

Several approaches may increase builders' willingness to include resilience investments in construction. All require some degree of coordination and cooperation among different stakeholders in the housing industry. Builders are unlikely to make significant progress on their own.

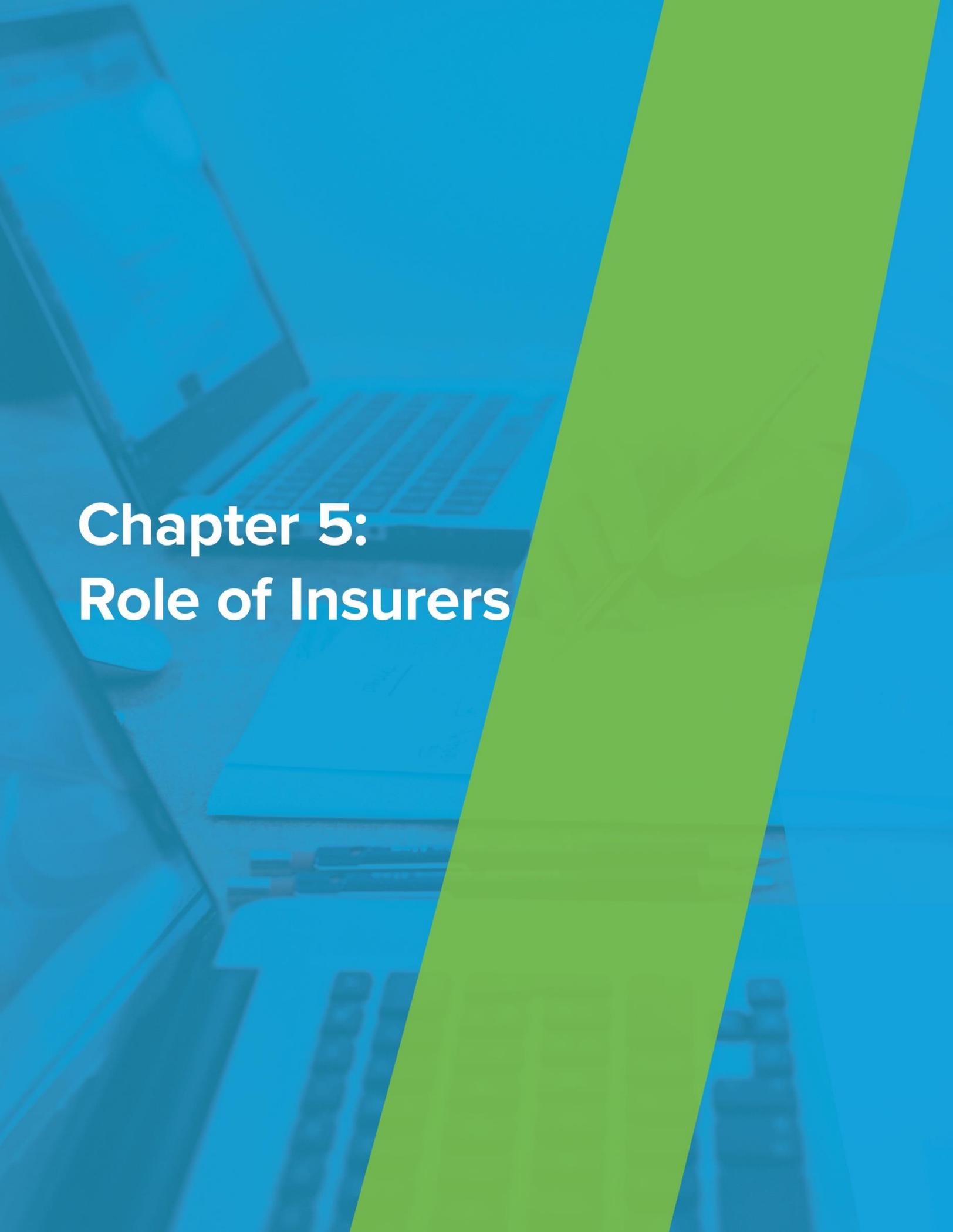
- Reluctance of homeowners to pay for resilience features is the greatest deterrent to including them in new homes. [As we've pointed out](#), one way to overcome this reluctance is to provide a certification program to help homeowners recognize their true value. Such a program is likely to be more trusted by consumers if it originates with an organization like the National Association of Home Builders (NAHB)<sup>13</sup> or an engineering standards organization than if it is the creation of a company that profits directly from greater resilience investment. Such a certification program might usefully be combined with an education program, along the lines described in our section on [homeowners' incentives](#).
- [As noted above](#), communities frequently require fees and expensive set-asides before they approve a proposed development. In areas of elevated flood risk, the community has a vested interest in increasing the resilience of new homes. As a result, communities may be willing to trade off some of their usual requirements for an agreement to incorporate a list of key resilience features in each new home. While this type of negotiation may be attractive to communities, it does not appear to be a common practice at present. This idea may require some socialization among communities and developers before it gains traction.
- Retrofitting houses for flood risk is a high priority in already-vulnerable communities, such as Norfolk, Va. The required retrofitting can be expensive, and often the greatest need for such retrofitting is in less-affluent neighborhoods. Communities can offer property tax breaks to encourage homeowners to undertake the needed investments. To further reduce the cost, community, state, and federal programs can offer subsidized financing. The Federal Housing Finance Agency (FHFA) may choose to permit Fannie Mae and Freddie Mac to increase the available financing by purchasing special home equity loans (HELoans) or home equity lines of credit (HELOCs) where the borrower commits to use the funds for retrofitting for resilience.
- Building codes can be revised to require additional resilience features in areas of elevated flood risk. Existing building codes already require some resilience features for properties in the

For builders, confidence that home buyers will be willing to pay for the inclusion of resilience features in a house appears to be the most important financial incentive. Some type of certification—similar to the FORTIFIED™ Home Hurricane designation program—that highlights the value of these features to the homeowner may help.

<sup>13</sup> Or the NAHB's independent research subsidiary, the Home Innovation Research Labs.

FEMA floodplain. Communities may nonetheless choose to add additional requirements and to employ a more nuanced definition of a property's flood risk than that provided by FEMA.

This list indicates there are many ways, not mutually exclusive, to encourage increased investment in resilience. However, the key to these approaches—and some of the approaches we will discuss in other Chapters—is a high level of coordination and cooperation among governmental and non-governmental stakeholders in the housing industry.



# **Chapter 5: Role of Insurers**

## Chapter 5: Role of insurers

Property/casualty insurers have strong incentives to encourage policyholders to make home improvements that reduce the risk of costly claims. In the case of flood risk – an increasingly expensive peril outside the FEMA-designated flood zones called special flood hazard areas (SFHAs) – encouraging such improvements is preceded by a different challenge: persuading homeowners to obtain flood insurance.

Estimates of size of the “flood protection gap” vary widely among experts, but illustrations worth noting include:

- Less than 25% of buildings inundated by Hurricanes Harvey, Sandy, and Irma had flood coverage (Kousky et al. 2018);
- Inland areas hardest hit by the remnants of Hurricane Ida in 2021 were in areas in which less than 2% of properties had federal flood insurance (National Flood Insurance Program, NFIP, data)
- In 2022, historic flooding in and around Yellowstone National Park affected areas in which only 3% of residents have federal flood insurance (National Flood Insurance Program data and Falconer 2022); and
- More recently, precipitation from atmospheric rivers affecting the U.S. West Coast has resulted in an “unrivaled, unparalleled weather event not experienced in several decades, perhaps back to 1969,” according to Kris Mattarochia, a science and operations officer at the National Weather Service office in Hanford, California (Jones et al. 2023). Much of this activity has affected areas with low flood insurance purchase rates (National Flood Insurance Program data).

Consumer research has consistently shown that some of the most common reasons for not buying flood insurance include:

- Erroneous belief that flood risk is covered under standard homeowners insurance
- If the mortgage lender doesn’t require flood insurance, it must not be necessary
- Too expensive

About 90% of U.S. natural disasters involve flooding (U.S. Department of Homeland Security 2022a). For decades, U.S. insurers considered flood risk “untouchable” because of how hard it is to quantify their risk (Insurance Information Institute 2021a). As a result, flood is excluded under standard homeowners’ and renters’ policies, but coverage is available from FEMA’s National Flood Insurance Program and a growing number of private insurers that have gained confidence in recent years in their ability to underwrite this risk using sophisticated risk modeling.

## Private insurers' stake in flood is rising

Total direct premiums written (DPW) for flood insurance in 2016 was \$3.29 billion, with less than 13% written by 18 private insurers, according to data from S&P Global. By 2022, total flood DPW was over \$4 billion, with over 32% written by 77 private insurers. The private market clearly recognizes the potential in flood.

But outside FEMA-designated special flood hazard areas (SFHA), flood insurance purchases remain low. With more than 20% of NFIP claims coming from outside high-risk flood areas, the National Association of Insurance Commissioners (NAIC) [advises homeowners](#) who live in areas with low-to-moderate flood risk to consider flood insurance.

## NFIP's limited ability to promote homeowner mitigation

Congress created the [National Flood Insurance Program](#) (NFIP) in 1968, partially because people could not buy flood insurance from the private market. At the time, flood was viewed as an uninsurable risk and coverage was virtually unavailable from private insurance markets after frequent widespread flooding along the Mississippi River in the early 1960s.

Communities that join the program make their residents eligible to purchase flood insurance. Upon joining, communities must adopt minimum floodplain management regulations within the special flood hazard area – the area of the floodplain that has a 1% annual chance of flooding. Special flood hazard areas tend to be the places threatened by riverine or coastal flooding – i.e., water rising over stream banks and beaches. They tend to exclude places threatened by pluvial flooding (also called overland flooding or urban flooding), where water cannot flow fast enough downhill to streams and other water bodies. Owners of residential buildings in a special flood hazard area (SFHA) can buy up to \$250,000 of building coverage and up to \$100,000 of coverage for contents. Commercial clients can insure up to \$500,000 each for their building and contents.

The NFIP has played a critical role in filling a protection gap the private market was long unwilling or unable to address, but there are advantages and disadvantages to government-run insurance. On the plus side, the government tends to more highly value positive outcomes for the public than does the private sector. Given a pricing choice in which broader coverage (good for the public) conflicts with higher profits (good for shareholders), the government tends to value the former; the private sector, the latter. On the minus side, the government responds more slowly to exigencies and opportunities than does the private sector. It's also insulated from competitive considerations that drive insurance availability and, in some circumstances, affordability.

In an ideal world, a competitive private market would provide coverage for most homeowners and renters – in a manner consistent with risk-based pricing and compliant with regulations – with state and federal backstops protecting people whose risk profiles make them less insurable.

Clearly, it will be some time before the private flood insurance market is able to relieve the National Flood Insurance Program of enough of the burden for the two to, in effect, switch places. But that is not to say the industry cannot and does not play a role right now. In fact, to benefit from the opportunities in flood, insurers must be engaged in developing the requisite incentives for governments, communities, businesses, and families to adapt to flood risk by adopting relevant mitigation measures.

### Role of private insurers

Governments, universities, insurers, and catastrophe-modeling firms have greatly improved flood models. Contributing to these improvements: Better understanding of hydrodynamics, more granular mapping capabilities based on satellite and aerial technology, increased computing power, and better image resolution. The more accurately insurers can measure a risk, the more incentive exists to make coverage available and to price it competitively. More granular mapping enables insurers to customize policies, setting prices more precisely based on the risk characteristics of specific properties.

#### What is risk-based pricing?

Risk-based pricing of insurance is a fundamental concept that might seem intuitively obvious when described – yet misunderstandings about it regularly sow confusion.

Simply put, risk-based pricing means offering different prices for the same level of coverage, based on risk factors specific to the insured person or property. If policies were not priced this way – if, for example, insurers had to come up with a one-size-fits-all price for auto coverage that didn't consider vehicle type and use, where and how much the car will be driven, and so forth – lower-risk drivers would subsidize riskier ones.

Risk-based pricing allows insurers to offer the lowest possible premiums to policyholders with the most favorable risk factors.

The concept becomes complicated when actuarially sound rating factors intersect with other attributes in ways that can be perceived as unfairly discriminatory – or when changing risk conditions drive increases in policyholder premium rates.

For a detailed explanation of how risk-based pricing works, see the [Insurance Information Institute's Issues Brief](#) on the topic.

The U.S. residential flood insurance market has roughly \$4 billion in written premium, but risk-management firm Milliman Inc. estimates that the total potential market stands between \$37 billion and \$47 billion. Milliman cites “a relative lack of consumer demand” as being at the root of the insurance gap, with many homeowners only wanting coverage if their mortgage provider requires it (Baeder and Evans 2021).

As of April 1, 2023, FEMA has fully implemented the NFIP’s pricing methodology called [Risk Rating 2.0](#), which applies industry best practices and technology to deliver rates that are actuarially sound, equitable, easier to understand and better reflect a property’s flood risk. One consequence of the new methodology is that many policyholders’ premium rates will rise significantly as pricing is more closely linked to actual risk.

While this may negatively affect affordability for some property owners in the near term, it also can be expected to serve as a further impetus for private insurers to become more involved in the writing flood coverage, providing additional capacity, fostering competition, and ultimately putting downward pressure on premium rates.

### Existing incentive programs

The complexity of underwriting and pricing flood coverage, the relative lack of private competition, the market dominance of a federal agency as a provider, and the lack of consumer understanding of both the severity of the peril and the value of the product all contribute to the challenge of using insurance rates or endorsements as incentives for homeowners to:

- Purchase coverage
- Invest in resilience-oriented mitigation measures.

To get a grasp of how hard it may be to get individual homeowners to take proactive steps toward flood mitigation, it’s instructive to look at an existing program for communities.

### FEMA’s CRS program

FEMA’s [Community Rating System](#) (CRS) is a voluntary incentive program that encourages community floodplain management practices that exceed the minimum requirements of the [National Flood Insurance Program](#) (Federal Emergency Management Agency 2023a).

In CRS communities, flood insurance premium rates are discounted to reflect the reduced flood risk resulting from community efforts that address the three goals of the program:

- Reduce and avoid flood damage to insurable property.
- Strengthen and support the insurance aspects of NFIP
- Foster comprehensive floodplain management

Flood insurance premium discounts in CRS communities range from 5% to 45% and are discounted in increments of 5%. A class-10 community is not participating in the CRS and receives no discount. A

class-9 community receives a 5% discount for all policies, a Class 8 community receives a 10% discount, all the way to a class-1 community, which receives a 45% premium discount.

Over 1,500 communities participate in the program nationwide, but only Tulsa, Okla., and Roseville, Calif., have taken sufficient actions to achieve class-1 status and have their citizens receive the greatest flood insurance premium discount. Both of these communities previously experienced disastrous flooding. Tulsa spent decades developing and implementing stormwater management improvements before [receiving its class-1 designation](#) in 2022.

Having said this, Folly Beach, S.C. – a small barrier island with 2,400 residents – was able to achieve a 30% reduction in its NFIP flood insurance premium rates by becoming a CRS Class-4 community. The program does offer resilience value. Here is a [current list](#) of CRS participants, their class and the size of the discount their residents have received.

Unfortunately, in communities in which NFIP or private flood insurance purchases are low, reduced premium rates provide little to no incentive for homeowners to invest in flood mitigation. Better and more robust communication efforts are needed to increase recognition and utilization of pre-emptive programs, like CRS and grants available from FEMA and other government entities (see Chapter 9).

### Strengthen Alabama Homes program

Models exist for providing discounted premiums for property improvements or offering endorsements that, in a covered event, would upgrade damaged property to [IBHS FORTIFIED](#) standards. The State of Alabama created the poster child for such incentives when it enacted the 2011 Strengthen Alabama Homes Act. The act produced the Strengthen Alabama Homes program, which provides grants up to \$10,000 to owners of existing homes to upgrade them to the FORTIFIED standard.

Open to all homeowners with a primary residence in Alabama, the program provides grants to Alabama residents for residential wind mitigation on existing, owner-occupied single-family homes. Funding for the program comes from the insurance industry in Alabama. Insurers in Alabama are mandated to offer discounts to homes with a FORTIFIED designation that can be as high as 55%.

### California Earthquake Authority

The California Earthquake Authority (CEA), which provides \$3,000 grants to subsidize the cost of seismically retrofitting houses with new cripple-wall bracing and foundation bolts (California Residential Mitigation Program 2023). The improvements bring the house into compliance with California Existing Building Code Chapter A3.

An additional grant is available for low-income homeowners, on top of the \$3,000. For properly retrofitted qualifying homes, the California Earthquake Authority offers an insurance premium discount of up to 25%.

## Louisiana Fortify Homes Program

In June 2023, Louisiana lawmakers appropriated \$30 million to the [Louisiana Fortify Homes Program](#) (LFHP) in a budget bill approved after establishing the program in 2022 absent funding. The program – modeled after the Alabama program – will enable eligible homeowners to apply for up to \$10,000 in grants to make their homes meet the IBHS FORTIFIED roof standard.

Lawmakers also passed accompanying legislation that will require insurance companies to provide actuarially justified discounts to policyholders who build or retrofit structures to comply with the IBHS Fortified standard.

### Risk-based pricing is essential

Any discounts offered to provide incentives to homeowners or developers would have to be consistent with principles of risk-based pricing. In other words, they must be based on a measurable expected decrease in annual losses due to the changes being made. The devil, as always, is in the details. As private insurers become more comfortable writing flood insurance demonstrates, they can assess and price the risk.

Standardizing the process in a manner that aligns the complex risk that is a flood with the abstract reward of resilience requires more than the traditional risk-transfer approach.

### Innovative approaches

A pilot program recently launched in New York City uses a parametric approach to provide a low-to-moderate-income community with financial protection from flooding. The program was developed through the combined efforts of a leading reinsurer, reinsurance broker, technology provider, national and local nonprofit organizations, and the National Science Foundation. It may prove to be a model worth emulating, especially for communities that lack traditional flood insurance. (See [Swiss Re, Guy Carpenter & ICEYE deliver NYC parametric flood insurance](#).)

Parametric insurance can create incentives for investing in mitigation by uncoupling payout from damage. For example, a writer of parametric insurance for hail markets the product to car dealerships in the Midwest. If the parametric trigger is activated, the dealer gets paid, regardless of whether its

#### What is parametric insurance?

Unlike traditional indemnity insurance, parametric insurance pays out whenever certain agreed-upon conditions are met – for example, a specific wind speed or earthquake magnitude in a particular area. If coverage is triggered, a payment is made, regardless of damage.

Speed of payment and reduced administration costs can ease the burden on both insurers and policyholders. Alone, or as part of a package including indemnity coverage, parametric insurance can provide liquidity that businesses and communities need for post-catastrophe resilience.

To learn more, see [Insurance Information Institute blog post Rising Interest Seen in Parametric Insurance](#)

inventory experiences damage. Although the policy doesn't require the dealer to invest in protective measures, such an approach creates an incentive.

Community-based catastrophe insurance (CBCI) – arranged by a local government, quasi-governmental body, or a community group to cover individual properties in the community – has been gaining attention. In addition to improving financial recovery for communities, CBCI can provide more affordable disaster insurance coverage and could be linked directly to financing for community-level hazard mitigation.

As CBCI allows for multiple delivery models, officials and risk managers can explore and implement it as part of an integrated risk-management strategy, rather than an isolated risk-transfer solution.

Marsh McLennan outlines such arrangements in four broad categories and discusses how they can promote community resilience (Marsh McLennan 2021). Such structures must incorporate outreach and education – including financial literacy – to support risk-related decision-making at all levels. Investments in risk reduction at the individual property and community level can improve insurability and lower prices.

### Roadmap to insurance incentives

As members of the only industry whose business consists of assuming property risk, Property & Casualty insurers have strong incentives to encourage improvements to reduce the risk of costly claims. While the term of a policy may be one year with non-renewal an option, insurers are strongly motivated to retain customers for the longer term.

The industry is actively engaged in this effort at many levels and stands ready to apply its centuries of experience and wealth of expertise to these challenges, within the regulatory and operational constraints that ensure its ability to keep its promises to policyholders. The industry has done so with regard to wind and earthquakes, and it can and will with floods. Industry efforts to date include:

#### Community-based catastrophe insurance

Four broad structures for CBCI illustrate the different roles and responsibilities of the community and other partners:

- Facilitator model
- Group policy model
- Aggregator model
- Purchase through a community captive.

In these frameworks, the community's role and responsibility increase from lowest to highest. In the first, the community is a facilitator and negotiator. In the second, it takes on a role in distribution, choosing insurance options and collecting premiums. In the third, the community plays a dual role: as the insured on a contract with a re-insurer and as the disburser of claims funds.

The fourth model harnesses an existing structure — an insurance captive — that enables the community to provide disaster policies.

- Participation in public-private partnerships to promote pre-emptive mitigation and reduce costly damage wherever possible.
- Sophisticated modeling to prospectively price coverage in a manner that aligns tightly to specific risks, reducing uncertainty that can lead to lower-risk policyholders, in effect, subsidizing higher-risk ones and potentially improving insurance affordability.
- Harnessing Internet of Things technology to detect issues that might lead to damage and warn property owners so they can take steps to prevent or mitigate the damage – steps often paid for by the insurer; and
- Developing products like parametric insurance to speed payment and improve property owners' resilience after a damaging event.

Separately and in combination, these sorts of solutions can help prevent damage, reduce losses, and improve resilience. None is a silver bullet. All should be considered for inclusion in any pilot program implemented using this framework.

An important objective, and consistent with all federal and state antitrust laws, is robust involvement by a greater number of private insurers, creating competition that would put downward pressure on premium rates, improving affordability. Toward this end, we recommend an "all of the above" approach that more deeply engages P & C insurers in this effort. Such an approach would include:

- Public-private collaboration
- Community-focused solutions
- Technology
- Strategic combination of traditional indemnity products with new products, such as parametric insurance

Next steps:

1. Form a panel of actuaries, underwriters, claims professionals, and product developers representing a cross-section of U.S. homeowners' insurance exposure and reinsurers who provide capacity.
2. Panel reviews this report and assesses pluvial flooding risk and the effect of various mitigation actions on risk reduction.
3. Report authors revise proposed framework according to the insurers' recommendations.
4. Hold a conference at which the panel's findings are presented to insurers who currently offer residential flood insurance and representatives from the National Association of Insurance Commissioners and state insurance regulators.
5. Conduct one or more pilot studies in communities (a city, metropolitan area, or state). In this pilot, the participating insurers collaborate with other stakeholders offering incentives. In coordination with relevant state regulators, participating individual insurers incorporate information about pluvial flooding and risk-reducing mitigation actions into pricing and underwriting in the state in which the pilot occurs.
6. Measure success by:

- Number of insurers participating in the pilot;
- Engagement level of community and property owners;
- Number of properties in which mitigation measures are implemented; and
- Applicability of pilot-specific findings to more diverse use cases.

The image features a hand holding a dark wallet containing several banknotes and credit cards. The scene is overlaid with a semi-transparent blue filter. A large, diagonal green shape cuts across the right side of the image. The text 'Chapter 6: Finance and Investor Incentives' is centered in white, bold font.

# Chapter 6: Finance and Investor Incentives

## Chapter 6: Finance and investor incentives

Homeowners and developers are not the only important stakeholders in housing and housing finance. Lenders provide mortgages for home buyers who cannot, or prefer not to, make a cash purchase. Government agencies and government-sponsored entities (GSEs) purchase loans from lenders, securitize them and sell the securities to investors in the capital markets. Investors buy and trade mortgages and mortgage securities. The actions of each of these stakeholders can affect homeowner and developer incentives to undertake investments in resilience.

### Portfolio lenders

Portfolio lenders underwrite mortgages, then retain those loans in their portfolio. They may also be securitizing lenders – that is, they may sell some of the mortgages they underwrite to securitizers such as Freddie Mac and Fannie Mae. For example, lenders may sell loans within the conforming limit<sup>14</sup> — the legal maximum loan size that Freddie Mac and Fannie Mae are permitted to purchase — while retaining jumbo loans — loans larger than the conforming limit.

A portfolio lender bears credit risk: the risk that a borrower may not repay their mortgage on schedule or at all. In addition, a portfolio lender bears interest rate risk on the mortgages in its portfolio. Portfolio lenders fund mortgages with deposits. Most mortgages are 30-year, fixed-rate loans, while the deposits funding the mortgages are much shorter term. If interest rates increase sharply during the life of the mortgage, the lender's *margin*—the difference between the interest rate on the mortgage and the interest the lender pays for the deposits financing the mortgage—may shrink<sup>15</sup>. Portfolio lenders also face *prepayment risk*, another form of interest- rate risk. When interest rates fall, borrowers with high-rate mortgages have an incentive to refinance their existing mortgages with new mortgages bearing lower rates of interest. These prepayments also can reduce the lender's margin.

### Flood-risk exposure

When a flood occurs, some borrowers will be unable or unwilling to make their mortgage payments for a period<sup>16</sup>. These delinquencies impose costs on the lender, even if the borrower eventually repays the skipped payments with accrued interest. Some borrowers will ultimately default on their mortgages<sup>17</sup> imposing credit losses on the lender.

