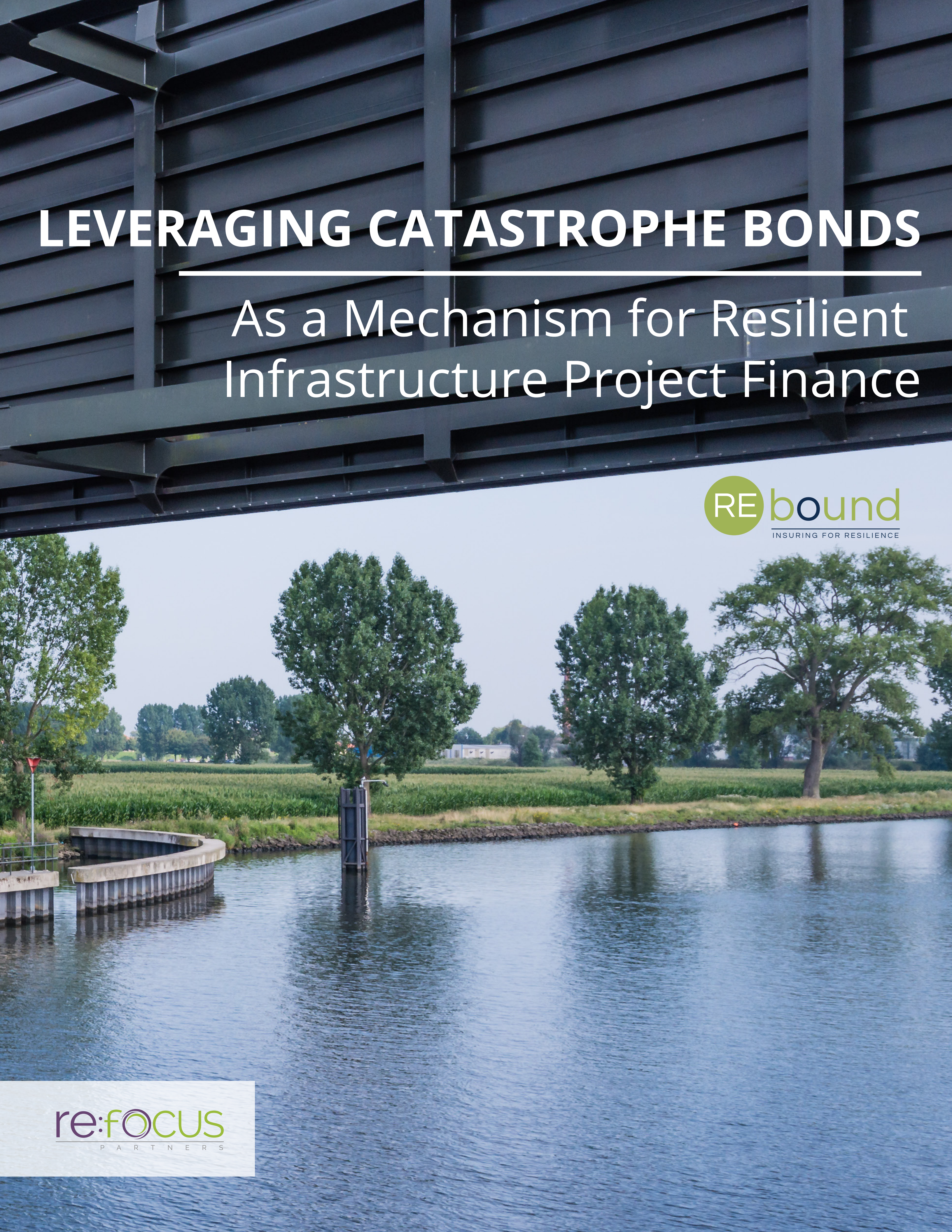
LEVERAGING CATASTROPHE BONDS

As a Mechanism for Resilient Infrastructure Project Finance



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REPORT CONTRIBUTORS

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INTRODUCTION

Investing in resilience is complicated. Like healthcare, there are multiple strategies that can and should be combined to improve overall health. For example, there are things you can do regularly to ward off risks (preventative care), other options to address acute conditions (treatment or medical intervention), and finally actions you can take to ensure that illness doesn't bankrupt you or those who depend on you (health and life insurance).

Strategies to protect communities from disasters follow a similar pattern. Projects to increase resilience—infrastructure upgrades or new protections—are designed to reduce the physical risks of damages. Once prevention is no longer an option, disaster response and recovery measures, including disaster aid and reconstruction funds, are designed to help the system recover and rebound back to health more quickly. Finally, at the far end of the spectrum, financial instruments, like catastrophe bonds, are designed to help protect those who could suffer devastating financial disruption in the event of a disaster, including owners of large assets and insurance companies.

Just as life insurance doesn't actually make you physically healthier, financial insurance instruments *do not* reduce physical risks. In contrast, projects designed to reduce physical risk and damages *do* reduce financial risks. In other words, effective on-the-ground **resilience projects are designed to ensure that a severe event doesn't become a physical or financial disaster**. Despite the obvious connection that physical protections provide financial protections—a storm hits but doesn't create massive economic losses—there are