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<sup>14</sup> The conforming limit is adjusted each year to reflect the increase in U.S. home values over the previous four quarters. The limit for a given year is set by the Federal Housing Finance Agency (FHFA) in the fourth quarter of the previous year. Higher loan sizes are permitted in Alaska, Hawaii, Guam, the U.S. Virgin Islands and certain counties with median house prices that are high relative to the conforming limit. The cap on these higher loan sizes is 150 percent of the conforming limit. The conforming limit in 2023 is \$726,200 and the cap is \$1,089,300. For more information, consult the FHFA web site (<https://fhfa.gov>).

<sup>15</sup> The U.S. savings and loan crisis of the 1980s was due in part to this type of interest rate risk.

<sup>16</sup> If a disaster is declared, mortgage borrowers will receive automatic forbearance.

<sup>17</sup> Some research suggests that homeowners with flood insurance have an increased probability of prepayment, possibly using insurance proceeds to repair the home, sell it and move to a safer location. The same research

A flood typically damages the collateral for the mortgage. After foreclosure, the lender may have to undertake expensive repairs before the house can be sold. As a result, the losses<sup>18</sup> from a flood-triggered default may be larger than the losses from a non-flood-related default.

A portfolio lender is exposed to the risk of these potential losses for the life of the mortgage. Most mortgages in the U.S. are 30-year loans. However, mortgages rarely last the entire 30-year term. When borrowers move, they must pay off the balance of the mortgage. Also, when interest rates fall, some borrowers choose to refinance their existing mortgage at the lower interest rates. In practice, the typical mortgage is repaid in less than 10 years.

### Benefits from resilience investments

If a house incorporates features making it more resilient to floods, securitizers likely face lower losses in the event a borrower experiences a flood. A more resilient house is likely to sustain less property damage, and the resilience features may make it unnecessary to vacate the house temporarily. If borrowers can remain in their home, they are more likely to continue working without interruption, thus reducing the risk of defaulting on their mortgage payment. Even if the borrower ultimately defaults, the resilience features of the house may limit property damage and reduce the costs of making the house ready for sale<sup>19</sup>.

### Incentives portfolio lenders can offer borrowers

No matter how creditworthy the borrower, all mortgage loans involve credit risk and its associated costs. Those probability-weighted costs are lower when the collateral is a resilient house than when the collateral lacks any resilience to a flood. Said another way, mortgages collateralized by resilient homes are likely to be more profitable to portfolio lenders on average. Accordingly, portfolio lenders may wish to offer some sort of financial incentive to attract potential borrowers with resilient houses.

Lenders have several structures through which to offer such incentives. The lender might reduce loan-origination fees. If the lender is a bank or credit union, it might offer discounts on other services or products it offers. The lender may offer a slightly lower interest rate on the mortgage.

It is standard practice for lenders to offer different rates to different borrowers that reflect the loan's credit risk. For mortgage loans, these differences are based on the combination of the borrower's credit score and the loan-to-value (LTV) ratio of the loan, that is, the original balance of the mortgage divided by the appraised value of the home. To the extent that greater resilience of the house reduces the risk of credit losses, it would be logical to incorporate a measure of the resilience into the traditional FICO®/LTV tables.

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suggests that impacted homeowners without flood insurance have an elevated risk of delinquency and default. See Kousky, Palim and Pan (2020).

<sup>18</sup> More precisely, the loss rate.

<sup>19</sup> Not to be overlooked are the health risks that resilience investments may prevent. Even a small amount of water damage may trigger mold issues that may make the residents vulnerable to respiratory issues.

For instance, the lender might calculate a risk-adjusted LTV to reflect the reduction in credit risk, then use this adjusted LTV to look up the appropriate mortgage rate in the existing FICO®/LTV tables.<sup>20</sup> Alternatively, the lender might set higher allowed LTV limits for borrowers with resilient houses.

## Challenges to adoption of incentives

It is clear that greater resilience should reduce expected credit losses. What remains less immediately clear is the mechanism to measure that reduction, at least with the current generation of credit models<sup>21</sup>. Research about the impact of borrower and collateral differences on credit losses from a disaster is still in its early stages. Perhaps the best current source of this type of information may be the models used by the insurance industry; however, the insurance models focus on covered losses and do not concentrate on the creditworthiness of impacted borrowers.

Part of the difficulty of modeling the impact of resilience is estimating the impact of each type of investment. In terms of reduction in expected credit losses, how much is a backflow preventer worth compared to a sump pump with a backup battery? Furthermore, the probability-adjusted value of those investments differs across houses, given the variables of construction and location.

## Ways to overcome the challenges

All models are simplifications. The industry-standard FICO®/LTV table abstracts from the many other factors that may affect credit risk. Borrowers in the same FICO®/LTV “bucket” pose varying degrees of credit risk. The table provides a guide to average behavior; it is not a precise measure of every single borrower’s creditworthiness.

Accordingly, a practical approach to providing portfolio lenders with a reasonable measure of the benefit of greater resilience will involve some significant simplifications. Current and on-going research can measure the average benefit of different resilience features. A table of average benefit by feature—so much for battery-backup sump pumps, so much for backflow preventers—can be generated. For decades, a similar approach has been applied to estimating the price of a used car. A list of characteristics is collected—make/model, model year, mileage, previous accidents, condition of interior and so on—and a price estimate is calculated. The system isn’t perfect, but it suffices.

Another possibility is to rely on certification, similar to the FORTIFIED™ designation offered by the Insurance Institute for Business & Home Safety (IBHS). Such certification provides a portfolio lender

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<sup>20</sup> In principle, greater resilience both reduces the likelihood of default and increases the expected value of the collateral post default for the reasons discussed in the section on Flood-related risk exposure. Accordingly, one could calculate a resilience-adjusted credit score in addition to a resilience-adjusted LTV. However, from the perspective of the credit modeler, a single-adjustment to LTV may be a more tractable way to capture the overall impact of resilience on credit risk.

<sup>21</sup> Beckett (2021) points out some of the challenges in updating the PD/LGD credit models used by the financial industry to incorporate the impact of changing disaster risk. Measuring the impact of greater resilience involves some of the same challenges.

both a standardized measure of the resilience of the home and a standardized method of adding resilience to a credit model.

## Securitizing lenders

Securitizing lenders underwrite mortgages then sell them to securitizers like Freddie Mac and Fannie Mae. Securitizing lenders may also be portfolio lenders – that is, they may retain some of the mortgages they underwrite in their portfolios. For example, lenders may sell loans that are within the conforming limit<sup>22</sup>—the legal maximum loan size that Freddie Mac and Fannie Mae are permitted to purchase—while retaining jumbo loans—loans larger than the conforming limit.

## Flood-risk exposure

A securitizing lender has almost no exposure to flood risk. Securitizing lenders typically hold the mortgages they underwrite for less than a month before they are conveyed to a securitizer.

Frequently a securitizing lender will service the mortgages they sell to securitizers – that is, they will collect payments from borrowers and send those payments — minus a servicing fee — to the securitizer. Servicers can suffer flood-related losses, particularly if a period of forbearance is ordered by the securitizer.

Given its lack of exposure, a securitizing lender is not a candidate for offering incentives on loans collateralized by resilient houses.

If the lender is also the servicer, the servicing arm of the lender is exposed to potential flood-related losses for the life of the mortgage. It is unclear whether any effective incentive could be offered by the servicer.

## Securitizers

Less than a fifth of the outstanding single-family mortgages in the U.S. are retained in the portfolios of the lenders. Instead, two-thirds of these mortgages have been sold to either a government agency, such as the Federal Housing Administration (FHA) or the Veterans Administration (VA), or to a government-sponsored entity (GSE), such as Fannie Mae or Freddie Mac. The agencies and GSEs

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<sup>22</sup> The conforming limit is adjusted each year to reflect the increase in U.S. home values over the previous four quarters. The limit for a given year is set by the Federal Housing Finance Agency (FHFA) in the fourth quarter of the previous year. Higher loan sizes are permitted in Alaska, Hawaii, Guam, the U.S. Virgin Islands and certain counties with median house prices that are high relative to the conforming limit. The cap on these higher loan sizes is 150 percent of the conforming limit. The conforming limit in 2023 is \$726,200 and the cap is \$1,089,300. For more information, consult the FHFA web site (<https://fhfa.gov>).

pooled these mortgages to form mortgage-backed securities, which were sold in the capital markets<sup>23</sup>.

The agencies and GSEs (the securitizers<sup>24</sup>) evolved over multiple decades in the 20<sup>th</sup> century in pursuit of public-policy goals of increasing liquidity, stability, and affordability in the housing market. The primary mechanism for achieving these goals is the creation of MBS — debt securities backed by the cash flows from large pools of individual mortgages — that are sold to institutional investors. These securities offer several advantages to investors over individual mortgages:

- Most importantly, the agencies and GSEs retain the credit risk of the mortgages underlying the securities<sup>25</sup>. When a mortgage in the pool defaults, the issuer of the related mortgage-backed security remits the unpaid balance of the mortgage to the security investors. And, unlike in an individual mortgage where it is difficult to predict if a borrower will make their future mortgage payments, the rate of default on a large group of mortgages is relatively predictable.
- Mortgage-backed securities eliminate the significant task of monitoring and administering individual mortgages:
  - Mortgage servicers collect the payments from the borrowers and forward them, minus servicing, and ancillary fees (late fees, escrows, etc.), to agencies and GSEs. Bond-administration departments of the agencies and GSEs direct those fees — minus the guarantee fee (the portion of the cash flow retained by the agencies and GSEs for their default guarantees) to the appropriate securities.
  - When borrowers fail to make their payments, the servicers, agencies, and GSEs work with them to catch up on late payments, arrange some form of foreclosure alternative, such as a loan modification, or, when all else fails, foreclose on the borrowers. All these tasks would pose significant operational costs on institutional investors if they simply purchased thousands of individual mortgages, rather than mortgage-backed securities.
- Mortgage-backed securities, like mutual funds, are divisible into whatever amount the investor desires, while individual mortgages come in idiosyncratic amounts determined by the values of the underlying houses and the borrowers' down payments.

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<sup>23</sup> This sentence abstracts from the details of the legal structure of the mortgage pools and the securities they back. Regardless of these technicalities, the cash flows from these mortgages flow to the investors in the mortgage-backed security minus fees to cover the cost of servicing and the guarantee against default provided by the agencies and GSEs.

<sup>24</sup> Some private firms also issue securities backed by residential mortgages. These private label securities account for only about 3 percent of the outstanding mortgages, and we do not consider them further.

<sup>25</sup> In essence, mortgage securities provide a way to separate the credit risk of the mortgages from the market risk of the securities, a risk well-understood and well-managed by institutional investors.

- Mortgage-backed securities are highly liquid; individual mortgages are highly illiquid. This liquidity allows institutional investors to recalibrate their positions as market conditions change<sup>26</sup>.

## Flood-risk exposure

Agencies and GSEs have an interest in the resilience of the houses collateralizing the millions of mortgages they have purchased, the same interest a portfolio lender has in the resilience of a house that collateralizes a loan it has made.

In the event of a flood, many borrowers will be unable or unwilling to make payments for some time. The securitizers, however, must continue to make payments to the mortgage-backed securities investors<sup>27</sup>. The borrower remains obligated to make up missed payments. However, some borrowers may be unable to make these overdue payments and may remain delinquent or approach default.

For severely distressed borrowers, the securitizers may attempt to find an alternative to foreclosure, typically a loan modification. When a loan is modified, the original loan is terminated and the securitizer remits the unpaid balance to the investors. The terms of the modified loan are likely to be more advantageous to the borrower than the terms of the original loan. While modified loans can be re-securitized, this process may impose losses on the securitizer.

Some flood-impacted borrowers will ultimately default. The securitizer will have to remit the unpaid balance of the loan to the MBS investors. The securitizer will attempt to recover its losses by disposing of the flood-damaged house, the collateral for the mortgage. If the house is in an area designated by FEMA as a Special Flood Hazard Area (SFHA), the borrower would have been required to obtain a flood insurance policy from the National Flood Insurance Program (NFIP). This policy will compensate the securitizer for some, and possibly all, of the flood damage<sup>28</sup>. If the house is located outside the SFHA, flood insurance is not required, although the homeowner may have chosen to obtain a flood insurance policy.

Securitizers are exposed to the risk of these potential losses for the life of the mortgage. Most mortgages in the U.S. are 30-year loans. However mortgages rarely last for the entire 30-year term. When borrowers move, they must pay off the balance of the mortgage. Also, when interest rates fall, some borrowers choose to refinance their existing mortgages at the new, lower interest rates. In practice, the typical mortgage is repaid in less than 10 years.

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<sup>26</sup> An indication of the liquidity of mortgage-backed securities is the ease with which investors can take short positions in them.

<sup>27</sup> Initially, mortgage servicers are obligated to advance payments to the securitizers. In the event of a major flood disaster, securitizers typically announce a period of forbearance. The missed payments do eventually need to be paid.

<sup>28</sup> NFIP flood insurance policies cover a maximum of \$250,000 of loss.

## Benefits from resilience investments

If a house incorporates features that make it more resilient to floods, securitizers are likely to face lower expected losses in the event a borrower experiences a flood. A more resilient house is likely to sustain less property damage, and the resilience features may make it unnecessary to vacate the house temporarily. If the borrower can remain in their home, they are more likely to continue working without interruption, thus reducing the risk that the borrower cannot make their mortgage payment. Even if the borrower ultimately defaults, the resilience features of the house may limit property damage and reduce the costs of making the house ready for sale.

## Incentives securitizers can offer borrowers

The government agencies and GSEs that securitize mortgages do not make loans directly to borrowers. They can offer incentives indirectly by incentivizing lenders to sell them relatively more mortgages collateralized by resilient houses. The securitizers set the prices they are willing to pay lenders for mortgage loans. It is, in principle, possible for the securitizers to pay more for loans backed by resilient houses, reflecting the lower expected costs to the securitizers of these types of loans.

Given the extended time the securitizers are exposed to the impact of a flood, the actuarially fair value of these higher payments may be significant.

Financing for retrofitting can be difficult to secure. Securitizers could remove this obstacle by purchasing home equity loans (HELoans) tied to resilience investments. This approach is likely to be particularly important in periods of rising interest rates, when borrowers are reluctant to apply for a cash-out refinance of their existing mortgage. The relatively small size of a home equity loan or line may make borrowers willing to pay the higher interest rates, as they are able to leave their lower-interest-rate lien in place.

## Challenges to incentives adoption

Government agencies and GSEs may not be permitted to offer differential payments for loans backed by houses based on resilience features. The policies of the government agencies are subject to review and guidance by Congress. Fannie Mae and Freddie Mac remain in conservatorship since the 2008 financial crisis, meaning their policies must meet the approval of the Federal Housing Finance Agency (FHFA), their regulator and conservator.

Another possible impediment is the difficulty of determining the actuarially fair payment difference. Flood risk varies from house to house — even houses next to each other — therefore, the appropriate price benefit may be difficult to calculate.

Even if the securitizers are permitted to offer higher payments for loans backed by resilient houses, mortgage lenders may not pass these benefits to the borrower.

Resilience investments need to be in place before they can be recognized by lenders and securitizers. In other words, the resilience investments need to be performed by the existing homeowner (or builder of a new home), not the potential home buyer. To provide an incentive to the existing homeowner or builder, the incentive offered by the lender and securitizer has to be recognized as increasing sale price.

GSEs do not currently purchase home equity loans, but their charters include no obvious impediments to doing so. Starting a program to purchase home equity loans or lines to finance resilience investments will likely require consultation with the FHFA.

A program to purchase HE Loans faces challenges beyond regulatory review and approval. Given their short term and low original balance, HE Loans aren't exactly economically unattractive to banks. GSEs may be able to improve the profitability of originating HE Loans by subsidizing their purchase or by streamlining the funding process. Bank regulators may be willing to award additional Community Reinvestment Act credit for this type of HE Loan made to a less affluent borrower. These approaches may be justified by the difficulty faced by less affluent borrowers in financing retrofits.

### Ways to overcome challenges

Congress and FHFA may conclude that the benefit to society of encouraging investment by homeowners in resilience features justifies permitting higher payments by securitizers. In that case, they may not just allow, but encourage securitizers to increase their payments for loans backed by more resilient houses.

Certification along the lines of the FORTIFIED wind program offer a mechanism to simplify the difficulty of calculating the appropriate price increase for resilient loans. In addition to providing reassurance to the homeowner, certification would make it easier for securitizers and their regulators to calculate the typical dollar value of risk reduction associated with the resilience investments. Certification may also make it easier for existing homeowners and builders to ascertain the increase in the sales price of the house.

Securitizers may require evidence that the lender provided an appropriate incentive to the borrower so that it will pay a higher price to the lender in exchange for the mortgage.

## Investors

Institutional investors purchase several types of mortgage securities. Plain-vanilla mortgage-backed securities (MBS) represent the largest share. Investors also purchase derivatives, so-called structured securities, backed by MBS. These securities divide the cash flows of the underlying MBS into segments with varying timing and interest-rate sensitivity to meet the varying needs of investors. Neither the structured securities, nor the underlying MBS, carry any credit risk. The securitizers retain all the credit risk in exchange for a guarantee fee.

In the wake of the financial crisis of 2007 and 2008, Freddie Mac and Fannie Mae began offering credit-risk transfer (CRT) securities. These are structured securities in which cash flows are based on a reference pool of mortgages purchased by the securitizer. These securities convey some of the potential credit losses on the reference pool to the investors. Freddie Mac and Fannie Mae also offer reinsurance contracts on the portions of the potential credit losses they retain. Because CRT securities and reinsurance contracts carry credit risk, they offer investors higher yields than comparable mortgage securities that bear no credit risk.

## Flood-risk exposure

Investors in CRT securities and reinsurance contracts are exposed to a portion of the credit risk that would normally have accrued to the securitizer. See the section on securitizers for a detailed explanation.

The length of exposure varies by the type of CRT security or reinsurance contract.

## Benefit from resilience investments

See the [section on securitizers](#) for a detailed explanation.

## Incentives investors can offer to securitizers for resilience investments

Investors have even less of a direct connection to borrowers than do securitizers. The securitizers can offer incentives only indirectly through the lender. Investors are once more removed from the borrower. They can offer incentives only by higher prices to securitizers (accepting lower yields) for CRT securities or reinsurance contracts backed by reference pools with a relatively large share of resilient houses.

Securitizers may wish to construct resilient reference pools precisely to appeal to investors. If they do so, investors will indicate, via the prices they are willing to pay, exactly what the market believes to be relative value of a resilient house. That information can be used by the securitizer to confirm the appropriateness of any incentive it offers lenders for mortgages collateralized by resilient houses. These pools bear some similarities to Green MBS, which include loans collateralized by houses receiving approved green building certifications. These types of securities provide a framework and estimated impact that private investors can support.

### Key Findings:

- Meaningful financial incentives are practical if the stakeholder obtains a significant benefit from resilience investments (an upside to offering the incentive) or the stakeholder has an extended period of risk exposure (reducing a downside of not offering the incentive).
- Portfolio lenders and securitizers obtain a significant benefit from resilience investments and have risk exposure that lasts the life of the mortgage. For the portfolio lenders, incentivizing resilience investments supports their local communities and helps meet their CRA requirements. For the GSE securitizers, incentivizing resilience investments also aligns with their missions, ESG goals, and duty-to-serve requirements.
- Investors in CRT securities and reinsurance contracts may have a significant benefit and an extended risk exposure depending on the terms of the security or contract in which they invest.
- Securitizing lenders obtain almost no benefit from resilience investments. The risk exposure of securitizing lenders lasts less than a month.
- An incentive is easier to craft and likely to be more effective if the stakeholder deals directly with mortgage borrowers.
  - Portfolio lenders deal directly with mortgage borrowers and have wide scope to craft their incentives to fit their business model.
  - Actions by securitizers have an instant and powerful impact on the mortgage market, however securitizers do not deal directly with borrowers. It may be difficult to verify that any financial incentive offered by the securitizers is passed through in full to the borrowers and is perceived as linked to an investment in resilience. Furthermore, securitizers may face challenges obtaining approval from regulators and conservators for any resilience incentive program.
  - Investors cannot offer incentives to borrowers; however, they can convey information on the value of resilience investments by their pricing of CRT securities and reinsurance contracts differentiated by the share of mortgages in the pool that are collateralized by resilient houses.



**Chapter 7:  
Real Estate Agents**

## Chapter 7: Real Estate Agents

Real estate agents bring home buyers and sellers together. They advise sellers on preparing houses for sale and on marketing and pricing strategy. They may help stage a home to increase its attractiveness to home buyers, host open houses to attract potential home buyers and inform them about the features of the house. They help home buyers locate houses in their price range that meet their requirements. They also advise buyers and sellers during negotiations and the closing process.

### Flood-risk exposure

Some states require sellers to disclose information about flood risk or previous floods, and additional states are considering similar requirements. Depending on the wording of the legislation in each state, real estate agents may bear some responsibility for these disclosures. In the event of a future flood, a buyer may allege that the seller failed to meet the disclosure requirements or that the seller actively misled the buyer about flood risk and previous floods.

The exposure to this type of liability is open-ended. Even if the original buyer resells the property and is sued later by the subsequent buyer, the first buyer may assert that they relied in good faith on the original seller's disclosures.

### Benefits from resilience investment

Features that increase resilience to floods may increase the market value of a house and, hence, the commission of the real estate agent. Several studies have found that houses with resilience features to disasters (other than floods) have a higher market value than comparable houses without those resilience features. Research sponsored by the National Association of Home Builders suggests home buyers would be willing to pay \$5,000 more for new, code-compliant homes with extra flood protection in places with high flood hazard where those buyers also perceive the risk is high. An increase in resale value would increase the sales commissions of both the buyer's and seller's agents.

Resilience investments that reduce the risk of flood damage would also reduce the likelihood of a buyer alleging a failure to disclose as required.

### Incentives real estate agents can offer to sellers to invest in resilience

To the extent that resilience features may increase the market value of a house or reduce litigation risk in the event of a flood, real estate agents may find it advantageous to encourage sellers to do disaster mitigation prior to placing a house on the market, just as they commonly encourage sellers to make other improvements. They can then highlight those resilience features in real estate listings and in other marketing efforts, and set the asking price accordingly.

## Challenges to incentive adoption

Some real estate agents may resist highlighting the resilience features of a house for fear that discussing flood (or other perils) can remind buyers of a risk they had not previously considered.

## Ways to overcome the challenges

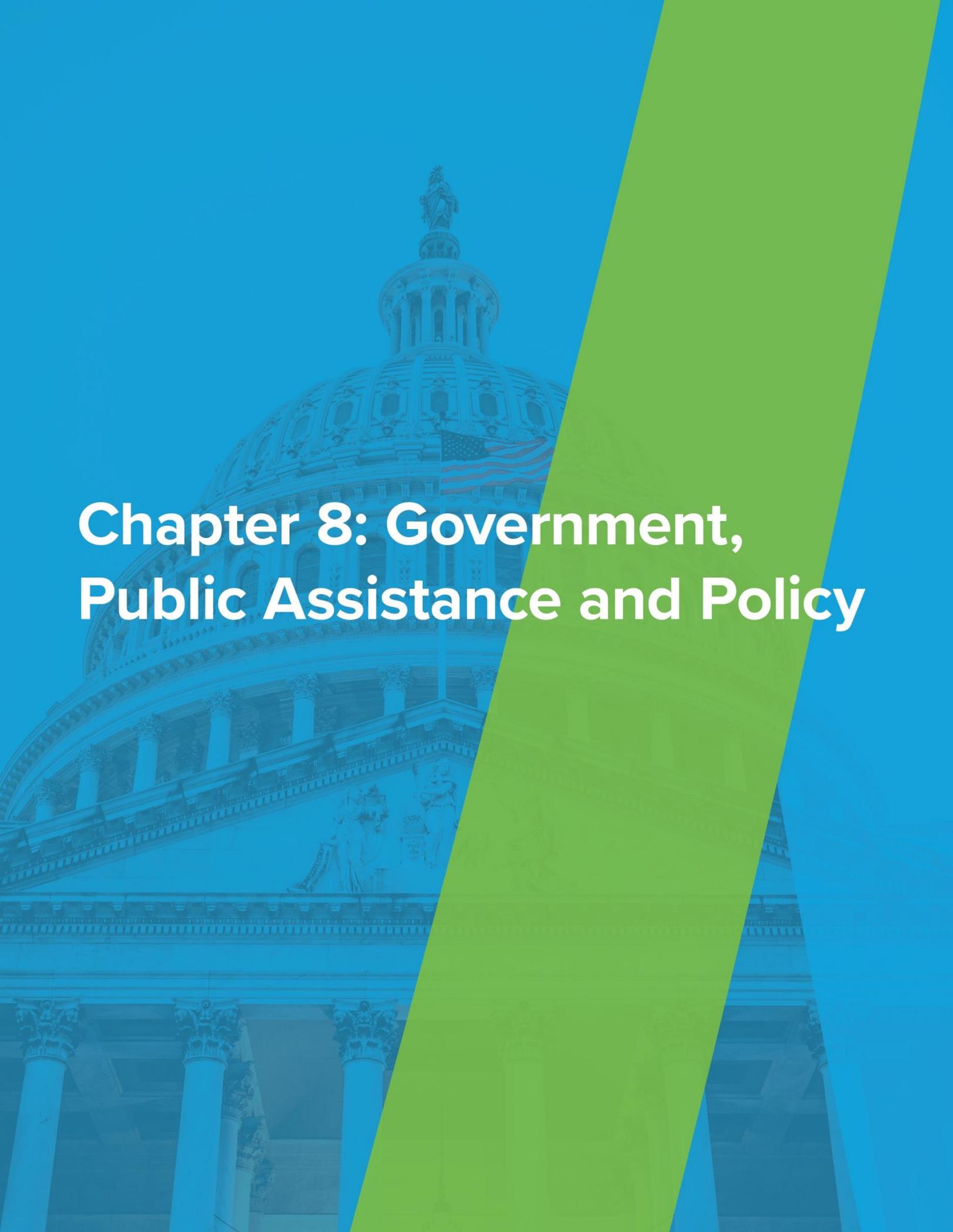
Certification of the presence and correct installation of resilience features—similar to the FORTIFIED™ Home Hurricane designation program—may shield the seller and real estate agent from future disagreements about the performance of the resilience features. Furthermore, the National Institute of Building Sciences could ensure that the certification documentation clearly manages the buyer's expectations.

We do not yet know to what extent basement-flood resilience features increase a home's resale value. The sales-price evidence cited above considers only wind and earthquake hazards. The \$5,000 willingness-to-pay estimate for above-code flood resilience in high-hazard locations speaks to the hypothetical value of above-code design of new buildings, but *not* specifically to basement-flood mitigation within the larger population of new and existing houses. The organization leading the pilot program could carry out the sales-price flood research and then create literature to educate real estate agents on its use. It also could address agents' reluctance to highlight potential risk by quantifying the market value of resilience features. The apparent market value of seismic retrofit in California excited agents who heard about it, according to the California Earthquake Authority (Janiele Maffei, chief mitigation officer, verbal communication, May 30, 2023).

## Roadmap to real estate agent incentives

To encourage real estate agents to push for resilience features try the following:

1. ***Draft guides specifically for real estate agents.*** Combine information from the mitigation technical guides with research on the impact of the market value of resilience investments. This arms real estate agents with data about the benefits of resilient houses that they can highlight to potential home buyers. The guides also can help the seller's agent search for and procure a basement-flood certificate.
2. ***Partner with a real estate professional society to pilot test incentivization.*** Partner with an organization such as the National Association of Realtors and some of their state or local associations to pilot test the guides and measure their impact on sales prices and days on market.



# **Chapter 8: Government, Public Assistance and Policy**

## Chapter 8: Government, Public Assistance and Policy

This chapter discusses policy opportunities and funding resources with the government. For context, governments include:

- The U.S. Treasury and agencies that address mitigation:
  - Federal Emergency Management Agency
  - U.S. Department of Housing and Urban Development
  - Small Business Administration
  - Economic Development Administration
  - U.S. Department of Transportation
  - U.S. Department of Energy
  - Veterans Administrations
  - U.S. Army Corps of Engineers
- State revenue departments and state agencies: fire and offices of emergency services
- Cities and their agencies: fire, emergency medical services, local utilities, building and safety departments, emergency managers
- Counties and their agencies: fire, emergency medical services, building and safety, emergency managers, floodplain managers
- Other public utilities and their emergency managers

Mitigation benefits governments in several ways:

- **Lower response cost.** Mitigation reduces the amount of public funds and labor spent to respond and recover from disasters and provides tax relief for covered losses.
- **Stable economy and tax base.** It increases federal, state, and local sales, property, and income taxes through a more stable economy and better buildings. Some disaster repair costs are tax deductible (see Chapter 2), so better buildings means lower repair costs and lower tax losses.
- **Protecting people.** It protects its people (citizens), saves taxpayer money, and provides for the collective future.
- **Greater job opportunities.** Areas where homes aren't wiped out by disaster because of mitigation planning enjoy an improved local reputation to attract and retain residents and businesses. Better buildings require a little more construction material, a little more work, and a little more training and expertise, which equals more jobs and more pay.

While the government plays significant roles in all aspects of our social economic life, the policy and funding opportunities could be complex. The intent of this chapter is to focus on the most promising and tangible incentives government can provide. We think government can serve as the catalyst and a leading force to promote private-sector mitigation investment. It can offer several kinds of incentives:

- Mitigation grants
- Tax incentives
- Development impact fee
- Public awareness campaigns
- Leading by example (pilot communities, success stories)

## Mitigation grants

The Natural Hazard Mitigation Saves study (Multi-Hazard Mitigation Council 2019) showed that pre-disaster mitigation strategies prevent many kinds of losses. The study estimated that the \$27 billion in public-sector investment in mitigation since 1993 by the Federal Emergency Management Agency (FEMA), Economic Development Administration, and U.S. Department of Housing and Urban Development will ultimately save \$160 billion, meaning \$6 saved per \$1 invested on average.

The Biden administration emphasized the estimated 6-to-1 benefit-cost ratio of resilience investment throughout its successful promotion of its \$1.3 trillion infrastructure bill. With the rising number of disasters, more communities than ever are relying on these government funding sources to better prepare for risks.

Across the federal agencies, various hazard-mitigation programs provide grants or loans to state, local, tribal and territorial governments to support local communities. These grants allow entities to develop hazard-mitigation plans and build or rebuild in a way that reduces or mitigates future disaster losses in their communities. The following is a long, but non-exhaustive, list of leading programs that support mitigation investment and go beyond urban flooding:

- **Building Resilient Infrastructure and Communities (BRIC).** This FEMA grant program aims to shift federal focus from reactive disaster spending and toward research-supported proactive investment in community resilience through greater investments in resiliency and preparation for extreme weather events. BRIC supports mitigation planning and project grants, as well as management costs. A FEMA-approved mitigation plan is required to receive FEMA assistance.
- **Hazard Mitigation Grant Program (HMGP).** This FEMA program funds long-term hazard mitigation planning and activities to reduce or eliminate the losses of life and property in future disasters. Individuals and businesses can apply through, or be sponsored by, their local, state, or tribal government agency. The work must conform with approved state and local mitigation plans. Funding is available for mitigation planning and planning-related activities, as well as management costs.
- **Flood Mitigation Assistance (FMA).** This FEMA grant program funds projects and planning that reduces or eliminates long-term risk of flood damage to structures insured under the National Flood Insurance Program (NFIP). Funding also covers management costs.
- **STORM Act.** Becoming law Jan. 1, 2021, the STORM Act authorizes FEMA to provide capitalization grants to states, eligible federally recognized tribes, Puerto Rico, and the District of Columbia to establish revolving loan funds for local governments to reduce risks from natural hazards and disasters. The STORM Act is intended to provide a streamlined

mechanism to fund local hazard-mitigation projects. For the first year, FEMA is making \$50 million available to eligible entities to establish revolving loan funds.

- **Community Disaster Resilience Zones (CDRZ) Act of 2022.** The CDRZ Act amends the Stafford Act to establish a statutory structure to identify and designate community disaster resilience zones. These are zones deemed most in need and most at risk to natural hazards, including hurricanes, flooding, earthquakes, and wildfires. The designation is meant to increase public and private sector investments in housing, infrastructure, and community-wide resilience. It requires agencies to:
  - Review the underlying methodology of any product that is a natural hazard risk assessment and receive public input on the methodology and data used for the product, and
  - Consider including additional data in any product that is a disaster hazard risk assessment.

Using the reviewed assessments, the president must periodically identify and designate community disaster resilience zones, which shall be:

- the 50 census tracts assigned the highest individual hazard risk ratings; and
- In each state, not less than 1% of census tracts that are assigned a high individual risk rating, taking into consideration specified geographic balance.

The president may provide financial, technical, or other assistance to an eligible entity (a state, Indian tribal government, or local government) that plans to perform a resilience or mitigation project within, or that primarily benefits, a community disaster resilience zone.

- **Community Development Block Grant (CDBG) State Program.** This program by the U.S. Department of Housing and Urban Development (HUD) helps states ensure affordable housing, provide services to low- to moderate-income communities, and create jobs. The CDBG program allows states to award grants to smaller units of local government. The annual CDBG appropriation is allocated between states and local entitlement jurisdictions (metropolitans). States allocate to non-entitlement localities.
- **Community Development Block Grant-Mitigation (CDBG-MIT).** This HUD program enables grantees to mitigate against disaster risks while allowing grantees to transform state and local planning. Grantees are required to reference applicable FEMA hazard mitigation plans in their action plan and describe how the hazard mitigation plan has informed the CDBG-MIT action plan. Grantees may also use these funds for planning activities, including but not limited to regional mitigation planning, the integration of mitigation plans with other planning initiatives, activities related to FEMA's pre-disaster mitigation.
- **Community Development Block Grant – Disaster Recovery (CDBG-DR)** This HUD program provides funds to help cities, counties, and states to recover from Presidentially declared disasters.
- **National Coastal Resilience Fund (NCRF).** This program of the National Oceanic and Atmospheric Administration (NOAA) restores, increases, and strengthens natural infrastructure to protect coastal communities from flooding and associated threats to property and key assets, such as hospitals and emergency routes, while also enhancing habitats for fish and wildlife.

- **Emergency Coastal Resilience Fund (ECRF).** This NOAA program funds projects that assist coastal communities and ecosystems prepare for and recover from extreme weather events, climate hazards, and changing ocean conditions.
- **National Coastal Zone Enhancement Program Grants.** This NOAA program aims to help improve states' coastal management plans. It focuses on nine enhancement areas: wetlands, coastal hazards, public access, marine debris, cumulative and secondary impacts, special area management plans, ocean and Great Lakes resources, energy and government facility siting, and aquaculture.
- **National Flood Risk Management Program/Silver Jackets.** This program of the U.S. Army Corps of Engineers (USACE) aims to increase capabilities across all aspects of the Corps to improve decisions made internally and externally that affect the nation's flood risk, including risk to life, the economy, and natural environment. The Silver Jackets Program facilitates connections and networking for state teams and the USACE, as well as helping state teams navigate to services from other agencies. It develops information resources and supports sharing and networking among teams and agency partners to implement flood-risk management efforts that improve flood-risk awareness and result in actions to reduce risk. The program assists states with identification of available USACE resources and technical services to support flood-risk management challenges and coordinates provision of technical assistance, when appropriate.
- **Watershed management.** The USACE watershed management program studies water resource needs of river basins and regions in the U.S. in consultation with federal, state, tribal, interstate, and local government entities to develop a watershed plan. It does not encompass feasibility-level planning for specific USACE projects, but addresses identified water resources needs from any source, regardless of agency responsibilities, and provides a shared vision of a desired end state that may include recommendations for potential involvement by the USACE and other federal and non-federal interests.
- **Environmental Quality Incentive Program (EQIP).** This program of the U.S. Department of Agriculture (USDA) assists producers to recover from disasters like floods, hurricanes, wildfires, and drought. The program provides financial assistance to repair and prevent excessive soil erosion caused or impacted by disasters to promote conservation practices to protect land from erosion, support disaster recovery and repair, and mitigate loss from future disasters.
- **Natural Resources Conservation Service (NRCS).** This service of the USDA's natural resources conservation programs helps people reduce soil erosion, enhance water supplies, improve water quality, increase wildlife habitat, and reduce damages caused by floods and other disasters.
- **Economic Development Disaster Supplemental Funding.** This program of the Economic Development Administration (EDA) helps regions recover from the economic harm and distress resulting from disasters to rebuild stronger, more resilient economies.
- **Investment for Public Works and Economic Development Facilities.** This EDA program helps distressed communities revitalize, expand, and upgrade their physical infrastructure. It enables communities to invest in mitigation, planning, response, and recovery activities to attract new industry. It encourages business expansion; diversifies local economies; and generates or retains long-term private-sector jobs and investment through the acquisition or development

of land and infrastructure improvements needed for the successful establishment or expansion of industrial or commercial enterprises.

- **Water Infrastructure Finance and Innovation Act (WIFIA) program.** This program of the Environmental Protection Agency funds development and implementation activities for eligible water and wastewater infrastructure projects, including enhanced energy efficiency projects for water facilities.
- **Disaster Loan Assistance.** This program of the Small Business Administration provides long-term, low-interest loans to rebuild damaged facilities, with additional loans for mitigation assistance to prevent future loss of the same type.

Some state governments have similar programs, outlined below:

- Some governments have provided mitigation grants directly to residents using pre-approved, cost-effective strategies. Florida implemented such a strategy after the 2004 and 2005 hurricane seasons. Its Task Force on Long-Term Solutions for Florida's Hurricane Insurance Market made numerous recommendations, including one from the Federal Alliance for Safe Homes (FLASH), to create a mitigation consumer assistance program. The program provided free retrofit inspections, retrofit grants for low-income families, and low- or no-interest loans for proven mitigation methods. In 2006, the state created the Florida Comprehensive Hurricane Damage Mitigation Program and appropriated \$250 million (Florida State University 2010, pp. 12-13). By 2007, FLASH had completed 14,116 inspections and 400 quality-assurance inspections in 17 counties; developed an inspection report that included return on investment for mitigation options; developed a curriculum to qualify inspectors and contractors; and created a rating scale. In 2007, the state took over full implementation. By 2009, the funding had paid for 401,372 home inspections and \$82,650,215 in mitigation grants (Florida State University 2010, p. 18). By then, 40% of residential policies in the state were receiving windstorm mitigation discounts, with an average premium reduction of 26% (Florida Commission on Hurricane Loss Projection Methodology 2010, p. 21).
- South Carolina modeled its South Carolina Safe Home Program on the Florida Program and asked FLASH to develop eligible mitigation activities, provide training programs for both inspectors and contractors, and assist with development of inspection protocols and accompanying forms. The program provides matching or non-matching grants (based on income, as per U.S. HUD guidelines, and the value of the home) not to exceed \$5,000 to retrofit properties to increase resistance to hurricane and high-wind damage. Since the program began in 2007, it has awarded more than 3,900 grants, totaling more than \$17.7 million (South Carolina Department of Insurance 2015, p. 26). The program is funded through a 1 % tax on insurance premiums.

Many cities offer grants for disaster mitigation. This non-exhaustive list of 13 cities in 10 states plus 10 communities in the Canadian province of Ontario covers programs that pay all or part of the costs for basement flood protection, with grants ranging from \$1,000 to \$6,000 per household. Note that in at least some of these communities, the program imposes an administrative burden on the homeowner and some uncertainty about whether a retrofit will qualify for the grant.

- **Hammond, Ind. (2023):** \$1,000 to help homeowners install a sewer backflow valve.
- **La Porte, Ind. (2023):** up to \$4,750 for basement flood protection.
- **Des Plaines, Ill. (2023):** up to \$2,000 for basement flood protection
- **Baltimore, Md.** offers up to \$5,000 per dwelling unit to repair basement damage (Baltimore City Department of Public Works 2018).
- **Lansing, Mich., (2023)** offers a program like that of Baltimore and grants up to \$4,750.
- **Detroit (2023)** offers up to \$6,000 for property owners to mitigate basement flooding in flood-prone neighborhoods. It pays for disconnecting downspouts from the sewer system, backwater valves, and sump pumps.
- **East Lansing, Mich. (2023):** up to \$3,000 for basement flood protection
- **Albany, N.Y. (2023):** \$2,000 for backwater valves, with additional funds for disadvantaged homeowners
- **Oregon, Ohio (2023):** up to \$2,000 for basement flood protection
- **Toledo, Ohio:** up to \$2,000 to mitigate basement flooding using standpipes, check valves, sewer or plumbing modifications, and sump pumps
- **Alexandria, Va.(2023)** subsidizes 50 % of the cost of a variety of flood protection measures up to \$5,000.
- **Toronto, Ontario, Canada (2022)** offers a basement flooding protection subsidy of up to \$3,400 per property to install a backwater valve or sump pump. Several Ontario communities offer similar programs, including Brant County, Brantford, Charlottetown, London, Niagara Falls, St. Catharine's, St. Thomas, Welland, and Windsor.

## Challenges

Communities – especially poorer ones – find it hard to get federal funding. Over two-thirds of FEMA hazard mitigation grant funding between 2010 and 2018 went to just three states: New Jersey, New York, and Texas (Government Accounting Office 2021). For FY2021 Flood Mitigation Assistance program, 31 states and territories did not submit applications (FEMA 2023b).

The National Institute of Building Sciences (2021) conducted a national survey to identify the challenges and barriers faced by communities in searching for federal grants. The top three are technical challenges (like conducting benefit-cost analysis), lack of time and/or resources to pursue, and inability to find a match for cost-share requirements. Other barriers also have received at least 25 % or higher votes, including grant deadline does not coincide with projects, too few precedent examples, don't know where to begin, and too many places to search.

See Figure 8-1 for survey responses.

Value	Percent
I don't know where to begin.	25%
There are too many places to search.	24%
I don't have the time or resources to pursue.	37%
There are technical challenges like conducting a required benefit-cost analysis (cost effectiveness).	47%
I cannot find a match for grants requiring cost shares or matches.	33%
Grant deadlines do not coincide with our project.	31%
There are few examples of what has worked and what has not worked.	27%
Other, please specify:	14%
I do not experience these difficulties.	12%

Figure 8-1. Survey response to "What, if any, difficulties do you encounter when searching for funding and resources from the federal government?"

## Opportunities

Create a one-stop mitigation resource portal that contains a centralized inventory of available resources across different grant programs and federal agencies. Some of the key features of the portal should include:

- **Grant Identification and Matching:** The tool should have access to a database of various grants and funding opportunities offered by governmental agencies, nonprofit organizations, and private foundations. It can match the specific needs and priorities with the available grants, making it easier for the local government to find suitable funding sources.
- **Customized Recommendations:** Based on the specific vulnerabilities and characteristics of each community, the tool can generate customized recommendations for appropriate grant programs. These recommendations may include funding for infrastructure improvements, community-engagement initiatives, training programs, early warning systems, and other resilience-building projects.

- **Streamlined Application Process:** Applying for grants can be a complex and time-consuming process. The tool can streamline this process by providing step-by-step guidance and assistance, ensuring that the local government submits complete and well prepared grant applications. Artificial intelligence and other technology will help to load information into the application drastically reducing time and minimizing the potential for human error.
- **Capacity Building and Technical Assistance:** Many communities may lack the expertise and resources to develop strong grant proposals. The tool can offer capacity building and technical support, providing training and resources to enhance the community's ability to compete for grants successfully. Also, match the local government to academic and non-profit institutions that can assist with the application process and eventually with project management support and implementation once the grant is awarded

## Tax incentives

The federal government could offer tax relief to homeowners who retrofit their homes for greater resilience, or to developers who build new homes to exceed building-code minimum requirements. In this roadmap Appendix A, we show how to estimate the benefits of such programs in terms of tax revenues, and illustrate the case of basement flood protection. We can do so for other mitigation programs as well. In Chapter 1, we discuss why tax incentives are important for homeowners. Below are some existing and working examples at the federal and state level.

- SHELTER Act (S. 1805) intends to amend the Internal Revenue Code of 1986 to provide a credit against tax for disaster mitigation expenditures. The Shelter Act was reintroduced in June, 2023. It allows a tax credit to individuals and businesses for disaster mitigation expenditures. The allowable amount of such credit is 25 % of the mitigation expenditures, up to \$5,000 in any taxable year.
- Louisiana offers residents a tax deduction of up to 50 % of the cost paid to bring existing homes into compliance with the building code and provides sales tax exemptions on the installation of storm shutters (Adams 2015, p. 6).
- Alabama passed a law in 2011 that allows homeowners to qualify for a \$3,000 state income tax deduction if they retrofit or upgrade their homes to FORTIFIED standards.
- The City of Berkeley, California, provides a seismic retrofit refund on its 1.5 % real property transfer tax for residential property. The program allows for up to one-third of the transfer tax (0.5 % of the purchase price of the dwelling) to be refunded for voluntary seismic upgrades to residential property (City of Berkeley 2019). Within 10 years of the program's inception in 1992, 40 % of single-family homes had been voluntarily retrofitted (EERI Northern California Chapter 2020). Between 2003 and 2014, the city provided 1,400 refunds, an average of 130 retrofits per year in that city of 113,000 people (Daniel 2015). The program costs the city very little, since the buyer is paying for the retrofit.

## Development fee and permitting incentives

Although some developers treat resilience as a market feature (see Chapter 2), many developers and builders face cost pressures that limit their willingness to add mitigation features to a house, as discussed in Chapter 4. State and local governments could attract developers and builders by reducing development impact fees, decreasing parking requirements, increasing density, or reducing barriers to speed permitting, in exchange for more-resilient buildings. As previously noted, resilient buildings tend to reduce disaster response and recovery costs and reduce income tax losses from tax deductions from disaster losses. Below listed some of the existing practices, which we could learn from, adapt, and expand in other communities:

- Chicago implemented streamlined local permitting to encourage green construction (Rainwater 2007, p. 32), a concept that could be exercised for enhanced resiliency as well.
- San Francisco expedites permits and waives fees for voluntary seismic retrofits (San Francisco Department of Building Inspection 201)
- The Alaska Division of Community and Regional Affairs and the Alaska Division of Homeland Security and Emergency Management have advocated incentives including tax abatement, density bonuses, and waiving parking requirements to encourage developers to locate projects outside of hazardous areas and to adopt hazard mitigation measures above legal requirements (Cox et al. 2012, p. 3)
- Accelerate local permitting and inspection procedures for mitigation, e.g., with standard plans and resolutions like those of Association of Bay Area Governments (2016).

## Public awareness

In earlier chapters, we discussed public awareness, behavioral incentives for homeowners, and insurance education. We identified several communities and states where certain resilience features increase the market value of real estate, often far in excess of the cost of the resilience feature.

But as noted in Chapter 2, the National Association of Home Builders sponsored surveys that found that many builders and home buyers do not perceive resilience as a market value, or that many buyers assume that buildings are safe enough and are unwilling to pay for greater resilience.

The contrast between those two facts – resilience sometimes appears to have a market value and sometimes not – suggests that market awareness may matter to whether people value resilient buildings. Plenty of research suggests that the public is unaware that code-compliant buildings are only intended to remain life safe after a disaster, not functional or even repairable. Most people expect buildings to be functional after a big disaster (earthquakes, at any rate) and are disappointed when they learn otherwise. See Davis and Porter (2016) and Porter (2021) for evidence.

We think a strong need exists to educate consumers on the resilience of houses. Figure 8-2 shows the 10 home features that are most wanted by first-time buyers, according to the National Association of Home Builders (Emrath 2022). The list of features most wanted by first-time buyers is similar to the list

for home buyers in general, although the most noticeable difference is the absence of energy saving features on the first-time buyers’ top 10 list. Among buyers in general, ENERGY STAR rated windows ranked as the #4 most wanted feature and ENERGY STAR rated appliances ranked No. 9.

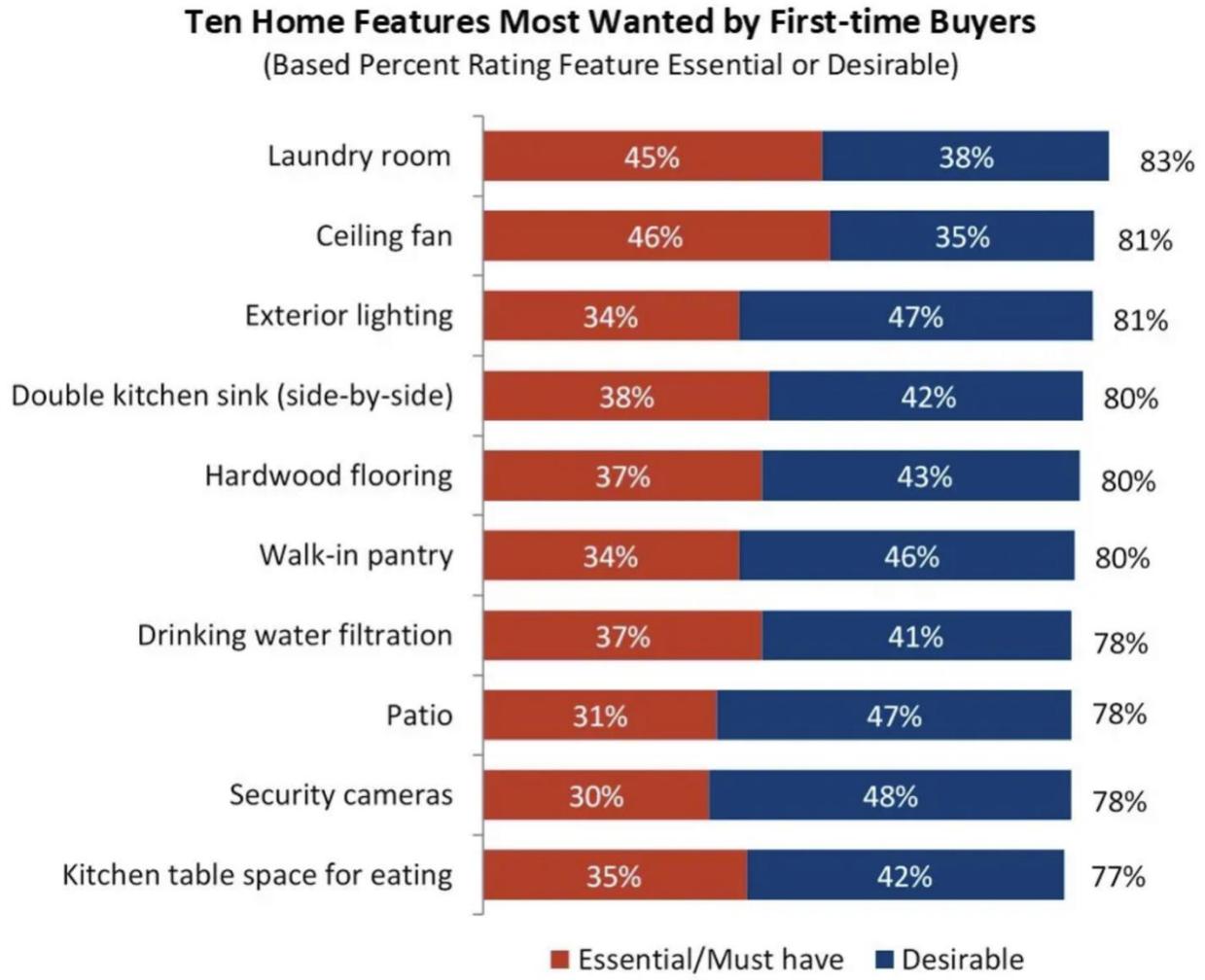


Figure 8-2. Ten home features most desired by first-time home buyers

Table 8-1 offers our general checklist of recommended lessons for an educational campaign for home buyers. The table includes resilience features that a public awareness campaign could address, the opportunities and existing examples and programs that we could learn from.

Table 8-1. Proposed checklist of lessons to teach the public about the resilience of houses.

Homebuyer checklist for a new or existing house	Public awareness campaign	Opportunities	Existing examples or similar programs/concept
Location	Natural hazard risk	National or local government led effort	1) No codes, no confidence (Federal Alliance for Safe Homes 2023)  2) Lessons we may learn from car seat belt movement, tobacco use
School rating	House vulnerability rating	Government regulated or industry led effort to have real estate disclose house’s related history to natural hazard damages	
Home features like number and/or condition of bedrooms, bathrooms, kitchen, patio, and deck, ENERGY STAR rated windows and appliance	Flood certification program	Government funded engineering research and study to support establish such a program.	1) ENERGY STAR (2023)  2) IBHS Fortified Roof (Insurance Institute for Business & Home Safety 2022)

## Long- and near-term recommendations

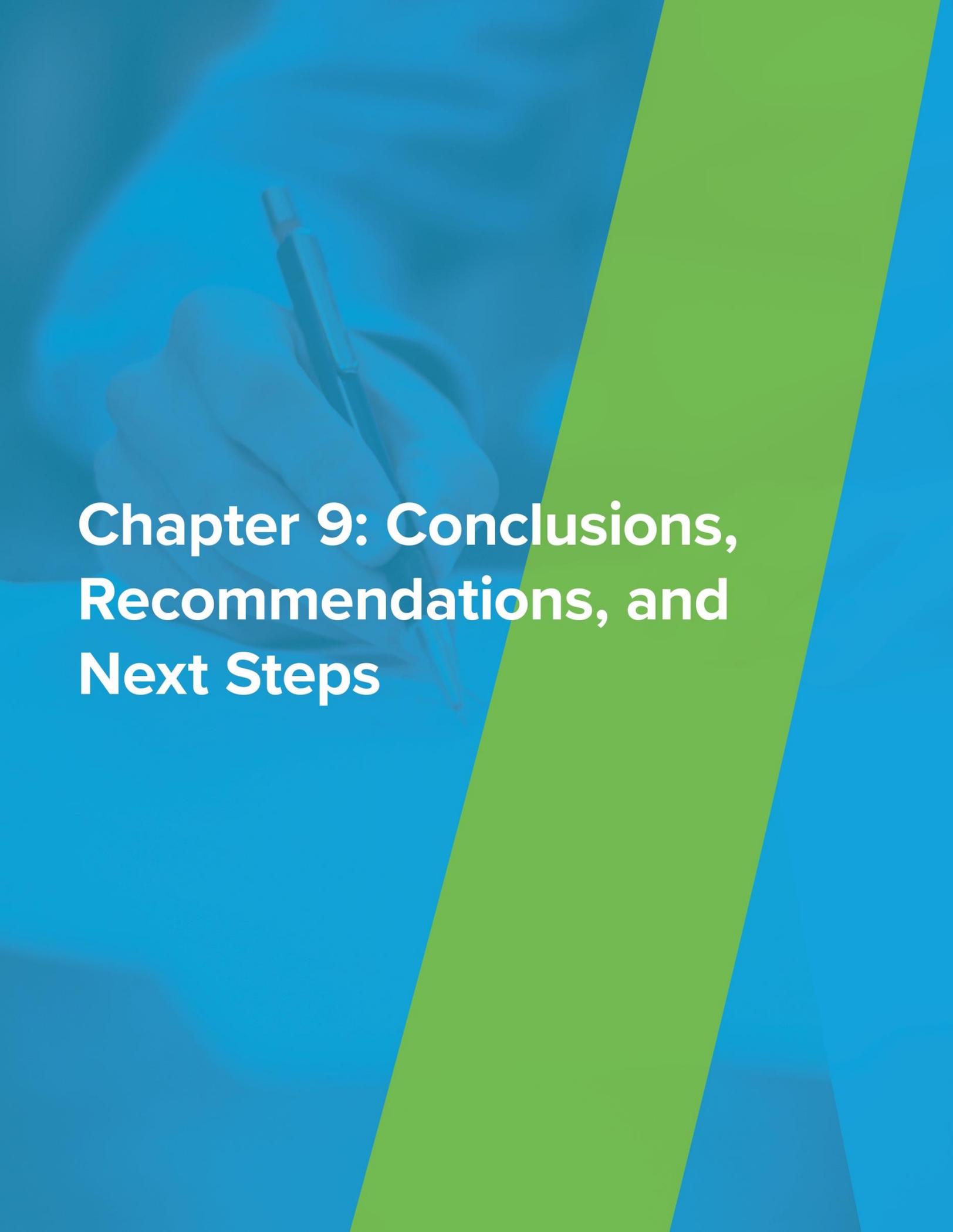
Here we offer recommendations for federal and local governments. Some are long-term goals and need consistent effort and investment. Some are near-term goals that are ready to adopt.

### *Long-term policy recommendations*

- Streamline the grants process at the federal and state levels. Distribute funding more efficiently and equitably.
- Offer federal and state tax incentives for resilience. See Appendix A for methods to estimate federal and state resilience savings, as a possible basis for setting incentives.
- Inform the public about the limited goals of the building code via a public-private partnership.

### *Near term, community pilot studies*

Either a federal government or a local public office would provide seed funding for pilot studies. See Chapter 9 for the potential pilot program plan.

The image features a background of a hand holding a pen, writing on a document. The scene is overlaid with a blue and green geometric design. A large, solid green diagonal shape runs from the top right towards the bottom left. The rest of the background is a solid blue color. The text is white and positioned in the lower-left quadrant of the image.

# **Chapter 9: Conclusions, Recommendations, and Next Steps**

## Chapter 9: Conclusions, Recommendations, and Next Steps

*Mitigation saves, but not in proportion to each stakeholder's expense.* Disaster resilience can make great financial sense at the societal level, saving far more than it costs. But because only some of the benefits accrue to current owners, many do not do it. For example, retrofitting an average existing house to prevent basement flooding can cost \$5,000. Doing so saves society more than it costs in places with at least a 1 in 100 chance of basement flooding per year. It saves up to 13 times the cost in the highest hazard locations. But so much of the benefit goes to other people, such as the lender and governments, that spending the \$5,000 only makes financial sense to the homeowner at much higher hazard levels.

*Co-beneficiaries can help owners to undertake resilience.* Resilience provides benefits to several stakeholders other than the owner: insurers, lenders, governments, and others. If these co-beneficiaries offer monetary and psychological incentives to help owners implement mitigation, more will do it and everybody wins. In the example \$5,000 basement-flood retrofit, lenders and governments would save money in the long run by offering a total of \$3,300 in incentives anywhere with at least a 1 in 100 chance of basement flooding per year. If they did, homeowners would end up paying only \$1,700 for the retrofit and save more than they pay in both moderate- as well as high-hazard locations.

*This roadmap shows how.* With support from Fannie Mae, the National Institute of Building Sciences has developed a roadmap toward creating and implementing these incentives, including a conceptual resilience certification program and three possible pilot studies. Several organizations have developed rating systems for other perils, especially earthquake and wind, but not yet flood.

### Candidate programs for a pilot test

This work has sought to advance the development of incentives whereby multiple co-beneficiaries help a building owner pay to add resilience to a building. It is important to note that we do not mean one co-beneficiary, such as the insurer, urging a homeowner to take action. We mean multiple co-beneficiaries--government and businesses – all reinforcing the same clear message and providing clear incentives for the owner to increase the building's resilience in specific ways with clear tasks, relatively predictable costs, and the work done by people qualified to carry it out.

We conjecture that such a program would bring about more mitigation, enough to make a difference in a community's, or the country's, resilience. We recommend testing that conjecture with a pilot study to take place in one willing community where most or all of the players can be convened to implement the incentives.

A pilot study could involve as many of the existing approaches to incentivization as can be practically coordinated: government grants, insurance premiums that accurately reflect risk, and consumer advice. It could also include new experimental incentives. The table below suggests three such

experimental incentives. The rows show the role for each stakeholder in the new incentive. Some stakeholders have no obvious role in some of the new incentives, but we will recruit leaders from these groups to suggest a role that we do not currently see. The table does not show psychological incentives discussed in Chapter 2, but these would be included as well.

### Three possible pilot programs

Program	1. Trade development impact fees for resilience	2. Finance home equity loans (HELoans) for resilience	3. Tax relief for resilience
Description	Provide a framework to enable communities and developers reduce development impact fees in exchange for including resilience features in new homes	Allow government-sponsored entities, such as Fannie Mae, to purchase home equity loans that require borrowers to use the funds for resilience retrofits	Provide a range of tax incentives for specific resilience investments in new and existing houses
New construction or retrofit?	New construction	Retrofit	Both
<b>Principal stakeholder roles</b>			
Homeowner	Advice*	Homeowner commits to use home equity loan funds for specific resilience investments	Homeowner invests in specific resilience retrofits in exchange for tax credits
Developers	Developer commits to include specific resilience features in new homes in exchange for a reduction in development impact fees	Installs and verifies required resilience retrofits	Developer includes specific resilience features in new construction in exchange for tax credits
Government	Local government reduces development impact fees in exchange for commitment to include specific package of resilience features in proposed new homes	Regulatory review and approval of government-sponsored entities program	Federal government provides tax credits in exchange for approved resilience investment in either new or existing houses
Insurers	Risk-appropriate rates with pricing signal for mitigation action, share language of	Risk-appropriate rates with pricing signal for mitigation action, share	Risk-appropriate rates with pricing signal for mitigation action, share language of

	expert advice, share stories about others who did mitigation, and show solidarity with city leaders	language of expert advice and stories about others who did mitigation	expert advice, share stories about others who did mitigation, and show solidarity with bill sponsors
Portfolio lenders	Not necessary, but a cost-effective bonus if they pay for mitigation for underwater loans (basement flood: moderate to high hazard)	Not necessary, but a cost-effective bonus if they pay for mitigation for underwater loans (basement flood: moderate to high hazard)	Not necessary, but a cost-effective bonus if they pay for mitigation for underwater loans (basement flood: moderate to high hazard)
Securitizing lenders	Advice*	Offer government-sponsored entities - compliant home equity loans to borrowers	Advice*
Real estate agents	Highlight resilience features in real estate listings	Highlight resilience features in real estate listings when owner sells	Highlight resilience features in real estate listings
GSEs	Not necessary, but a bonus if they express expert advice, show solidarity with city leaders, and offer grants for low- and moderate-income owners whose loans they buy in light of their lower risk	Purchase home-equity loans from lenders that commit the borrower to retrofit, focusing on low- and moderate-income borrowers	Not necessary, but a bonus if they express expert advice, show solidarity with city leaders, and offer grants for low- and moderate-income owners whose loans they buy in light of their lower risk
Investors	Advice*	Advice*	Advice*
Engineers, architects, building officials, floodplain managers, other building professions	Create or improve technical guides. Define appropriate packages of resilience features. Perform, evaluate, and certify mitigation actions.	Create or improve technical guides. Define appropriate packages of resilience features. Perform, evaluate, and certify mitigation actions.	Create or improve technical guides. Define appropriate packages of resilience features. Perform, evaluate, and certify mitigation actions.

*\* We will recruit leaders from these groups to provide advice. They may see opportunities for their groups to participate that we do not.*

We envision a six- or 12-month schedule in which the players turn the ideas proposed here into contracts or other tangible, implementable incentives. This is followed by 12 months during which the players offer the incentives and try to persuade property owners to take advantage of them. The program can be deemed a success if many people retrofit their houses, and more successful the more people do it.

## Pilot test tasks

1. ***Project kickoff plenary meeting.*** Convene leaders from professional societies, trade organizations, and others in the public and private sectors at a plenary kickoff meeting to elucidate project goals, organization, timelines, and ultimate deliverables, and to allocate attendees and proxies into working groups.
2. ***Working groups draft incentive documents and direct the development of online training programs.*** Working group leaders will convene their groups separately in a series of meetings to agree on guideline objectives and scope, identify existing relevant resources, outline their incentives, draft and review them in possibly several increments, and plan their rollout to the community. One or more working groups can collaborate to develop technical guides and checklists like those suggested in Appendix C. Many of the working groups may call for development of a training program. See sections 2.6, 7.8, and 8.6 for detailed tasks for several working groups. A coordinating group will ensure compatible language and common resources between groups.
3. ***Rollout plenary meeting.*** Project participants will meet to ratify the incentives and initiate the pilot rollout.
4. ***Implementation.*** Implement the incentives in a 12-month pilot. Success will be measured in terms of the number of mitigation projects undertaken using the incentives and characterized by the feedback of the people who undertake, or decline to undertake, mitigation using the incentives. Working groups and mitigation project leaders will check in halfway through the pilot rollout to discuss progress on guideline uptake and identify and address emergent issues.
5. ***Wrap-up.*** At the end of the pilot, it is essential to summarize findings, characterizing the number of completed (or likely to be completed) projects, what worked, what did not work, and what might help to improve the program for future application; and publish the incentive guideline documents and publish a short summary of the project findings. Depending on the success of the pilot and availability of resources, additional work may be performed to disseminate and institutionalize the incentives, such as providing webinars and establishing a long-term effort to maintain, disseminate, or further develop the incentive guideline documents and data.

## Pilot test participant candidates

Exactly which leaders should be convened for a pilot study?

1. ***Lenders and investors:*** The authors recommend reaching out beyond GSEs. Real estate investment management firms exist that have expressed a commitment to global sustainability. Those firms have individual executives who have taken personal public responsibility for making good on that commitment.
2. ***Government agencies:*** the White House Council on Environmental Quality, the Federal Emergency Management Agency, and other agencies. The authors recommend reaching out

beyond federal agencies to local governments, particularly to prominent cities with a climate action plan, and to the individual city officers charged with carrying out those plans. Not just any city will do: for a pilot to mean anything to other cities, the pilot community must resemble many other U.S. cities in terms of the hazard they face and the resources they can dedicate to incentivization.

3. **Insurers:** Recruit insurers who prioritize resilience as a corporate mission and have a focus on flood insurance. Many U.S. insurers have committed to promoting their clients' resilience as a public good and for business reasons, and they charge certain groups and executives within their corporate structure with carrying out that mission.
4. **Developers:** Recruit leading partners in development companies that are known to make resilience a centerpiece of their development strategy. Again, to carry out a successful pilot will require careful selection of the developer. Not just any convenient or familiar developer will do. Partner with companies that are already committed to resilience and those executives within those companies who are already helping to lead their efforts.
5. **Real estate agents and brokers:** Partner with leaders within real estate professional societies who have personal responsibility and a track record advancing disaster resilience.

## Develop a flood resilience certification program

The authors recommend the development of a flood resilience certification program starting with the technical guides in Appendix C, considering existing certification programs within professional societies. It might want to create a more exhaustive set of flood resilience technical guides and perform the additional benefit-cost analysis for them when developing such a program.

## Test conjecture that flood resilience has a market value

People pay for peace of mind in many ways. Tornado shelters added 4% to the resale value of homes in Oklahoma six years after deadly tornadoes struck nearby (Simmons and Sutter 2007). Storm shutters added 17% to the resale value of coastal houses (Simmons and Kruse 2000). California home buyers paid 17% more for seismically retrofitted older houses (Porter et al. 2022). And home buyers in coastal Alabama communities paid up to 25% more for houses with FORTIFIED Home Hurricane designation (Awondo et al. 2019). All of these figures greatly exceed the cost of the mitigation measure.

It seems possible that some home buyers will respond similarly to flood resilience features and pay more for a house that has them. If they did, that would turn flood mitigation from an option that merely avoids possible future losses into an investment that could more than pay for itself at resale. The pilot program could test that conjecture. If the test supports the conjecture, it could incentivize sellers to invest in mitigation and incentivize real estate agents to promote mitigation to their clients.

The National Association of Home Builders sponsored surveys of potential home buyers, asking how much extra they would pay for a new, code-compliant home that minimized losses from floods, earthquakes, and other disasters (Home Innovation Research Labs 2019a, b). In places with high or severe flood hazard (where mitigation matters the most), 50% of respondents who also perceived that risk said they would pay an additional \$5,000, enough to fully pay for the urban flood mitigation

measures detailed in Appendix A. Furthermore, 44% said they would pay at least \$7,500, and 23% said they would pay at least \$25,000. The authors found that respondents placed similar premiums on minimizing damage from earthquakes, hurricanes, and tornadoes in places with where they perceived a high risk of those hazards. Even in places where respondents did not perceive high flood hazard, 27% of respondents said they would pay at least \$7,500, and 14% said they would pay at least \$25,000.

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## Appendix A. Pricing financial incentives with benefit-cost analysis

### A.1 Why benefit-cost analysis matters and how to do it

*Does incentivization require a benefit-cost analysis?* Incentivization partly relies on the business case to the owner and other stakeholders (insurers, lenders, governments, and others) about how their interests align if the building owner undertakes some mitigation measure. Incentives mostly mean transferring money to the building owner to help pay for the mitigation. The money comes from the other stakeholders, the other people who enjoy a benefit if the owner undertakes the mitigation. (People sometimes call these other stakeholders “co-beneficiaries.”) People who design incentives will need to know how much benefit they enjoy.

*Benefits must be expressed differently to different co-beneficiaries.* Different co-beneficiaries think about their costs and benefits in different ways, so to speak with them clearly about incentivization requires using the terms they use regularly.

- Uninsured homeowners might think about the chance that they will avoid a loss during their ownership period, and whether a mitigation measure might at least partly pay for itself with a higher resale value.
- Insurers care about how a mitigation measure will change the frequency and severity of future claims, and want to know that the mitigation measure meets some objective, verifiable standard.
- Lenders may care about natural-hazard mitigation, but may have trouble finding a proven market for resilience products. Lenders have been slower to react to the need for physical risk mitigation and to the linkage between natural hazards and loan distress. For a few lenders, their corporate culture promotes making significant effort and expense to help borrowers. We suspect that if one can quantify loan-distress risk, show lenders that they face substantial risk, lenders will be more able to participate in incentivization. they will care about the chance of loan distress or default, and the severity of loss in case such a default occurs.
- Governments at many levels care about protecting constituents and need to know the value of doing so, perhaps in terms of annualized losses, numbers of constituents affected, how the mitigation measure benefits those constituents, whether other stakeholders also support mitigation, and perhaps other parameters.

*How to do a benefit-cost analysis.* Many engineering economics textbooks explain how to do benefit-cost analysis, e.g., Newnan et al. (2006). Multi-Hazard Mitigation Council (2019, 2020) offers several benefit-cost analyses of natural hazard mitigation. Details differ between applications, but there are two general patterns for benefit-cost analysis of natural-hazard mitigation:

1. The analytical approach. One creates a mathematical model with the four steps shown in Figure A-1: define the asset, calculate the hazard, characterize the vulnerability (i.e., the degree of harm given the occurrence or degree of the hazardous event, possibly as a function of a measure of the severity such as depth of flooding), and allocate the loss (who loses, how much). The loss analysis often requires one to estimate an average annualized loss and calculate its present value. One does this analysis twice: once without the mitigation measure, once with. The difference between the present value of loss without the mitigation measure and with the mitigation gives the benefit of mitigation,  $B$ . Divide the benefit by the cost to do the mitigation measure,  $C$ . The ratio is called the benefit-cost ratio,  $BCR$ .
2. The empirical approach. One compiles observations of past losses with and without the mitigation, and calculates an average or a weighted average of the two losses. The difference between the two is the benefit,  $B$ . Divide the benefit by the cost,  $C$ . The ratio is the benefit-cost ratio,  $BCR$ .

In either case, if  $BCR > 1$ , the benefit is bigger than the cost and the investment is desirable. The higher the benefit-cost ratio, the more desirable the investment. When it is used, benefit-cost analysis is often only one among many considerations in a financial decision.

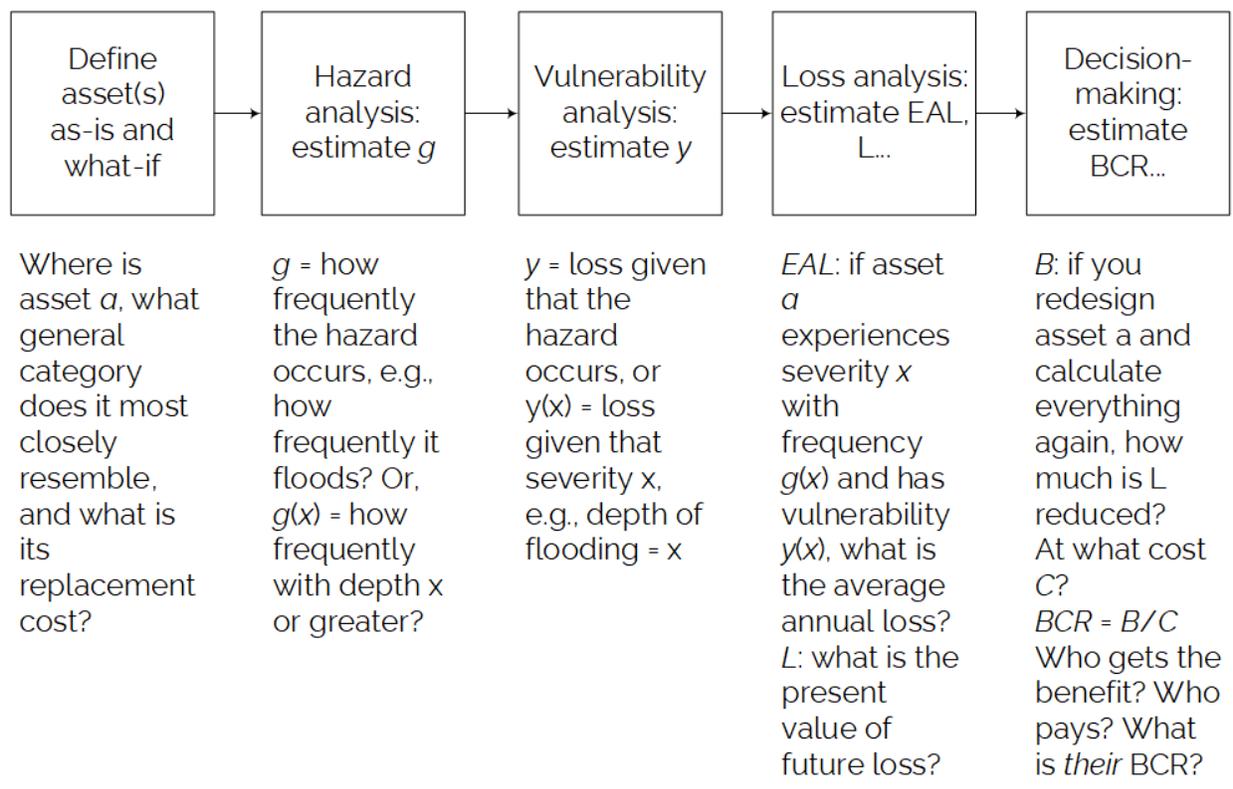


Figure A-1. General steps in an analytical benefit-cost analysis

## A.2 Choosing sample mitigation measures to illustrate incentivization

This appendix Chapter of the roadmap focuses on urban flooding, especially of houses that are outside the special flood hazard area, but are subject to damage from overland flow, called pluvial flooding. It offers guidance for hazard awareness and detailed guidelines for three mitigation measures that are mostly effective against inches, rather than feet, of flooding. Why illustrate incentivization with residential pluvial flood mitigation? Why not fluvial? The choice offers several pros and cons.

### Pros

1. To make the example relevant to a country, it seems wise to illustrate it with the natural hazard that causes the most frequent and most costly loss to that country. The Multi-Hazard Mitigation Council (2019) shows that flood is the leading cause of loss in US disasters on a long-term average basis. Flood represents the most frequent and costly source of US building loss. Hence flood risk mitigation.
2. Given the peril, to make the example relevant to the largest number of people, it seems wise to select a class of buildings that cause loss to the largest number of people. Houses represent the majority of the US building stock and the largest investment by most families. Hence residential flood risk mitigation.
3. Given the foregoing choices, to make incentivization useful for individuals, it seems wise to illustrate incentivization for the kind of mitigation measures that a large number of individual homeowners can afford and can choose for themselves. Pluvial rather than fluvial flood mitigation better fits those criteria: household-level actions costing hundreds or thousands of dollars, rather than a choice between household-level actions (e.g., elevation) costing tens of thousands of dollars and community flood-control measures costing millions of dollars. Hence residential pluvial flood risk mitigation.

### Cons

1. Unlike fluvial flood risk, we know little about the total value of pluvial flood risk. Few people buy insurance for it. What insurance data exist are tightly held by private insurers, who find it challenging to share loss data. But "poorly measured" is not the same as "small." New flood models suggest that US pluvial risk may exceed fluvial risk by some measures. With flood maps that include both pluvial and fluvial flooding, Wing et al. (2018) and Fathom Global (2023) estimate that 41 million Americans (12% of the U.S. population) face at least a 1-in-10 chance of flooding during a typical ownership period, a figure that is three times the 13 million figure estimated using (mostly fluvial) National Flood Insurance Rate Maps. Writing for one of the world's largest catastrophe risk modelers, AIR Worldwide, Jemberie et al. (2020) agree. Approximately 35% of single-family houses completed since 1971 in the U.S. and 21% of those completed in 2022 have a full or partial basement (U.S. Census Bureau ND, 2023). To America's north, the Insurance Bureau of Canada estimates that 6% to 10% of Canadian homes are currently uninsurable because of flood risk, and expect that estimate could rise. Is the entire difference of 28 million Americans attributable to pluvial flooding? Probably not. But even if those Americans at risk to pluvial flood are merely equal to those exposed to fluvial

flood, their side of the scale is loaded with private, mostly invisible harm that pose little threat to insurance companies or the federal government.

2. Even worse, addressing pluvial flood risk lacks the appeal of large, high-cost projects. Fluvial risk mitigation involves big, exciting projects to build levees, elevate or buyout thousands of houses, restore wetlands, and other efforts costing millions of dollars or more. Pluvial mitigation involves \$300 gutter downspout extensions, \$500 sump pumps, and wheelbarrows full of dirt moved to slope the soil the right direction way away from the house. Pluvial mitigation falls to individual homeowners to climb a learning curve without prominent teachers. They shoulder the cost themselves and hire contractors to do unfamiliar things that nobody is telling them to do. Fluvial mitigation by contrast makes big money for big contractors and saves the federal government bigger money. If flood risk mitigation were human health, fluvial mitigation would be blockbuster drugs, while pluvial mitigation would be diet and exercise.

The cons make incentives for pluvial flood mitigation seem less attractive, daunting, unprofitable, and boring. They suggest a challenge engaging potential supporters of incentives to promote pluvial flood mitigation. Who might care enough to participate?

***Mortgage holders and investors:*** banks, non-bank mortgage providers, and investment managers who are focused on the importance of resilience and physical risk mitigation as key to their investment decision making. those whose corporate culture predisposes them to help individual homeowners or who have already resilience as an investment goal.

1. ***Government agencies:*** those with a mission to help homeowners or to reduce disaster risk, such as the White House Council on Environmental Quality, the Federal Emergency Management Agency, and cities that have been recently struck by severe floods.
2. ***Insurers:*** those who already express a corporate mission to help their customers.
3. ***Developers:*** those who have adopted resilience as a market strategy. Several options exist.
4. ***Real estate agents and brokers:*** the National Association of Realtors has an advocacy group that offered congressional testimony to support FEMA's Risk Rating 2.0 (National Association of Realtors 2019). In that testimony, the association's selected speaker argued that "Our [flood] maps currently do not account for urban or future flooding, which makes it a challenge for property buyers, owners, renters and others to know where and how high to build or locate safely."

***This appendix provides three examples and calls for five more.*** Before the organization that leads an incentivization effort can implement incentivization in a real pilot community, say one that experiences frequent flooding, it might need to create a fairly exhaustive set of flood mitigation options. Box A-1 lists eight leading ways homeowners can reduce their flood risk and increase their home's value for themselves and for other stakeholders. The box draws on several sources: the recommendations for all houses come from the Institute for Catastrophic Loss Reduction's (2011) guidance on protecting homes from basement flooding. The other recommendations come from many sources but are summarized by the Multi-Hazard Mitigation Council (2019).

To roll out incentivization, the organization that leads an incentivization effort might need to create similar guides for the other five. Conceivably, it might have to create guides to include community flood mitigation measures like levees and stormwater systems, though these would have a different recipient for incentives, such as a flood protection district rather than a homeowner.

**Box A-1: Residential flood-risk resilience measures. All costs are approximate.**

All houses, especially those subject to pluvial flooding

1. **Side grading and downspout extensions:** Side grading means ensuring that the soil within 3 meters (10 feet) of the edge of the house slopes away from the house and drops at least 15 cm (6 inches). This costs on the order of \$3,000 to fix. Downspout extensions mean light metal or plastic tubes attached to the bottom of eavestrough downspouts that discharge water 1.8 meters away from the house and the neighbors' houses. This can cost \$300 to fix.
2. **Backwater valve:** for houses on streets with a combined sewer and stormwater system, a valve prevents water from flowing back from the sewer into the house. \$3,000 to fix.
3. **Sump pump battery backup:** for houses with a basement or slab-on-grade foundation, a battery-backup sump pump removes water from the sump pit and pumps it away from the house. \$1,000 to add battery backup.

Existing houses in a special flood hazard area ("fluvial flooding")

4. **Wet floodproofing.** In this retrofit, the homeowner or a specialty contractor removes damageable contents from the basement and changes basement wall openings to reduce hydrostatic pressure on the exterior walls that can allow floodwater to break basement walls. Doing so does not change the chance of water getting into the house, but it does reduce the loss when flooding occurs. In future development, the National Institute of Building Sciences can document best practices for wet floodproofing in collaboration with the Federal Emergency Management Agency, building professionals such as the Flood Mitigation Industry Association, and advocates for homeowners such as state hazard mitigation officers.
5. **Equipment elevation.** In this retrofit, a specialty contractor raises damageable equipment such as heat pumps, furnaces, and air conditioning units higher above the basement or ground level to reduce the chance that flood water will reach, contaminate, and damage the equipment. In future development, the National Institute of Building Sciences can document best practices for equipment elevation in collaboration with the Federal Emergency Management Agency, building professionals such as the Flood Mitigation Industry Association, and advocates for homeowners such as state hazard mitigation officers.
6. **Dry floodproofing.** Costs \$15,000 to fix on average. In this retrofit, a specialty contractor adds protection to the outside of a building including a waterproofing membrane and removable barriers at openings that prevent flood water from entering the building. Dry floodproofing is more commonly applied to non-residential buildings than to houses. In future development, the National Institute of Building Sciences could document best practices for dry floodproofing in collaboration with the Federal Emergency Management Agency, building professionals such as the Flood Mitigation Industry Association, and advocates such as state hazard mitigation officers.

7. **Building elevation retrofit.** Costs \$60,000 to fix on average. In this approach, a specialty construction contractor temporarily disconnects the home from its foundation, adds several feet of height to the walls between the foundation and the ground floor, and reconnects the house. Doing so raises the house relative to floodwaters and makes it less likely that water will reach the ground floor. In future development, the National Institute of Building Sciences can document best practices for building elevation in collaboration with the Federal Emergency Management Agency, building professionals such as the Flood Mitigation Industry Association, and advocates such as state hazard mitigation officers.
8. **Buyout.** Costs a reasonable market value for the house. In this approach, one removes the house and changes the land use to something that can tolerate flooding such as a park or wetland.
9. **Relocation.** Some buildings with substantial elevation differences within their parcel can be relocated within the parcel. We do not have a cost estimate for this action.

New houses

10. **Building elevation.** Build the house so that the first floor and all equipment are located 1.5 meters (5 feet) above base flood elevation. Adds on the order of \$5,000 to construction cost.

\* A 1-to-10 rating system

### A.3 Frequency of basement flood loss

Many US and Canadian homes are far enough from bodies of water that they are unlikely to experience flooding from water rising above banks or overtopping levees. But they can still be subject to rainwater falling on the house or in the neighborhood where the water cannot flow fast enough into rivers and stormwater systems, and instead flows into the house, especially into basements or parts of the house that are at or near grade level, either through openings in the wall near or below ground level, or by backing up from sewer lines into the house. The water contaminates basement floor and walls finishes, wets contents, and damages boilers, electrical panels, or other equipment in the basement.

How frequently does that occur?

The Insurance Information Institute (NDA) estimates that in recent years, the average insured homeowner has about a 1.6% chance per year of experiencing an insured loss due to water damage or and freezing. (Not all of these result in basement flooding; more below.) On the order of half of total catastrophe losses in the US are uninsured (Munich Re 2022), a proportion that can be larger in some catastrophes (CoreLogic Hazard HQ Team 2022). Taken together, and without better information, these two facts suggest that in recent years, the average homeowner has about a 3.2% chance per year of experiencing an insured or uninsured loss due to water damage and freezing.

It is unclear what fraction of these losses result in basement flooding in the U.S. Some hints exist. First Street Foundation (2020) estimates that 22 million properties in the U.S. face at least moderate risk of flooding, about 2.6 times the 8.5 million properties that the Federal Emergency Management Agency

estimates are currently located in a special flood hazard area, colloquially called the 100-year floodplain (The FinReg Blog 2021).

In Canada, about 1/10<sup>th</sup> of water and freeze events cause basement flooding (TruShield Insurance 2022), suggesting that the average homeowner has about a 0.32% chance per year of experiencing basement flooding. That number may seem small, but it amounts to about 3.2% in a 10-year ownership period, and that 1 in 5 U.S. houses with basements will experience a basement flood at least once in a 75-year building life.

**Hazard awareness.** Homeowners can learn whether their house faces a significant risk of flooding by examining publicly available resources. The National Weather Service provides some hazard information (see appendix B). The National Flood Insurance Program's online digital flood insurance rate maps (dFIRMs) show whether or not one lives in a special flood hazard area. RiskFactor (<https://riskfactor.com>) offers a free, nationwide, easy-to-access online source of US flood risk information that includes both flood frequency and severity, including addresses outside special flood hazard areas, along with projections of flood risk in the future, accounting for future climate change. The site offers a score called a flood factor that reflects the likelihood and severity of flooding (Figure A-2). Any house with a score above 1 could realistically experience at least 3 inches of flooding above ground level at the edge of the building footprint in the next 30 years. The score considers the location, elevation of the building footprint, current and future weather, the ownership period, and how flood risk will change over time because of climate change and sea level rise. The score does not distinguish between pluvial and fluvial flood risk, which would have to be accounted for in some other way. Nor does the risk score account for first-floor elevation, number of stories, square footage, building materials, price per square foot, and other parameters. But one can purchase a risk estimate from First Street Foundation that accounts for these parameters (\$100 per address as of this writing). For technical details, see First Street Foundation (2023a,b) and Bates et al. (2021). Note that flood risk will change over time. Wing et al. (2022) estimate that US flood risk will increase by 26% by 2050, as measured by average annualized losses, equivalent to about a 1% increase per year under representative concentration pathway 4.5.

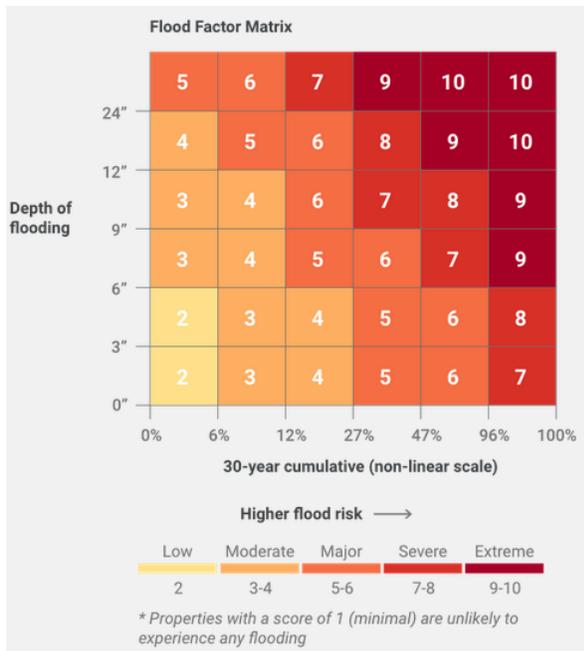


Figure A-2. Meaning of RiskFactor.com's Flood Factor (First Street Foundation 2023a, fair use claimed)

RiskFactor does not account for the slope of the soil next to one’s house. If the soil slopes toward the house, extreme precipitation in one’s yard and roof runoff can pool near the foundation. Let us consider extreme precipitation as a possible future second contributor to hazard. The National Weather Service offers tools described in Appendix B that do not seem ready for use in an incentivization program, but maybe with further development that could be used to quantify hazard for a pilot study. They are included there for completeness.

Let us treat basement flooding as an unpredictable event called a Poisson process that can occur over and over at any time with an average occurrence rate (also called frequency) that we can denote by the variable  $g$ . Let us treat the frequency of flood loss by considering a few homeowners, each of whom lives in a place where floods occur with a known value of  $g$ . Let us get that from a source like RiskFactor.com’s FloodFactor. Among other things, the FloodFactor relates to the 30-year probability of enough flooding to cause damage, say at least 3 to 6 inches, which is enough to get into a basement window or reach the sheetrock in the garage or cause a sewer backup. Under a Poisson process, we can estimate the probabilities as shown in Table A-1.

Table A-1. Treating flood mitigation through four flood hazard levels

FloodFactor	30-year probability of 3-6 inches flooding	Occurrence rate (events per year)	1-year probability
2	3%	0.001	0.1%
3	9%	0.003	0.3%

4	20%	0.01	1%
5	37%	0.02	2%
6	72%	0.04	4%
7	96%	0.11	10%
8	98%	0.13	12%
9	99%	0.15	14%
10	99.9%	0.23	21%

## A.4 Severity of basement flood damage

The National Flood Insurance Program (NFIP) offers a flood insurance calculator to estimate the cost of flooding to various depths, but does not offer a model of basement flooding; it seems only to model flooding to buildings at or above grade. The Hazus-MH flood module (Federal Emergency Management Agency 2011) uses depth-damage curves compiled from a variety of sources including the Federal Insurance and Mitigation Administration (FIMA) FIA credibility-weighted depth-damage curves, and selected curves developed by the U.S. Army Corps of Engineers (USACE), and the U.S. Army Corps of Engineers' Institute for Water Resources (USACE IWR). It focuses on riverine flooding, but includes a model of property damage to a 1,600-square-foot 1-story house with a basement, and 4 feet of basement flooding, with loss estimated to be 7% of building replacement cost. But the Hazus-MH developers (Federal Emergency Management Agency 2012) also report that claims data for basement flooding ranged between 7% and 15%.

Writing for Forbes, Abraham (2023) reports the average cost to build a new US house is about \$300,000. Multiplying that figure by the range of 7% to 15% just cited, the product means that a basement flood would cost on the order of \$21,000 to \$45,000, with the upper bound reflecting a fully flooded basement. Public Safety Canada (2022) suggests a figure near the middle of that range: about USD \$30,000. Miguelez (2021) suggests lower costs, between \$2,000 and \$7,000, depending on basement size and whether sewage enters the basement.

Let us parameterize basement flood damage through the cost to repair it, which we will denote by  $d$ . How shall we assign it a value? It seems possible to treat the repair cost as a random variable that can take on many possible values, but for simplicity, let us consider some sort of characteristic or typical repair cost. Let us take  $d$  from a middle level of the claims data reported by the Hazus-MH developers, 10%, times Abraham's (2023) average construction cost of \$300,000, producing what we will treat as a characteristic or typical value of  $d = \$30,000$ , which also agrees with the Canadian data. The \$300,000 house would correspond with a 2,000 square foot area and typical residential construction costs around \$150 per square foot.

## A.5 Homeowner benefit

How much do the mitigation measures in Box A-1 help a homeowner? Let us estimate the benefit primarily through the avoided property repair costs. Let  $f$  denote the fraction of loss  $d$  that basement flood mitigation prevents. Let  $t$  denote the duration over which the uninsured homeowner will enjoy a benefit from flood mitigation in terms of reduced future losses. We can take  $t$  as the average tenure of the homeowner if the flood mitigation is done by a previous owner or when the new homeowner buys the property, or half that tenure if the homeowner does the mitigation some time after buying the property. Let  $r$  denote the discount rate to reflect the time value of money, using the long-term average after-inflation cost of borrowing for a loan secured by the property.

The uninsured homeowner's expected annualized loss  $EAL$  is given by equation 1. The probability  $P$  that the owner experiences at least one basement flood loss during tenure  $t$  is given by equation 2. The present value of loss during the homeowner's tenure is given by equation 3. The present value of the reduction in property repair cost, denoted by  $B$ , is given by equation 4. In equation 4,  $f_i$  denotes the claim frequency after mitigation divided by the claim frequency before mitigation, and  $f_s$  denotes the claim severity after mitigation divided by the claim severity before mitigation.

$$EAL = g \cdot d$$

Equation 1

$$P = 1 - \exp(-g \cdot t)$$

Equation 2

$$L = EAL \cdot \frac{1 - \exp(-rt)}{r}$$

Equation 3

$$B = L \cdot (1 - f_i \cdot f_s)$$

Equation 4

How to assign values to the model variables? Let us take  $t = 10$  years for the average tenure. Let us consider two homeowners: owner 1 decides to mitigate halfway through his or her ownership period. Owner 2 does the mitigation at the time of purchase. Let us take a long-term average value of  $r = 0.02$ . To estimate the benefit  $B$ , let us assume  $f_i = f_s = 0.3$ , i.e. that implementing these mitigation measures reduces the frequency and severity of basement flood loss by about 2/3<sup>rd</sup>s. These seem like cautious, conservatively high values. The result of using them is that the benefit is about 90% of the pre-mitigation present value of loss. Their true value is probably lower, which would make the benefit greater.

With these quantities, we can evaluate equations 1 through 4. Table A-2 presents costs and benefits for uninsured homeowners. It also shows values for insurers, a lender for an uninsured home with an under-water mortgage, and several levels of government. The next several sections explain the calculations for those other stakeholders.

1. Uninsured homeowners who mitigate halfway through their ownership period
2. Uninsured homeowners who buy a previously mitigated house, or who do the mitigation at the time of purchase
3. An insurer
4. A lender for an uninsured home
5. Local, state, and federal governments

## A.6 Insurer benefit

The insurer's benefit is different from that of the uninsured homeowner. The insurer's discount rate can be better expressed as the after-inflation return on equity for capital that could otherwise be invested. The insurer of a mitigated property cannot be certain of insuring the property in the following year. Let  $p_1$  denote that probability, called the retention rate. It accounts for the chance that the insured will sell the property, so one can ignore the finite ownership tenure  $t$ . The insurer's expected annualized loss is also given by equation 1. Claim frequency is given by  $g$ , claim severity by  $d$ , as with the uninsured homeowner. Equation 5 gives the present value of loss,  $L$ , accounting for retention rate and the time value of money, and equation 4 again gives the benefit.

$$L = \sum_{i=0}^h EAL \cdot \left(\frac{p_1}{1+r}\right)^i$$

*Equation 5*

Let us take  $p_1 = 0.81$  and  $r = 0.06$ , from the Insurance Information Institute (NDA). In equation 5,  $h$  denotes the realistic remaining life of a house. One could take  $h$  as infinite, since  $p_1$  already accounts for the chance that the house will be demolished, and because the summand will approach zero long before  $i = h$ , with summands beyond about  $i > 10$  negligible anyway. But some readers will probably object to an infinite duration and demand an upper limit to  $i$ , so setting  $h$  to some realistic value such as  $h = 50$  does no harm.

## A.7 Lender benefit

Lenders may benefit from resilience through lower costs from distressed mortgages because borrowers have a lower chance of experiencing uninsured flood damage that they cannot afford to repair. Thompson et al. (2023) estimate that 2018 Hurricane Florence caused \$2.14 billion in insured and uninsured damages and property value reduction in North Carolina, plus \$562M in losses to

lenders and local governments because of mortgage default and abandonment, referring to the latter as cascading financial risk. They write that floods generally increase rates of mortgage delinquency, particularly in areas with lower levels of flood insurance uptake.

In 2017, Hurricane Harvey, the mortgage delinquency rate at flood-damaged properties in Houston increased by 205%. They offer a model of mortgage default in which the lender defaults with 100% probability when uninsured repair costs exceed the owner's equity. (This assumption simplifies modeling. Many borrowers perform when their loan to value ratio exceeds 100%.) The lender loses either the property repair cost plus the reduction in resale value (if the property value exceeds the uninsured repair cost), or the mortgage balance (if otherwise). If the uninsured repair costs exceed the property value, the local government bears the demolition costs. The model omits delinquency short of default and added management costs to the lender in that case. It also omits loss of tax revenue to the government and other indirect effects to the broader economy from economic contraction if people or businesses move away. In our experience, commercial catastrophe risk modelers have used similar assumptions to estimate mortgage default risk at least since 1990.

It might help in the present work to know that the U.S. national aggregate value of negative equity in the fourth quarter of 2022 was \$332 billion, and that 1.2 million mortgaged residential properties, about 2.1% of the total, had negative equity (CoreLogic 2023).

We propose to use a model similar to that of Thompson et al. (2023) to estimate the lender's benefit, but with two simplifications. First, let us assume a binary case of equity: either the homeowner has enough equity to pay for flood repairs, or has negative equity already and will default on the mortgage in the event of a flood loss. Second, let us assume that basement flood repair costs rarely exceed the value of the house, meaning a very low probability that a house with basement flooding will have to be demolished. The second assumption seems reasonable if the repair costs from basement flooding are typically on the order of \$30,000, as suggested above.

Let  $p_2$  denote the probability that the owner of any given home has negative equity, i.e., that the mortgage is underwater. Let  $n$  denote the average value of negative equity among underwater mortgages. Let us calculate the benefit to lenders under two situations: (1) where the homeowner's equity is unknown, and (2) where the mortgage is known to be underwater. Let  $t$  denote the weighted-average life of a mortgage and let  $r$  denote the lender's real return on its investment equity. Then equation 6 gives the lender's expected annualized loss for the situation where the borrower's equity is unknown. (It reflects zero loss for a borrower with nonnegative equity.) Equation 7 gives the chance of default during the life of the mortgage. For the situation where the mortgage is known to be underwater, one can use equations 6 and 7 with  $p_2 = 1$ . Then equation 9 gives the expected present value of loss and equation 4 gives the lender's benefit of mitigation.

$$EAL = g \cdot p_2 \cdot (d + n)$$

*Equation 6*

$$P = p_2 \cdot (g \cdot t \cdot \exp(-g \cdot t))$$

Equation 7

$$L = P \cdot (d + n) \cdot \frac{1}{t} \sum_{i=1}^t \frac{1}{(1+r)^{i-0.5}}$$

Equation 8

Equation 7 is different from equation 2 because at most one such default is possible for a given property during the  $t$ -year life of a mortgage. While a second flood is still possible, the next borrower will have positive equity and so a second default becomes extremely unlikely. Equation 2 gives the chance of one or more losses, while equation 7 gives the chance of one and only one loss. Equation 8 is different from equation 3 for the same reason.

Dividing nationwide negative equity by the number of underwater mortgages from CoreLogic (2023),  $n = \$270,000$  nationwide. Recall also that CoreLogic (2023) suggests  $p_2 = 0.021$ . Let us take the  $t = 5$  years for the weighted-average life of a mortgage, and the lender's average after-inflation return on equity as  $r = 0.02$ .

## A.8 Government benefit

Governments can lose money when home basements flood. FEMA's Individuals and Households Program provides grants to return one's house or apartment to a habitable condition after a presidentially declared disaster. Grants can reach up to \$33,000, and averaged \$8,016 after Hurricane Sandy in 2012 in current dollars, that is, without adjusting for inflation. The grants cover some repairs, temporary housing assistance, and some other needs. Everyone can apply, regardless of income level or whether they have flood insurance (Fitzpatrick 2022).

The Internal Revenue Services (2023) advises that one "may deduct casualty losses relating to one's home, household items, and vehicles on one's federal income tax return if the loss is caused by a federally declared disaster." Here, a casualty means a loss resulting from "the damage, destruction, or loss of one's property from any sudden, unexpected, or unusual event such as a flood, hurricane, tornado, fire, earthquake, or volcanic eruption." See also Tribunella and Tribunella (2018). Thus, the federal government loses tax revenues equal to one's marginal tax rate times the repair cost. The marginal federal personal income tax rate for a middle-income family is about 22% (Bird 2023).

State income taxes vary widely, from zero to 13%, with a variety of bracket structures. Colorado charges a flat tax of 4.4%. The median value of the top state personal income tax is about 5.8% (Rich States Poor States 2023).

Alonso and Sandel (2012) explain that despite sovereign immunity, local governments can be sued for basement flood losses if deficient sewer construction or maintenance caused the flooding. Saxe (2011) reports on a Canadian example: a successful class-action lawsuit against the city of Stratford, Ontario, which paid \$7.7 million in 2010 because of the city's negligence to address repetitive flooding.

Some cities offer support for remediation or reimbursement for flood damage caused by sewer backup. The City of Toledo Ohio (NDa) offers homeowners who have experienced basement flooding up to \$1,500 for remediation measures such as sump pumps and backflow valves. Lansing Michigan (NDa) offers a similar program and grants up to \$4,750. Under a consent decree, Baltimore, MD pays up to \$5,000 per dwelling unit to repair basement damage (Baltimore City Department of Public Works 2018). As discussed in chapter 8, several other northeastern cities offer grants of between \$1,000 and \$6,000 to promote basement flood protection; see Figure A-3."

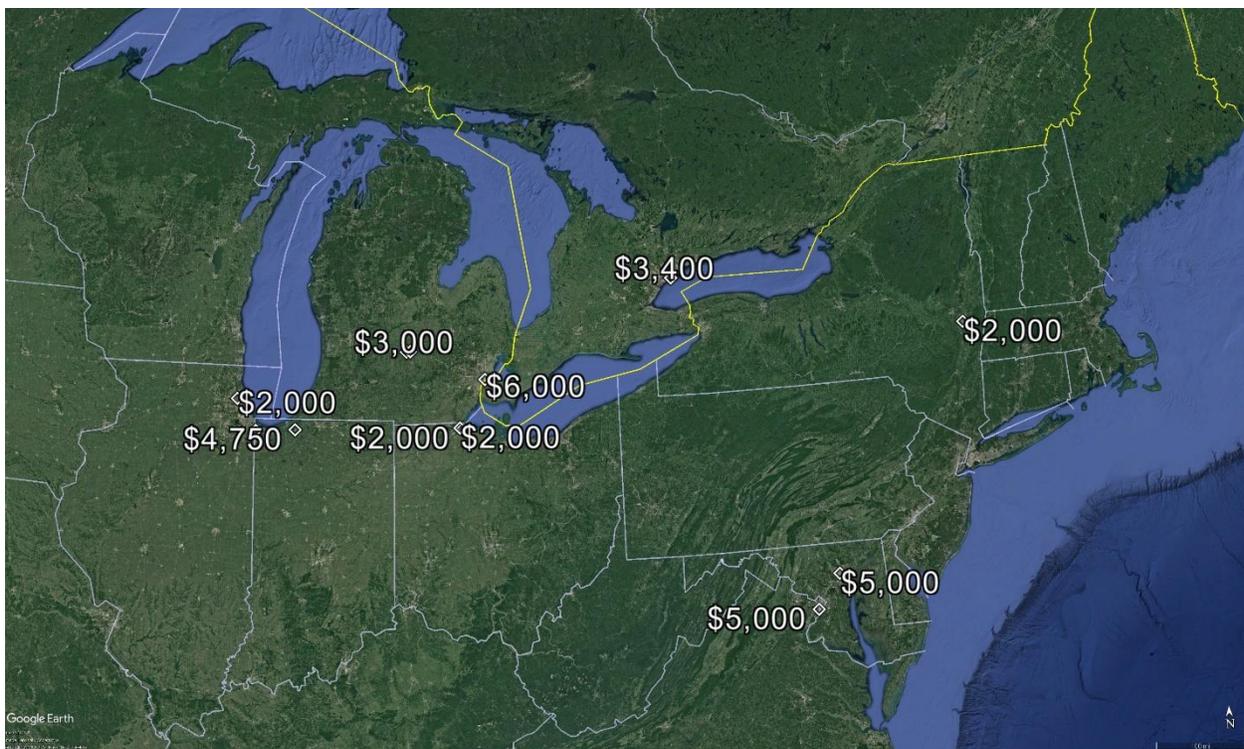


Figure A-3. Some city grants to promote flood protection, as listed in chapter 8

Let us estimate federal and state government losses in terms of reduced property tax revenues. Equation 9 gives their expected annualized loss of tax revenue from basement flooding, where  $a$  denotes the marginal income tax rate for the homeowner of the flooding building. Equation 10 gives the present value of that loss. It is different from equation 3 in that it includes a factor to account for geometric growth of flood frequency, because governments have a stake that lasts for the life of the property, which can be 75 years or more, and during which climate change could have a noticeable effect and one that is strong enough to offset the effect of discounting future losses.

$$EAL = g \cdot d \cdot a$$

Equation 9

$$L = EAL \cdot \left( \frac{1 - (1 + c)^h (1 + r)^{-h}}{r - c} \right)$$

Equation 10

Let us use state and federal tax rates as suggested above, say  $a = 0.06$  and  $0.22$ , respectively. Let us take flood occurrence frequency as increasing in proportion to Wing et al.'s (2022) estimate of the growth of risk, i.e.,  $c = 0.01$  per year. And let us take  $r$  as the government's after-inflation (real) cost of borrowing, about  $r = 0.02$  per year. This value is also consistent with considering that the largest source of federal revenue is personal income tax. The average homeowner's real return on investment, which taxes offset, is also about  $r = 0.02$  per year. Let us take  $h = 50$  years for a typical remaining life of a house.

Municipal costs are far more variable, apparently ranging from zero to several thousand dollars. If we take the examples of Toledo, Lansing, and Baltimore as indicative that in a hedonic sense some cities value the reduction of basement flooding between \$1,000 and \$5,000, let us imagine a middle case of a city that about \$3,000, let us take their average annualized loss from equation 1, with  $d = \$3,000$ , but equation 10 still gives the present value of loss.

## A.9 Summary of costs and benefits from basement flood mitigation

*Please see Appendix C, sections C.2.1, C.3.1, and C.4.1, the paragraphs labeled "cost," for details of the work involved in each measure, along with sources and citations for those estimated costs.* Table A-2 summarizes the benefits and costs of mitigating basement flooding using the three measures recommended by the Institute for Catastrophic Loss Reduction (2011) and the models and parameter values discussed above. Quantities in the table are rounded to reduce the appearance of excessive accuracy. See the bottom of the table for an example situation with the total cost, benefit, and benefit-cost ratio. In this example, a new owner retrofits the house at the time of purchase and does not buy flood insurance. See the notes that follow the table for advice on interpreting its contents. Benefits are limited here to the expected present value of avoided future losses.

Table A-2 shows results for three hazard levels: low, moderate, and high, where "hazard level" is defined in terms of the annual chance of basement flooding. One can estimate that chance by several means, but the simplest for present purposes is to get one's Flood Factor from the free online resource RiskFactor, at <https://riskfactor.com>. One enters a street address and the resource provides a number between 1 and 10 that expresses the likelihood of various combinations of flood depth frequency and severity, where 1 is good and 10 is bad. See Chapter 8 for the method used here to map from Flood Factor to hazard to hazard level.

Table A-2 shows benefits and costs for a typical case of basement flood mitigation: a 2,000-square-foot house with a basement. It shows the cost to repair a flooded basement and the costs to implement each of the three mitigation measures examined here. Then it shows the mitigation benefit and a few other relevant financial parameters for many of the co-beneficiaries discussed in Chapter 1:

- Owner 1 is an uninsured homeowner halfway through a 10-year ownership tenure
- Owner 2 is an uninsured homeowners who buys a previously mitigated home or who does the mitigation at the time of purchase, at the beginning of a 10-year tenure
- Future owners, from  $t = 10$  years in the future to 75 years in the future
- Insurers
- Lenders who do not know whether the mortgage is underwater (i.e., some chance that the borrower owes more on the house than it is worth)
- Lenders who know the mortgage is underwater
- Local government
- State government
- Federal government

Table A-2. Costs\* and benefits of basement flood protection for an existing 2,000-ft<sup>2</sup> house.

	Low-hazard location	Moderate-hazard location	High-hazard location
Annual chance of flooding (frequency)	0.1%	1%	10%
Chance of flooding in 10 years	1%	10%	63%
FloodFactor ( <a href="https://riskfactor.com">https://riskfactor.com</a> )	2	4	7
Basement flood repair cost	\$30,000		
Cost of side grading and downspouts (see Appendix C.2.1, the paragraph labeled costs, for sources and citations)	\$3,500		
Cost of side grading and downspouts (see Appendix C.3.1, the paragraph labeled costs, for cost sources and citations)	\$3,000		
Cost of battery backup sump pump (see Appendix C.4.1, the paragraph labeled costs, for cost sources and citations)"	\$1,000		

		Low-hazard location	Moderate-hazard location	High-hazard location
Total retrofit cost per house		\$1,000-\$7,500		
Owner 1: uninsured, halfway through a 10-year tenure, 2% after-inflation cost of borrowing	Chance of a loss during tenure	0.5%	5%	41%
	Present value of loss without mitigation	\$140	\$1,400	\$14,000
	Benefit	\$130	\$1,300	\$13,000
Owner 2: uninsured, beginning a 10-year tenure, 2% after-inflation cost of borrowing	Chance of a loss during tenure	1%	10%	65%
	Present value of loss without mitigation	\$250	\$2,500	\$25,000
	Benefit	\$220	\$2,200	\$22,000
Insurer, 81% retention ratio indefinitely, 6% after-inflation return on investment	Claim frequency without mitigation year <sup>-1</sup>	0.1%	1%	10%
	Claim severity without mitigation	\$30,000	\$30,000	\$30,000
	Present value of loss without mitigation	\$130	\$1,300	\$13,000
	Claim frequency with mitigation year <sup>-1</sup>	0.03%	0.3%	3%
	Claim severity with mitigation	\$9,000	\$9,000	\$9,000

		Low-hazard location	Moderate-hazard location	High-hazard location
	Present value of loss with mitigation	\$20	\$200	\$2,000
	Benefit	\$110	\$1,100	\$11,000
Lender 1: 5-year weighted average life of a mortgage, unknown equity, 2% after-inflation return on investment	Probability of loan default	0.01%	0.1%	0.6%
	Present value of loss without mitigation	\$30	\$290	\$1,800
	Benefit	\$27	\$260	\$1,600
Lender 2: 5-year weighted average life of a mortgage, under-water mortgage, \$270,000 negative equity, 2% after-inflation return on investment	Probability of loan default	0.5%	4.8%	30%
	Present value of loss without mitigation	\$1,400	\$14,000	\$87,000
	Benefit	\$1,300	\$12,000	\$78,000
Local government, \$3,000 hedonic value to avoid basement flood, 50-year planning period, 1% annual increase in flood frequency, 2% after-inflation discount rate	Expected annualized loss	\$3	\$30	\$300
	Present value of loss without mitigation	\$120	\$1,200	\$12,000
	Benefit	\$110	\$1,100	\$11,000
State government, 6% marginal tax rate, 2% after-inflation discount rate, 50-year planning period, 1% annual increase in flood frequency	Expected annualized loss	\$2	\$18	\$180
	Present value of loss without mitigation	\$70	\$700	\$7,000
	Benefit	\$63	\$630	\$6,300

		Low-hazard location	Moderate-hazard location	High-hazard location
Federal government, 22% marginal tax rate, 50-year planning period, 1% annual increase in flood frequency	Expected annualized loss, \$	\$7	\$66	\$660
	Present value of loss without mitigation	\$260	\$2,600	\$26,000
	Benefit	\$230	\$2,300	\$23,000

\*Mitigation costs are documented and detailed in sections C.2.1, C.3.1, and C.4.1

Some notes about the table: Costs and benefits can vary significantly, but to simplify communication, the table shows realistic central values, not necessarily average, but neither particularly high nor low within the range of possible values.

Benefits in the table do not sum, for several reasons. For one, a homeowner is either insured, in which case the insurer enjoys the benefit and the homeowner does not, or the reverse. The homeowner is either halfway through the average ownership period or has just begun it, but not both. The mortgage holder may know whether the mortgage is underwater or the mortgage holder may not know. One part of the table reflects the former case, another, the latter. Unlike the other stakeholders, mortgage holders face the possibility of an extra loss associated with market volatility because of an underwater mortgage.

The time windows of the different stakeholders differ: 5 or 10 years for the two homeowners, an indefinite time but reducing probability over time for the insurer, 5 years for the two mortgage holders, 50 years for the governments.

Some stakeholders are omitted: all the other homeowners after the two listed in the table; people who run their business out of their home; people who rent an accessory dwelling unit; the tenants of that accessory dwelling unit; and others.

And finally, we have not reduced the homeowner's losses to account for their tax deduction. One must draw lines like these between what to include, what to omit, and how far to carry the calculations, for the sake of brevity and clarity.

Figure A-3 shows just the mitigation cost (assuming a middle cost of \$5,000) and the expected present value of the benefits to each of the stakeholders considered here. In the figures, "Lender 1" is the mortgage holder who does not know the equity of the mortgage, or rather the mortgage holder who is considering mitigation benefits for any borrower without regard to equity. Lender 2 is the mortgage holder who knows the mortgage is underwater, e.g., by comparing the current loan

balance with the current estimated market value, such as that estimated by Zillow. “Gov” is short for government.

The figures show that basement flood mitigation makes the most sense at a high-hazard location and just about breaks for society even at a moderate-hazard location, assuming a \$5,000 retrofit cost and various other simplifying assumptions. The figures are meant to inform incentivization decisions by co-beneficiaries, but they do not presuppose particular incentives are already in place such as lower insurance costs.

They also clearly show the big winner: the holder of underwater mortgages, because of the reduced chance of mortgage default. This is not to say that people do not default for other reasons. The mortgage holder benefits calculated here are solely those associated with default resulting from costly basement flooding from which the uninsured homeowner cannot afford to recover.

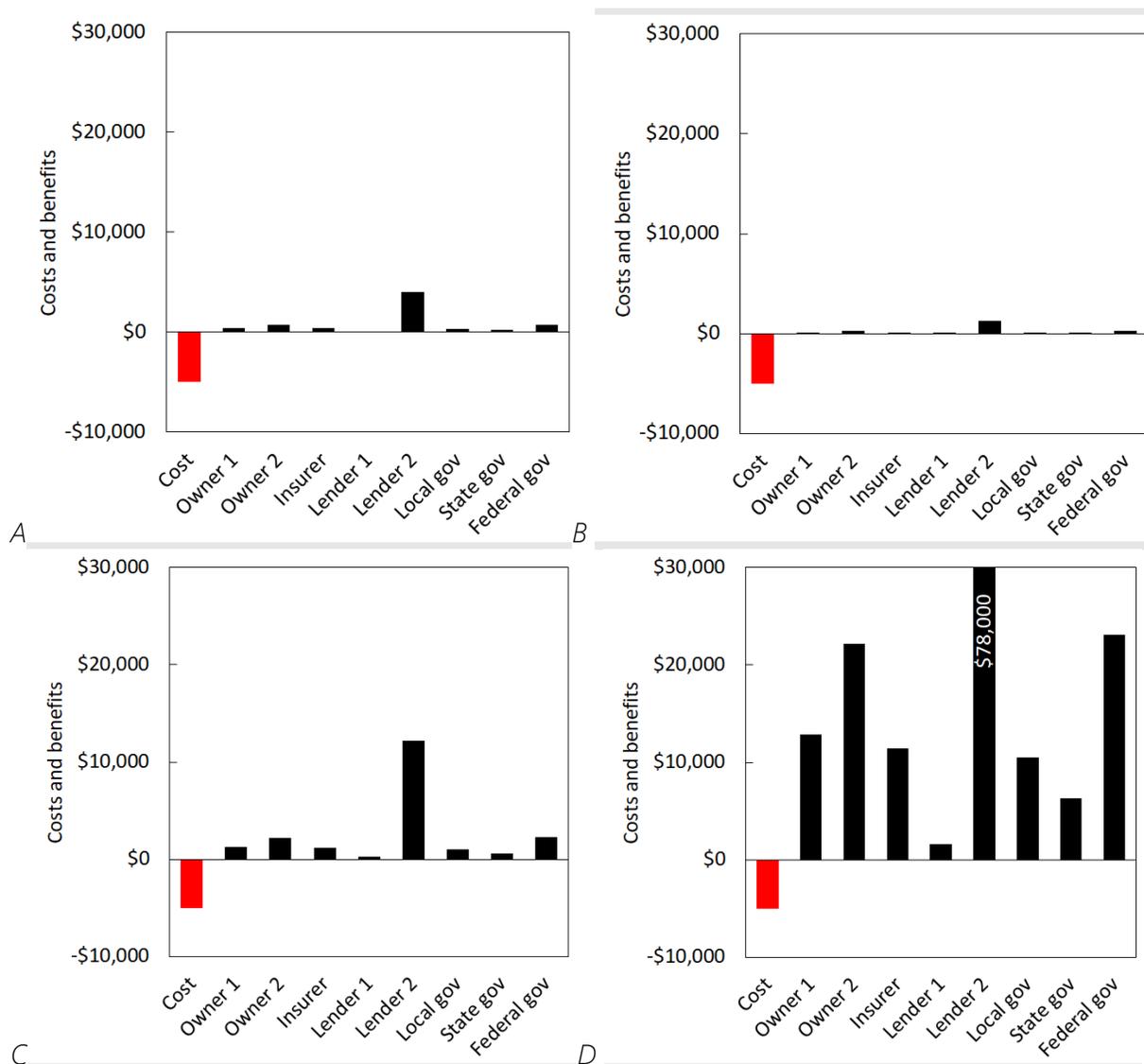


Figure A-3. Cost (red bar) and benefits (black bars) for every stakeholder in: A. average-hazard location, B. low hazard, C. moderate hazard, and D. high hazard. These stakeholders do not all play a role in a single decision situation.

Figure A-3 shows benefits to different stakeholders in different situations. There is no decision situation that includes both owner 1 and owner 2, or with both lender 1 and lender 2, or with owner 2 and lender 2. What might a real decision situation look like, and how might one price the incentives appropriately?

Table A-3 illustrates one possible incentivization situation: a new homeowner buys a house outside the special flood hazard area and opts to do the mitigation but not buy insurance. The mortgage holder offers a \$200 credit on the points (perhaps in the form of a pass-through from the GSE mortgage holder). The local government offers an \$800 grant, and the state and federal governments offer \$500 and \$1,700 tax credits. The amounts could be different.

The total shows the total costs and benefits to the mortgage holder and governments with incentivization, and the homeowner in two situations: without incentives and with incentives. It shows a societal benefit-cost ratio that one calculates by dividing the total societal benefit by the retrofit cost.

From a societal viewpoint, the retrofit saves more than it costs in moderate and high-hazard locations, i.e., anywhere with at least 1 in 100 risk of basement flooding in a year. At moderate and high-hazard locations, the *societal* benefit-cost ratio is 1.3:1 and 13:1 respectively. Cells with benefit-cost ratios above 1.0 are shaded green; below 1.0, red.

The table also shows a hypothetical incentive pricing structure that would produce the same benefit-cost ratio to each stakeholder that one gets. For example, it shows that the mortgage holder, state, and federal governments could provide \$200, \$500, and \$2,000 incentives respectively to anybody with an annual risk of basement flooding of at least 1 in 100. Providing such an incentive would save the mortgage holder and the governments money in the long run.

Figure A-4 shows the costs and benefits to the stakeholders in this particular decision situation.

Note that the retrofit makes sense from a societal viewpoint for moderate and high hazard situations, but without incentives, homeowners pay more than they save in the moderate-hazard situation (benefit-cost ratio = 0.4). In the high-hazard situation homeowners only get a benefit-cost ratio of 4:1, rather than the societal 13:1. With incentives, the homeowner has a net cost of \$1,700 instead of paying \$5,000 and has a benefit-cost ratio above 1.0 for both moderate and high-hazard situations, with a benefit-cost ratio as high as 13:1.

Table A-3. Using benefit-cost analysis to price incentives: owner 2 + mortgage holder 1 + governments

		Average hazard	Low hazard	Moderate hazard	High hazard
Retrofit cost		\$5,000	\$5,000	\$5,000	\$5,000
Total societal benefit		\$2,100	\$650	\$6,500	\$64,000
Total societal benefit-cost ratio		0.41	0.13	1.3	13
Mortgage holder 1	Incentive	\$200	\$200	\$200	\$130
	Benefit	\$85	\$30	\$260	\$1,600
	BCR	0.4	0.1	1.3	13
Local gov	Incentive	\$810	\$810	\$810	\$810
	Benefit	\$340	\$110	\$1,100	\$11,000
	BCR	0.4	0.1	1.3	13
State gov	Incentive	\$490	\$490	\$490	\$490
	Benefit	\$200	\$63	\$630	\$6,300
	BCR	0.4	0.1	1.3	13
Federal gov	Incentive	\$1,800	\$1,800	\$1,800	\$1,800
	Benefit	\$740	\$230	\$2,300	\$23,000
	BCR	0.4	0.1	1.3	13
	Cost	\$5,000			

Owner 2 <i>without</i> incentives	Benefit	\$710	\$220	\$2,200	\$22,000
	BCR	0.1	0.04	0.4	4.4
Owner 2 <i>with</i> incentives	Total incentive	\$3,300			
	Net cost	\$1,700			
	Benefit	\$710	\$220	\$2,200	\$22,000
	BCR	0.4	0.1	1.3	13

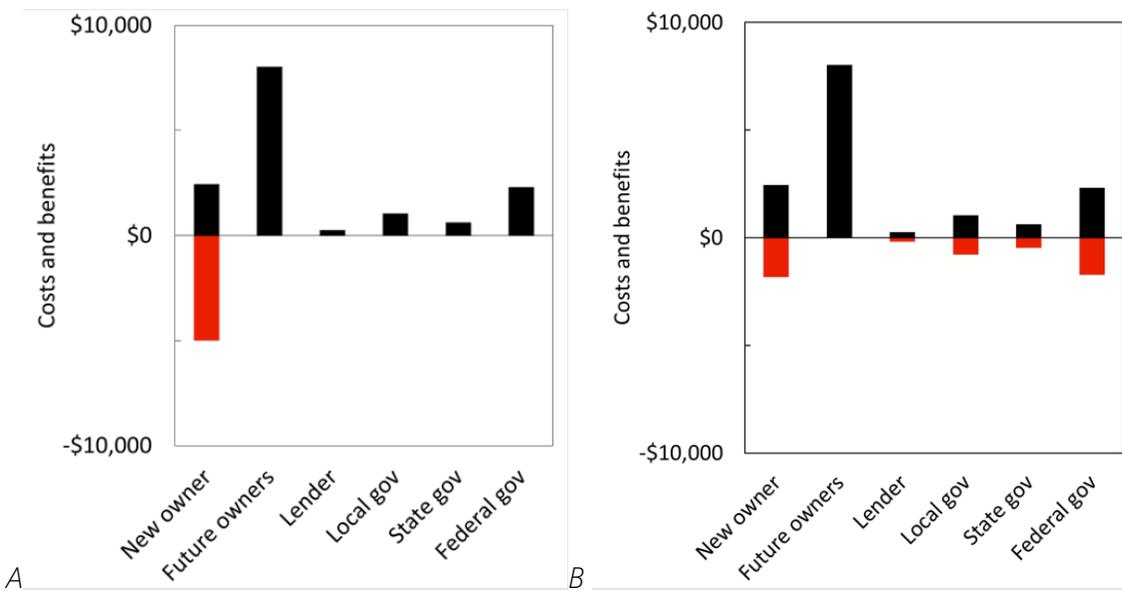


Figure A-4. Costs and benefits in a decision situation with owner 2, lender, and governments: A. moderate hazard, without incentives and B. moderate hazard, with incentives. Notice how at moderate hazard, even though the societal benefit-cost ratio is above 1, without incentives the investment does not make sense to the owner on a benefit-cost basis. With incentives, the owner's net cost drops from \$5,000 to \$1,800 and the investment provides a benefit-cost ratio over 1.0.

## A.10 Benefit-cost analysis of other flood mitigation measures

Because this document is only a roadmap, and because this appendix is intended only to illustrate how to do benefit-cost analysis for one group of flood mitigation efforts, we do not offer benefit-cost analysis for flood mitigation of houses in special flood hazard areas or other buildings or other perils.

But one could do so. See Multi-Hazard Mitigation Council (2019) for benefit-cost analysis of several of the other mitigation measures in Box A-1.

Buildings near rivers and lakes can face flood risk when the water rises above their banks (called riverine or fluvial flooding). One can protect existing homes by elevating them (raising the first floor higher above base flood elevation), by wet floodproofing (removing damageable furnishings and finishes from basements), and by elevating boilers, ductwork, and other equipment. For an extreme solution, but one that often makes sense, governments sometimes buy all the houses in a frequently-flooding area and remove them from land. The government then changes the land use to something less costly when it floods, such as parkland or wetlands.

Buildings near coastlines are subject to coastal flooding from high tides, storm surge, and sea level rise. One can protect existing houses from coastal flooding by elevating it higher above sea level, e.g., on stilts, and ensuring that any ground-level walls are designed to collapse without damaging the building.

New buildings can be better protected from riverine or coastal flooding by building them higher above base flood elevation. Multi-Hazard Mitigation Council (2019) showed that it can be cost-effective to build new buildings five feet above base flood elevation (in the case of riverine flood hazard) or eight feet above base flood elevation (in the case of coastal flooding). It is unclear what effect the subsequent development of Risk Rating 2.0 has on those findings.

### A.11 Financial considerations beyond benefit-cost analysis

Financial decisions involve more than benefit-cost ratios. Even when decision-makers consider benefits and benefit-cost ratios in disaster risk management investments, their decision context usually involves many other considerations, such as:

- Available resources: do they have the money to spend on mitigation?
- Business practices: do their accounting practices normally consider uncertain future expenses? Is there a person responsible for risk management?
- Corporate culture: does the organization care about the wellbeing of the people with whom it does business? Does it critically examine and manage its risk?
- Catastrophe risk: does the property or the peril represent an existential threat to the business' viability? Do regulations require catastrophe risk management?
- Various emotional and informational considerations: how uncertain are they about what work needs to be done, whether experts agree that it ought to be done, how likely the investment is to pay off, what other people have done, and so on. The present report addresses many of these issues.

## Appendix B. Other weather hazard information

### B.1 National Weather Service rainfall intensity hazard

The homeowner can check the National Weather Service's estimate of rainfall intensity by looking at <https://hdsc.nws.noaa.gov/hdsc/pfds/>. Click on the map to select the state (Figure B-1), then move the crosshairs to the city in question (Figure B-2). City is close enough; one does not need to know the exact latitude and longitude. Look at the table below the map. Look at the row labeled "60 min." Look at the numbers in that row in the columns labeled 1 (year) and 10 (years), as in Figure B-3. If the bold number in the table for 60 minutes (the row) and 1 year (the column) is at least 1.0, that means it rains at least 1.0 inches in per hour on average every year. Let us refer to that as a high precipitation hazard. If the value in the 1-year column is below 1.0 by the number in the 10-year column is above 1.0, that means that it rains at least 1 inch per hour at least once in 10 years, but not every year. Let us refer to that situation as a moderate precipitation hazard.

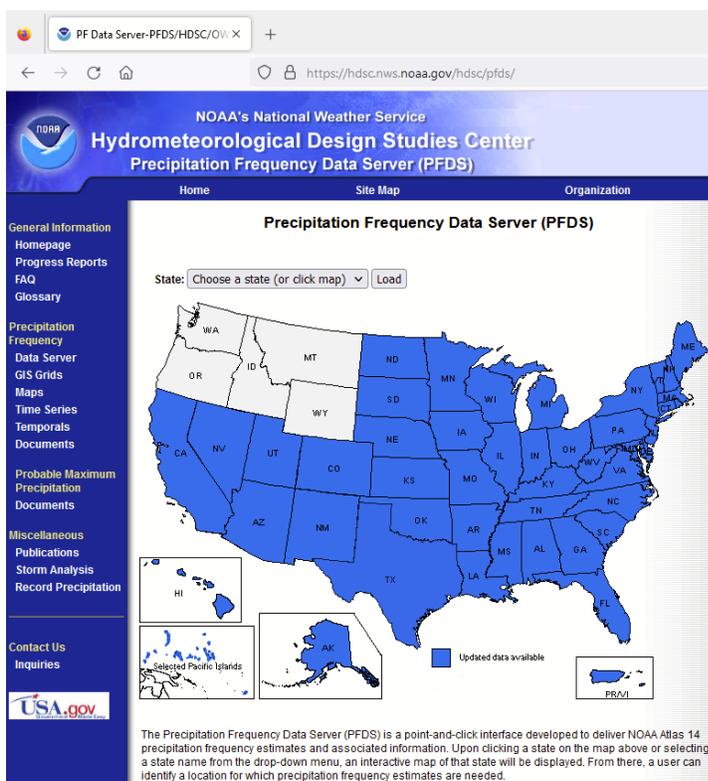


Figure B-1. Use the US National Weather Service website to find your hazard level in your state

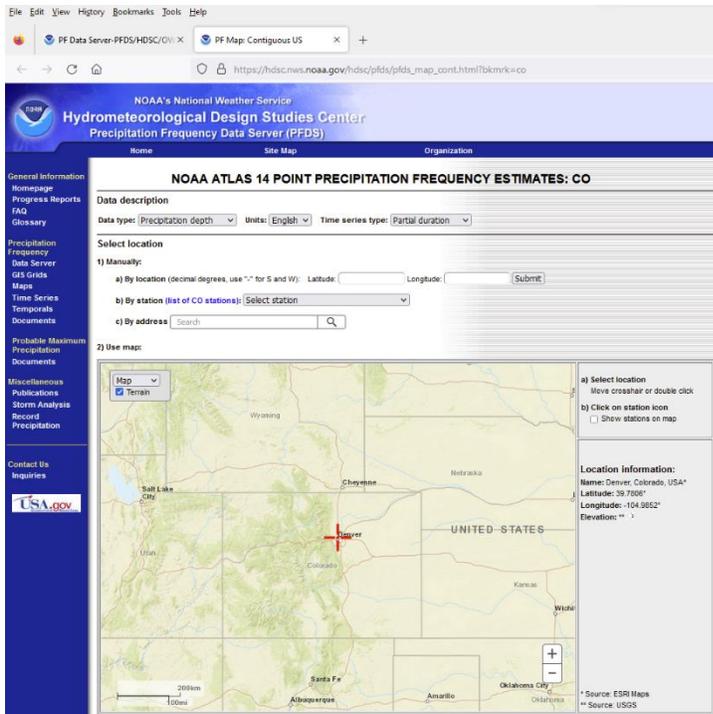


Figure B-2. Once you have chosen your state, get the hazard level in your city

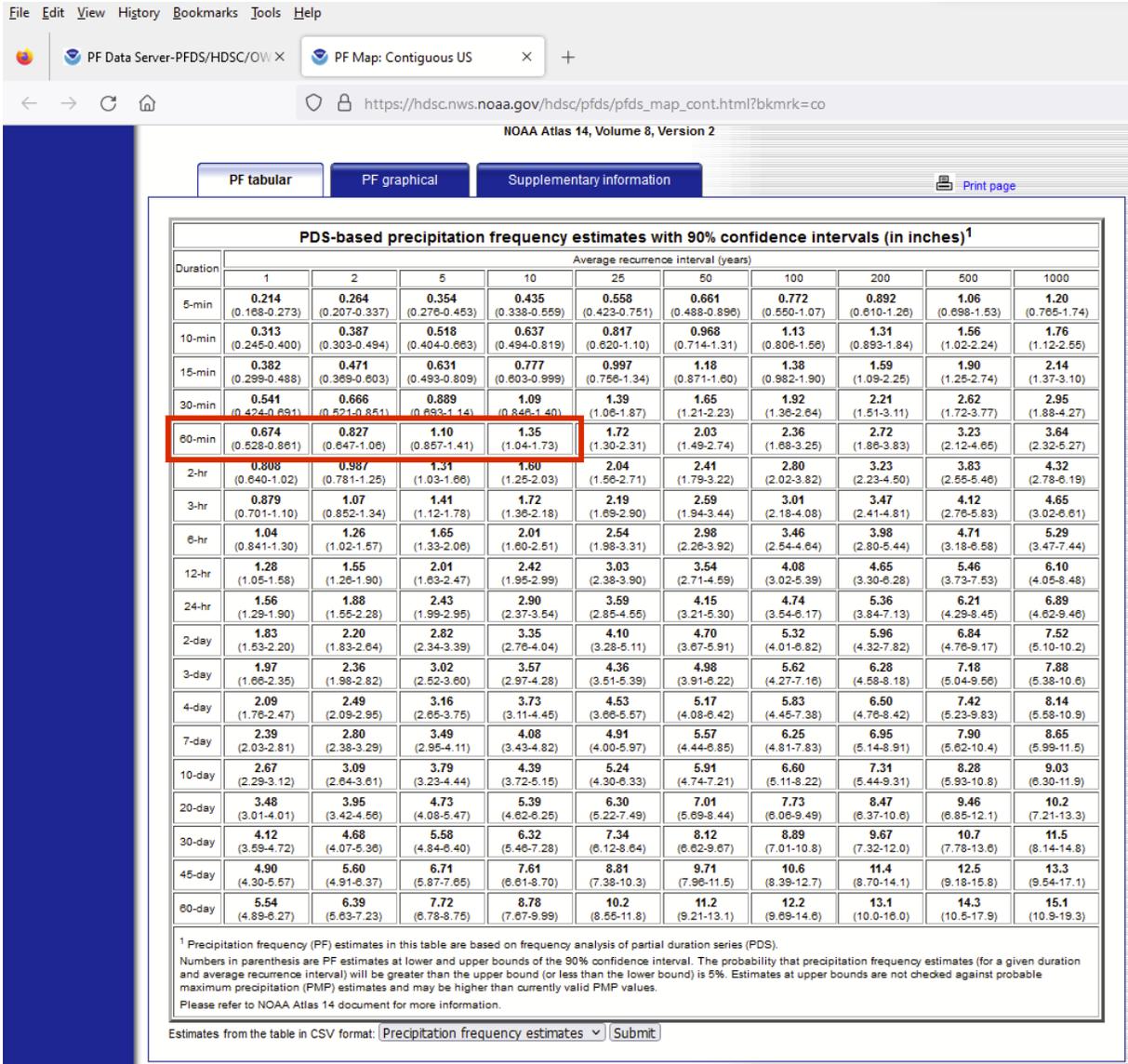


Figure B-3. Read the precipitation frequency to check for moderate or high hazard

Again, the foregoing National Weather Service tools seem relevant to precipitation hazard, but not enough to use them to measure hazard in a pilot incentivization project. They were included for completeness and future consideration.

## Appendix C. Mitigation technical guides

### C.1 Patterns for technical guides

*This appendix provides example technical guides for basement flood protection of homes.* This roadmap illustrates incentivization for one kind of residential flooding. One can group flood

protection for existing houses in three contexts or environments, each of which affects homes in different locations, and each of which is best addressed with a different set of mitigation measures:

1. Pluvial Urban flooding because of high-intensity rainfall (addressed here)
2. Riverine flooding because of overflowing rivers and streams
3. Coastal flooding because of high tides and coastal storm surge

Because this document is only a roadmap, and because this Chapter is intended merely to illustrate how to offer technical guidance for flood mitigation, we do not offer technical guidance for houses in special flood hazard areas or other buildings or other perils. But one could do so.

***Each technical guide details one mitigation measure for owners and co-beneficiaries.*** Before one can incentivize resilience measures, one must define them. This Chapter offers a pattern for defining individual resilience measures that a property owner can choose to implement. Each measure is explained in a technical guide. This Chapter offers three examples to mitigate pluvial flood risk to existing houses, but one can imagine any number of guides for other perils, building types, and so on. Each guide is arranged in five sections:

1. Who needs it, what to do, costs, and benefits. This section explains what best-practices experts call “the essence of the practice.” It describes the mitigation measure and the conditions under which it makes sense. It quantifies benefits to the homeowner and to all the other co-beneficiaries--the insurer, mortgage holder, real estate broker, governments, and others. It offers an estimate of the benefits in terms that are most meaningful to each co-beneficiary, to help them decide whether and how much of an incentive to offer. Chapter 8 offers an example benefit-cost analysis for the particular mitigation measures provided here. One must perform such an analysis for every mitigation measure, or in the present case, a package of mitigation measures.
2. DIY and contractor options because some mitigation measures can be done by the property owner.
3. Reasonable expectations. This section explains what can go wrong.
4. Checklists, standards, and certification. This section presents material to document that the mitigation measure was done properly and by a qualified person. One can imagine contracts making payment contingent upon the completion of this documentation. That is, the incentives described elsewhere in this roadmap would reference a particular guide and the checklists, standards, and certification. Draft checklists may ask questions that standard appraisal forms answer.
5. More information. Supplementary information that need not appear in earlier sections, but that might interest the user of the technical guide.

## C.2 Pluvial Urban flooding technical guide 1: side grading and downspout extensions

### C.2.1 Who needs it, what to do, costs, and benefits

**Who needs it?** Side grading and downspouts mostly deal with moving rainwater away from the house, either as it flows off the roof, falls into the yard, or flows into the yard from adjacent lots or down the street. It makes sense at almost any house where it sometimes rains intensely, which is almost anywhere.

**What to do.** This mitigation measure involves two changes, illustrated in Figure C-1.

1. **Side grading.** Grading helps water flow away from the house. Make the soil within 3 meters (10 feet) of the house slope away with a 15-cm (6-inch) drop over the 3 meters (10 feet), i.e., a minimum 1:20 slope or 5% grade. To do this work, the homeowner usually has to hire a landscaper, a general contractor, or a contractor who advertises a specialty in drainage systems.
2. **Downspout extensions.** These move water from the roof away from the house and drain away from the house and the neighbors' houses. Connect extensions to every downspout to discharge the water 1.8 meters (6 feet) from the house and from neighbors' houses. This can be a DIY project or the homeowner can hire a gutter or eavestrough contractor to do it.

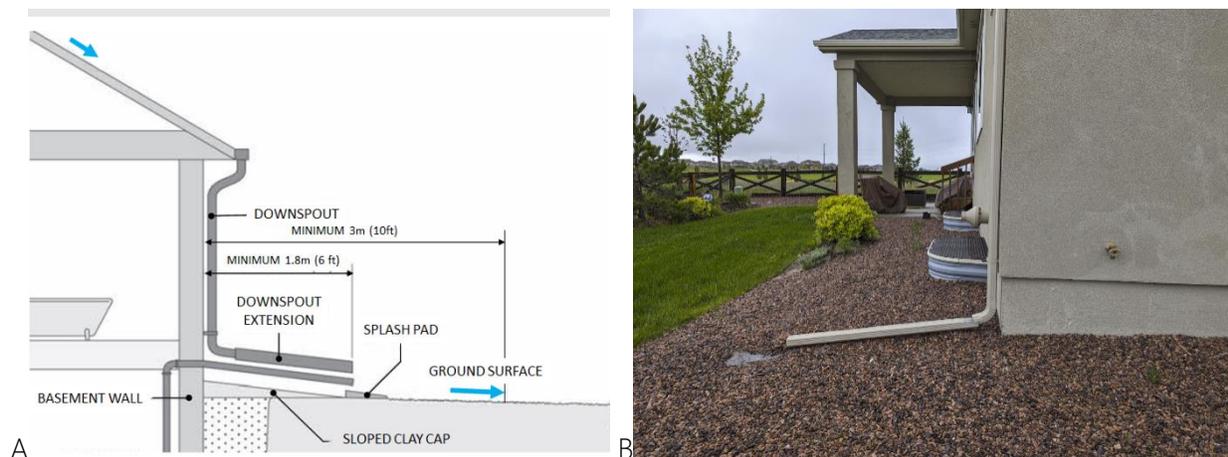


Figure C-1: Slope the soil away from the house for the nearest 3 meters (10 feet) and install downspout extensions that discharge the water that flows off the roof at least 1.8 meters (6 feet). (Image credit: A, Institute for Catastrophic Loss Reduction, B, Keith Porter with permission.)

**Costs.** An average house with a perimeter of 50 m (150 ft), if the soil sloped toward the house around the entire perimeter, would require 150 m<sup>2</sup> (1,500 ft<sup>2</sup>) of fine grading at a cost of approximately \$10.00/m<sup>2</sup> (\$1.00/ft<sup>2</sup>), or \$1,500, according to Gordian (2019 p. 139). Planting could realistically double that cost. Thus, grading may cost \$1,000 to \$5,000 if the entire house perimeter needs to be

regraded. Cramer (2023) suggests that to fix grading around a house costs \$500 to \$3,000. Johnstone suggests the cost ranges between \$1,000 and \$3,000, with an average of \$2,000. A cautiously high cost is about \$3,000. Costs are higher for bigger houses or challenging lots, smaller for smaller houses or where only a part of the lot needs to be regraded. Downspout extensions cost \$30 to \$100 per downspout handyman or contractor labor (Costhelper 2023), or about \$10 to \$30 per downspout to do it yourself (Fixr.com 2023). Homewyse (2023) suggests an average installed cost for 6 downspout extensions is about \$200. A cautiously high midrange cost to have downspout extensions added to an entire house is about \$300. Thus, while costs can vary widely, to have an average house graded so that the soil slopes away from the house and to have downspout extensions added, might cost about \$3,300.

**Benefits.** An uninsured homeowner who experiences basement flooding can expect repair costs that can be anywhere between \$1,000 and \$45,000, but the average is about \$30,000. Basement flood protection will avoid most of that loss, though possibly not all. The chance of a loss and the benefits to the various co-beneficiaries depend on the location. Use <https://riskfactor.com> to determine the likelihood of basement flooding. Appendix A shows the mitigation benefits to the homeowner, insurer, mortgage holder, and various levels of government.

## C.2.2 DIY and contractor options

One can buy and install aluminum downspout extensions oneself; see for example <https://www.thisoldhouse.com/gutters/21016457/how-to-install-rain-gutters>. A plumber or landscape architect can also do it for you. There is no DIY option for site grading; that generally requires a landscape architect or builder. Hire a licensed landscape architect or licensed general contractor. Ask for recent references and call the references to follow up.

## C.2.3 Reasonable expectations

Doing these two things helps, but water can still get into basements through sewer backups, window wells, missing or improperly draining weeping tiles, and other means. See the guidance on sewer backflow valves and sump pumps for more protection.

Downspout extensions can deteriorate over time. Site grading can be done badly and fail to move water away from the house. Neither helps if the water gets deep enough to reach the house, as in the case of houses close to overflowing rivers and flooded shorelines.

## C.2.4 Checklists, standards, and certification

It would be valuable for an incentivization project to have a simple handout with a checklist like Table C-1 that a homeowner or expert could complete and share with incentive offerers to document the mitigation work. The National Institute of Building Sciences could attach a handout with DIY instructions and instructions on how to hire a landscape architect, roofer, handyman, or other person

to do the work. The handout could include the credentials required to do the work or confirm that it has been done properly. Conceivably the National Institute of Building Sciences or others could create a some sort of certification program for contractors to inspect a property for flood-control needs and the adequacy of the measures taken to address the need, considering the likelihood of various depths of flooding.

Table C-1. Sample checklist to document downspout extensions and side grading

Homeowner name			
Phone and email			
Address			
Professional's name (landscape architect, builder, or handyman)			
Phone and email			
Address			
Do all roof downspouts have extensions that discharge at least 1.8 meters (5 feet) from the edge of the house? Attach photos of each.	Yes	No	Photo file names
<p>If not, hire a contractor (a roofer, builder, or handyman) to do the work. Then change the answer to yes and attach photos of the extensions. <i>To the contractor: In the US, comply with the US Department of Energy's Office of Energy Efficiency and Renewable Energy, Building America Solutions Center (2021) for downspout extensions. Why? Because the 2021 International Plumbing Code and International Residential Code are silent on downspout extensions, even though they are known to reduce basement flooding. In Canada, comply with Standards Council of Canada Z800-18 section 6.4(d).</i></p>			
Does the soil within 3 meters (10 feet) at all edges of the house slope away at 5% or more grade (i.e., dropping at least 15 cm or 6 inches)? Attach photos of the slope along each exterior wall.	Yes	No	Photo file names

If not, hire a contractor (a landscape architect, builder, or handyman) to do the work. Then change the answer to yes and attach photos of the slope along each exterior wall. *To the contractor: comply with 2018 International Building Code section 1804.4 or Standards Council of Canada National Standard Z800-18 section 6.3.1.*

## C.2.5 More information

The Institute for Catastrophic Loss Reduction (2009) offers homeowners a 35-page handbook on protecting homes from basement flooding. See <https://www.iclr.org/wp-content/uploads/PDFS/handbook-for-reducing-basement-flooding.pdf>

How common is this problem? We are unaware of any statistics on how many houses have lots that drain the wrong way or downspouts that don't discharge at least 1.8 meters from the house. But home improvement experts say it is common: "It happens to homeowners across the country more often than you'd think," (Howard 2019). HGTV suggests that most US homeowners have had this problem in at least one home they have owned: "Almost every homeowner has had to deal with a drainage problem in their yard at some point" (Stafford ND). Assuming HGTV is correct, both in the US and Canada, then perhaps 10% to 50% of homes have drainage problems, and something on the order of 5% of houses suffer from drainage problems in a given year. (The US has about 150 million homes and Canada has about 15 million, according to census statistics in the two countries.)

What are the risk factors? If the house is connected to a combined sewer system (one that carries away both wastewater and stormwater), it may be three times as likely to experience basement flooding as is a house in a neighborhood with separate stormwater and sewer systems, according to a study of 978 residential flood claims after an August 2014 storm that dropped up to 122 mm of rain in 6 hours (Mobini et al. 2021).

## C.3 Pluvial Urban flooding technical guide 2: sewer backwater valve

### C.3.1 Who needs it, what to do, costs, and benefits

**Who needs it?** This measure makes sense at any house with a basement on a street that has a combined sewer and stormwater system. To be more precise, the sewer backwater valve makes sense if the street has a combined sewer and stormwater system, and the house has plumbing fixtures on a floor whose elevation is lower than the elevation of the sewer manhole cover on the next upstream manhole. In severe storms, high runoff cannot flow fast enough through the sewer system to the wastewater treatment plant and outfall. It backs up into basements. Sewer backwater valves allow water to flow out of the house into the sewer, but have a valve that closes if water starts to back up from the sewer, preventing the backflow from entering the house.

**What to do.** Ask your city public works department if your street has a combined sewer and stormwater system. If so, hire a plumber to tell you if your home has a sewer backwater valve, and if

not, to quote you for installing one. You only need one if any of the plumbing fixtures are installed on a floor whose elevation is lower than the elevation of the manhole cover of the next upstream manhole of the public sewer.

To drain your foundation drain when the backwater valve is closed, also disconnect the weeping tile from the sanitary sewer and connect it to the sump pit, which will require the installation of a sump-pump and sump-pit. Disconnecting the weeping tile from the sanitary sewer lateral reduces the chance that water will back up into the weeping tile and cause structural damage and infiltration flooding in the home.

Figure C-2 illustrates how the backwater valve works. Figure C-3 shows what a backwater valve looks like during installation. As of this writing, some sewer backwater valves makers and models include the following.

- MAINLINE - Fullport Backwater Valve 4963
- Canplas 223254WPK1 PVC Fullport Backwater Valve, 4-Inch
- Canplas 123284 Backwater Valve, 4-Inch
- Canplas 123282 Backwater Valve, 2-Inch

**Costs.** To add a backwater valve to an existing house requires digging up the sewer line, possibly within the house, and can cost \$3,000, with a realistic range of \$2,000 to \$5,000 or more (Smythe 2023, Vaillancourt Plumbing 2023, Water Guard Plumbing 2023), although much higher costs are possible (Randshaw 2022). Hire the same plumber or another one to clear the valve every 3 years. Doing so can help avoid damage in the future.

**Benefits.** An uninsured homeowner who experiences basement flooding can expect repair costs that can be anywhere between \$1,000 and \$45,000, but the average is about \$30,000. Basement flood protection will avoid most of that loss, though possibly not all. The chance of a loss and the benefits to the various co-beneficiaries depend on the location. Use <https://riskfactor.com> to determine the likelihood of basement flooding. Table 2-2 shows the mitigation benefits to the homeowner, insurer, mortgage holder, and various levels of government.

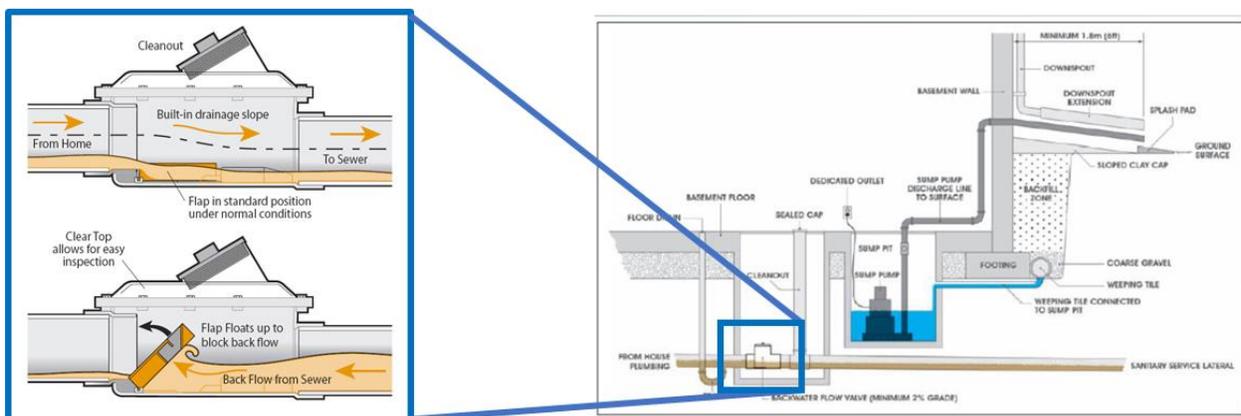


Figure C-2. How a backwater valve works.



Figure C-3: A backwater valve during installation

### C.3.2 DIY and contractor options

Engage a licensed plumber to perform the work. This is not a do-it-yourself activity.

### C.3.3 Reasonable expectations

An improperly maintained valve (especially a clogged one) can fail during a flood. If weeping tiles remain connected to the sanitary lateral, weeping tile drainage can back up into the basement when the backwater valve is closed, as this water will have no other way out of the home.

### C.3.4 Checklists, standards, and certification

To implement this portion of the incentivization program, the National Institute of Building Sciences or other lead can create a checklist like Table C-2 for a plumber to complete to indicate the following, to document the mitigation for incentive offerers. Note that some answers may appear in appraisal forms.

1. Homeowner's name, contact information, and address of the house in question.
2. Does the building already have a backwater valve? The plumber can document that one already exists with photos of its access and showing that the backwater valve is currently clean.
3. Is the building on a street with a combined sewer and stormwater system? If not, one need not add a backwater valve. What is the full name of the public works department person with whom the plumber spoke to check whether the street has a combined sewer and stormwater system? At what date and time?
4. Does the building have plumbing fixtures on a floor whose elevation is lower than the elevation of the sewer manhole cover on the next upstream manhole? What is the latitude

and longitude of the building's main entrance and the elevation of the lowest floor with plumbing fixtures? The plumber can determine those things using common map software (in 2023, e.g., Google Maps). What are the latitude, longitude, and elevation of the manhole cover of the next upstream manhole cover of the sanitary sewer?

5. If a backwater valve is required, show that it complies with ASME A112.14.1, CSA B181.1, or CSA B181.2. Attach a photo of the valve showing the manufacturer and model, plus a photo of the pages of the valve documentation showing that it complies with at least one of these standards.
6. The backwater valve installation complies with the International Plumbing Code sections 1101.9 and 714 (in the United States) or equivalent in Canada. Attach photos of the backwater valve in place, showing that access is provided to the working parts, per International Plumbing Code 714.3 or the equivalent in Canada.
7. The plumber's name, business name, contact information, and license number(s).
8. The homeowner can confirm that the plumber's license is active by checking with the licensing agency: often the state board of licensure's web page. Perform an Internet search for "state board of licensure for plumbers" and provide a screenshot showing that the license is still active.

*Table C-2. Sample checklist to document the need for and installation of a sewer backflow valve*

Homeowner name			
Phone & email			
Address			
Plumber's name and license number			
Phone and email			
Address			
Is the building on a street with a combined sewer and stormwater system? Call the city's department of public works, or by attesting to his or her prior knowledge. Under "information source," give the full name of the person at the public works department who answered the question, and the date of the call. Or write "plumber attestation."	Yes	No	Information source:
If not, there is less need to add a backwater valve. If yes, continue.			

Does the building already have a backwater valve? The plumber can document that one already exists with photos of its access and showing that the backwater valve is currently clean. Attach photos of each.	Yes	No	Photo file names
If not, hire a plumber to do the work. Then change the answer to yes and attach photos of the new backwater valve and the location of the cleanout. <i>To the plumber: install a backwater valve that at least complies with ASME A112.14.1, CSA B181.1, or CSA B181.2. Attach a photo of the valve showing the manufacturer and model, plus a photo of the pages of the valve documentation showing that it complies with at least one of these standards. Do the work in compliance with the International Plumbing Code sections 1101.9 and 714 (in the United States) or equivalent in Canada. Attach photos of the backwater valve in place, showing that access is provided to the working parts, per International Plumbing Code 714.3 or the equivalent in Canada.</i>			

### C.3.5 More information

How common is this problem? Home Performance Group LLC (2023) reports that is a survey of 79 municipal sewer agencies, “65 % reported sanitary sewer overflows during wet weather events. The utilities stated 15 to 35 % of their sewers were filled above capacity during heavy rains resulting in back-ups. The National Urban institute determined on average there are 827 backups and 143 pipe ruptures per 1,000 miles of sewer pipe.”

What are the risk factors? As noted in technical guide 1, if the house is connected to a combined sewer system (one that carries away both wastewater and stormwater), it may be three times as likely to experience basement flooding as is a house in a neighborhood with separate stormwater and sewer systems, according to a study of 978 residential flood claims after an August 2014 storm that dropped up to 122 mm of rain in 6 hours (Mobini et al. 2021).

Note that most sewer overflows are caused by pipe blockages, not by backflow from storms. That is not to say that one should not install a backwater valve, but that it is even more important to maintain and repair the sewer line. According to Home Performance Group LLC (2023), “Nearly half of all back-ups are caused due to pipe obstructions such as tree roots, followed second only to water infiltration into cracked or broken sewer pipes.”

The American Backflow Prevention Association (abpa.org) trains and certifies specialists. This national organization maintains a network of professionals with local Chapters and works to advance “all aspects of backflow prevention for the continued protection of all water users.”

## C.4 Pluvial Urban flooding technical guide 3: battery backup sump pump

### C.4.1 Who needs it, what to do, costs, and benefits

**Who needs it?** Most houses with a basement have a sump pit: a hole with a gravel base located at the lowest part of the basement. Any house with a floor at ground level or below needs a sump pit and sump pump to remove water from the sump pit, also called a sump basin. See Figure C-4. In storms, rainwater from the roof or from nearby land can accumulate at the edge of the house and infiltrate into the basement through low windows or cracks in the basement wall. Water from dysfunctional gutters or groundwater pooling around the foundation can also find its way into the house. The water drains into the sump pit rather than pooling in the basement. When the water level in the sump pit gets high enough, it lifts a float that triggers a switch that starts the sump pump, which removes the water via a discharge line out of the house and into a designated drainage area such as a dry well, neighborhood drain, a creek, or pond.

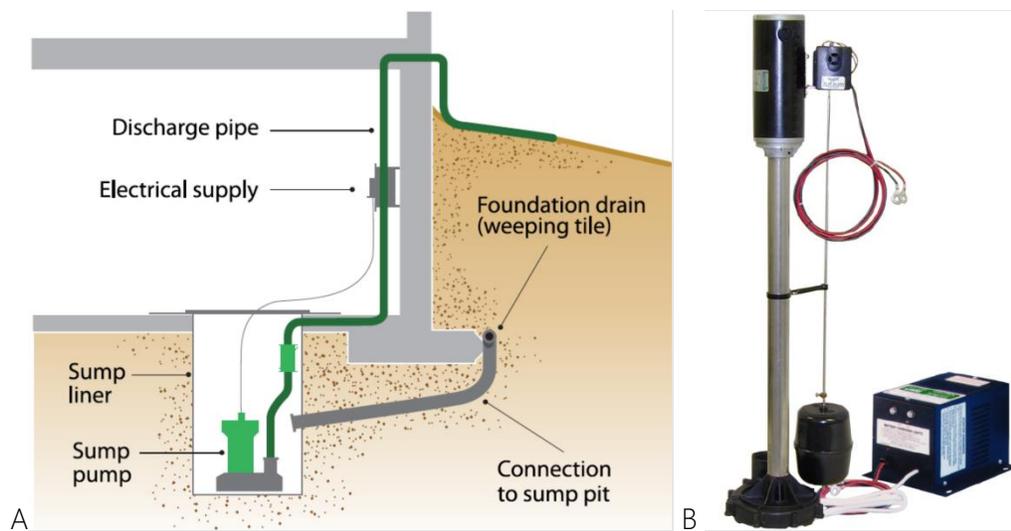


Figure C-4. A: Sump pit and sump pump. B: An example of a battery backup sump pump (image credits: Institute for Catastrophic Loss Reduction 2015, with permission).

The sump pump is usually powered from a wall outlet, which raises a problem when the power goes out in a severe storm. Storms that produce a lot of rain can also bring strong winds and lightning that damage power lines and transformers to interrupt commercial power to the sump pump. Hence the value of a battery backup sump pump (e.g., Figure 2-8B). It is usually a smaller pump powered by a battery on a trickle charger. It has a separate float higher in the pit so that it only starts if the primary sump pump does not start.

It is unclear what fraction of basement floods occur during power outages, but power outages tend to occur during storms. U.S. electricity customers generally experience 0.4 to 3.3 power interruptions per year (the U.S. average is 1.5), lasting a total of 1 to 80 hours per year. The U.S. averages for these

statistics are 7 total hours of outage per year in an average of 1.5 outages per year. Of the total outage duration, most of the total--5 hours--occurs in storms and wildfires (U.S. Energy Information Administration 2022).

It is possible to add battery power to the primary sump pump, but the risk is that the primary sump pump might not operate when it is needed. Electromechanical systems are not 100% reliable. Having a separate battery backup sump pump greatly reduces that risk.

**What to do?** Perform an Internet search of “best battery backup sump pumps” to choose one. Hire a licensed plumber to install the battery backup sump pump. A skilled amateur can also install one; see the DIY instructions in the next section.

**Costs.** A review of prices at Home Depot in 2023 indicates that to purchase a battery backup sump pump and battery costs \$400 to \$800. Wallander and Tynan (2023) suggest an installed cost range of \$600 to \$1,200, with an average installed price of \$900. DIY or Not (2021) agrees, although much higher costs are possible (e.g., Aquaduct Plumbing Services 2022). To have a plumber install the battery backup sump pump in an existing sump pit can cost another \$400 to \$800.

**Benefits.** An uninsured homeowner who experiences basement flooding can expect repair costs that can be anywhere between \$1,000 and \$45,000, but the average is about \$30,000. Basement flood protection will avoid most of that loss, though possibly not all. The chance of a loss and the benefits to the various co-beneficiaries depend on the location. Use <https://riskfactor.com> to determine the likelihood of basement flooding. Table 2-2 shows the mitigation benefits to the homeowner, insurer, mortgage holder, and various levels of government.

## C.4.2 DIY and contractor options

Almost any licensed plumber can install a battery backup sump pump. A skilled amateur can also install one by following the installation instructions that come with the pump. Online videos also exist to provide instruction. The Plumbing Source (2021a) offers a few cautions for DIY installation:

- Consider putting the battery in its own protective case, up on a wall-mounted shelf, well above any possible high water
- Make sure the circuit for the sump pump and its battery charger can handle both the continuous draw and the sudden amperage increase when the pump comes on
- Never use extension cords for either the sump pump or battery charger
- You may need to hire an electrician to provide a dedicated circuit for the sump pump.
- Remember, you are dealing with both water and electricity; if you do not know what you are doing, hire a professional.

### C.4.3 Reasonable expectations

Batteries provide a finite amount of power. Water Commander (2021a) advises: “During a power outage most new fully-charged batteries will last roughly 5-7 hours of continuous pumping and roughly 1-3 days of non-continuous pumping depending on the frequency.” A few other common problems can prevent the battery backup sump pump from running. Leading causes cited by Water Commander (2021b) and Family Handyman (2022) include:

- Improper installation of the sump pump switch
- Pump switch gets trapped against the pump, discharge pipe, or power cord
- Blockage around the pump strainer or debris clogging the pump impeller
- Partial or complete blockage of the discharge pipe leading out of the house
- A dead battery
- Mechanical failure of the switch or other component of the sump pump
- Check valve installed backwards
- Undersized pump, too small to handle the required flow

### C.4.4 Checklists, standards, and certification

To implement this portion of the incentivization program, Table C-3 offers a sample checklist for a plumber to complete to document the mitigation for incentive offerers. It asks,

1. Homeowner’s name, contact information, and address of the house in question.
2. The plumber’s name, business name, contact information, and license number(s).
3. Does the house already have a sump pit, and working AC powered sump pump and battery backup sump pump? The plumber can document which of these already exist with photos and a written attestation that the sump pit and pump(s) are currently clean and functional.
4. For information: the International Plumbing Code and International Residential Code appear to be silent about standards and other requirements for the pump, aside from having the required flow and pressure capacity. However, to demonstrate to incentive offerers that the battery backup sump pump has been installed, attach photos of the pump showing the manufacturer and model.
5. The homeowner can confirm that the plumber’s license is active by checking with the licensing agency: often the state board of licensure’s web page. Perform an Internet search for “state board of licensure for plumbers” and provide a screenshot showing that the license is still active.

Table C-3. Sample checklist to document the need for and installation of a battery backup sump pump

Homeowner name			
Phone & email			
Address			
Plumber’s name and license number			
Phone and email			
Address			
Does the house have a floor that is lower at any point than the highest ground at the house’s perimeter? If no, provide photos that show all exterior sides of the house.	Yes	No	Photo file names
If not, there is less need for a battery backup sump pump. If yes, continue.			
Does the building already have a battery backup sump pump in working condition? The plumber can document that one exists with photos showing it and an attestation that it is currently working and has adequate flow and pressure capacity. Attach photos of each and have the plumber write “plumber attestation.”	Yes	No	Photo file names, and plumber attestation
If not, hire a plumber to do the work. Then change the answer to yes and attach photos of the battery backup sump pump. <i>To the plumber: install a battery backup sump pump in the sump pit. Attest that the battery backup sump pump is installed correctly, that both the primary and backup sump pumps are functioning and have the required flow and pressure capacity.</i>			

### C.4.5 More information

For more information, see the Institute for Catastrophic Loss Reduction’s guidance at [https://www.iclr.org/wp-content/uploads/PDFS/Sump\\_pump\\_booklet.pdf](https://www.iclr.org/wp-content/uploads/PDFS/Sump_pump_booklet.pdf).

## Appendix D. Some theoretical considerations

This report offers applied research on incentives to increase mitigation actions. We do not intend it as a scholarly research project. But theories matter, especially when one is doing something new and past practice did not work. To ignore theory here means to dismiss hard-won knowledge about principles that could prevent new incentives from working, and producing the same poor outcomes that past practice produced. We reflect here on some relevant scholarship.

### D.1 Might monetary resilience incentives fail because they conflict with intrinsic motivations?

Gneezy et al. (2011) examine how monetary incentives to persuade people to take some action can conflict with psychological, non-monetary motivations. They focus on incentivizing effort in school, long-term health habits, and prosocial behaviors in general. They cite several examples where a monetary incentive produced the opposite behavior to what was desired. For example, a daycare provider fined parents who picked up their children late, because the monetary incentive signaled an affordable price for the undesirable behavior. Late pick-ups increased and did not return to the pre-incentive rate even after the fine was removed. In another case, a reward for academic performance backfired because it crowded out the intrinsic pleasure of learning and signaled that the desired performance was hard.

We considered the ways in which monetary incentives backfired in the ways Gneezy et al. (2011) warned about, but find that none of them seem to apply in the present case. We want to promote actions that take place at a discrete point in time rather than long-term behaviors. They have clear, concrete measures of successful completion and do not involve or compromise trust relationships. And although taking these actions benefit society, they take place in a mostly private, contractual environment. And we introduce these incentives because the intrinsic motivators have clearly failed.

However, Gneezy et al. (2011) highlight a potential pitfall. A homeowner could perceive a monetary offer from an insurer or mortgage holder as merely masking a punishment--a higher price--if they do not comply. In offering incentives, we can make clear that the costs without the incentive are unchanged from before the time when the incentive was introduced. That is, the incentive is kind, not hostile.

## Appendix E. Emotional Incentives to Promote Resilience

People often behave very differently from what Adam Smith's rational-actor model predicts, so the monetary incentives discussed above may have far less influence than one might hope. Cialdini (2021) offers extensive psychological research supporting seven principles businesses and others use to

persuade people to take desired actions, none of which have anything to do with benefit-cost ratios and only one of which (reciprocity) has anything to do with money.

This is important in two ways:

- If these principles did not work, advertising would not work. To ignore them is to ignore influences that may be more important than the amount of money offered to effect behavioral change.
- These principles speak to what people care about. Regardless of how economists and engineers think people *should* make decisions, or what we think they should value, actual people care about the things they care about, and often those things differ from what classical economics says they should care about (i.e., maximizing wealth). In a heavily cited scholarly work on behavioral economics, Richard Thaler (2000) makes this point with the metaphor of Homo economicus (an imaginary species of people who behave the way economists predict real people behave) versus Homo sapiens (people as they are). Behavioral economics seeks to evolve Homo economicus into Homo sapiens – i.e., to make economic models better reflect real human economic behavior.

The box below lists Cialdini's levers of influence. For each lever of influence, it briefly suggests how we might apply them here, as resilience incentives. In later work, we or others can turn these brief suggestions into specific actions.

***Merely theoretical?*** Note that there is nothing “merely theoretical” about these ideas, any more than economic models, insurance models, or engineering models are merely theoretical. If psychology did not work at the societal scale, nobody would use advertising (a \$350 billion market in the United States), at least not in the way advertising is actually done. To dismiss psychology would be to only value familiar methods because they are familiar and to discount unfamiliar ones merely because they are unfamiliar.

### Psychological incentives with Cialdini's (2021) principles of persuasion

***Authority:*** Have trusted authorities (building scientists, real-estate professionals, and emergency-response agencies) advise the decision-maker to do mitigation. State the authorities' credentials.

***Consistency:*** Identify and highlight how the decision-maker previously committed to or engaged in disaster risk reduction. Ask decision-makers to attest that they care about people reducing their disaster risk.

***Liking:*** Have people the decision-maker likes, such as celebrities (in the case of the public) or trusted colleagues (in the case of community, government, or corporate leaders), urge disaster risk reduction.

**Reciprocity:** Have governments, mortgage holders, insurers, or real estate agents and brokers offer something, even of small value, and ask the decision-maker to do mitigation. Make a large ask, then fall back to a small ask.

**Scarcity:** Point out to the decision-maker how a resilience feature might be scarce among available options, or how the incentive might only last a little while. The fact that many homes lack the desirable feature can be a selling point for resilience.

**Social proof:** Identify or count peers who have engaged in disaster risk reduction, or show that an increasing number of other property owners are engaging in it; offer concrete examples

**Unity:** Situate decision-maker within the group who want to increase society's disaster resilience. Use jargon specific to that group; convey exclusivity; identify out-group behavior; and invoke family ties.

We considered how monetary incentives can sometimes conflict with non-monetary motivations and fail to achieve the desired outcomes as a consequence. See Appendix A.1 for a discussion.

### D.1.1 Tactical psychological incentives

We can use psychology in smaller ways.

1. **Emphasize self-efficacy.** Bandura's (1997) heavily-cited theory of self-efficacy and collective efficacy can help inform efforts to motivate people to solve problems, including resilience. The theory holds that people and groups are more likely to attempt to act to solve a problem if they perceive a sense of efficacy, i.e., that their individual and collective actions can make a difference. Wherever we mention a reliance problem such as flooding, we can immediately follow the discussion of risk with a discussion of practical solutions.
2. **Consider cognitive biases when talking about probability.** People tend to perceive risk more clearly when they can imagine a particular situation more clearly, and when that situation seems familiar. We can depict the mitigation opportunity clearly with pictures of houses that seem representative, that is, considering the representativeness and availability biases identified by Tversky and Kahneman (1974). People have a hard time grasping low annual probabilities, so rather than talking about annual probabilities, we can depict probabilities and outcomes during the decision-maker's (generally longer) ownership period (Bonstrom et al. 2012).
3. **Speak to values that the stakeholder has already expressed.** For example, when speaking to a community that values stewardship of the land and strong connection to place, emphasize ways in which the resilience effort protects the land and reduces the stakeholder's chance of being displaced (Loflin 2013).

4. ***But you are free.*** When making a request, say “But you are free to...” or alternatives such as “don’t feel obligated,” “see for yourself,” “the choice is yours,” or “only if you want to.” Carpenter (2013) finds that adding this idea to a request can double compliance. People become more likely to comply and increase their degree of compliance. The technique affirms people’s autonomy and reduces resistance.
5. ***Literally show the rewards.*** When talking about a benefit of resilience, literally show the future reward graphically and vividly describe it. Show the reward at every step in the stakeholder’s process. Berridge and Kringelbach (2015) explain that dopamine motivates us to take action if we see a reward coming. For example, when talking about a higher sale price or faster sale, show a sold sign and the increased value in dollars or percentage.
6. ***Ask partners in incentivization for advice, not opinions.*** To make incentivization work will require cooperation with gatekeepers for many stakeholder groups, such as committee chairs or staffers of professional societies and legislative committees, executives of corporations that we want to offer incentives, and other leaders with whom we want to ally. We will need buy-in from those people. To make them more likely to engage, we should ask for their advice, not their opinion. The word “opinion” psychologically pushes them away and asks them to be critical. The word “advice” asks them to step in and become a partner (Liu and Gal 2011).
7. ***Frame compliance as a last step needed to accomplish some goal.*** Zeigarnik (1927) found that unfinished tasks leave one with a feeling of unease. We can use this feeling to motivate people to act by framing compliance as a final step, completion, or one last thing. For example, we can describe hiring a contractor to floodproof a house one has just bought as one last step to acquiring a safe home.
8. ***Frame the action as avoiding loss.*** People want to avoid loss more than they want to achieve a gain, in general (Kahneman and Tversky 1979). We can frame mitigation and participation in incentives to leverage loss aversion. For example, we can say, participate in this program to *avoid losing* \$30,000 of property value or to avoid losing \$270,000 from a mortgage default, rather than saying *to save* \$30,000 or *to save* \$270,000.
9. ***Show the personal nature of the risk, show that it applies to the decision-maker, and that the decision-maker can effectively reduce or prevent it.*** Frame compliance as preventing something that actually has happened to others, and could happen to you, and that you can effectively reduce or prevent.

### D.1.2. Behavioral economic frameworks

The foregoing psychological strategies and tactics reflect only some of the ways people think about how real economic behavior diverges from decision-making based on the financial considerations discussed earlier. In future work, we could also develop strategies and tactics to address the biases of judgment that Thaler (2000) or Meyer and Kunreuther (2017) discuss. But for present purposes of merely creating a roadmap to resilience incentivization, the foregoing seems to adequately illustrate a dual approach of financial and emotional incentives.

### D.1.3. Ethical considerations for using emotional incentives

Cialdini (2021) finds it necessary to discuss the ethics of persuasion repeatedly. Marketing organizations develop and enforce codes of ethics (e.g., American Marketing Association 2023). We think that opponents of incentivization could attack the foregoing discussion of emotional incentives as manipulative. It therefore seems to warrant at least a brief defense.

From a human-subjects perspective, it is rarely unethical to state facts; none of the foregoing emotional incentives advance falsehoods. We can further justify the use of emotional incentives to promote resilience actions on the basis of each of the four major western ethical theories:

**Virtue ethics.** These deal with good and bad personality traits. Virtue ethics hold that the good springs from good character. Aristotle advocates that a person embrace wisdom. Thomas Aquinas (in his work *Summa Theologiae*) named prudence as one of four cardinal virtues. For him, prudence meant “right reason with respect to action.” Benjamin Franklin advocated that a person should be industrious. These all seem to be the traits that best relate to disaster resilience, and they seem consistent with it.

1. **Duty ethics.** These hold that moral action springs from taking actions that you would advocate as a universal law, as opposed to the character of the person taking the action or the outcome of the action. Duty ethics call for treating people as ends in themselves, rather than as a means to one’s own ends, and acting accordingly. One way to test whether one is treating people as ends in themselves is the universality test: we ask ourselves if we would change roles with any of the stakeholders. We think incentivization passes that test. The whole point of the resilience incentives is to equate everyone’s benefit-cost ratio, to make it so that nobody loses or gains more than anybody else.
2. **Utilitarianism.** This ethical theory holds that one should act to maximize the public good or minimize the public harm. At least insofar as incentivization touches the people with a stake in the resilience of a particular property are concerned, we think incentivization passes this test.
3. **Ethics of care.** This theory holds that moral action centers on interpersonal relationships and care or benevolence as a virtue. It would have us (a) pay attention to and (b) take responsibility for the needs of others, (c) to act effectively and follow through on that care, and (d) to respond to the expressed desires of the person receiving care. Private-sector incentives satisfy most but not all of these requirements. It tends to fail test d, because the people who most need help, people who lack the resources to do the mitigation even after incentivization, get left behind.

Cialdini (2021) recommends three tests of ethical persuasion:

1. **True.** Am I telling the truth? Would I give the same advice to a loved one? We personally do recommend these mitigation measures to loved ones, so we think we pass this test.

2. **Natural.** Am I presenting my request naturally? It is unclear how Cialdini's test of naturalness applies in the present context. We think that it is natural for advocates of disaster resilience to request that people enhance their resilience, and it is natural for people to want to protect themselves from disasters. We think we pass this test.
3. **Wise.** Is it wise to make this request? If we persuade people to say yes, would they say yes in the future? We think they would, so we pass this test.

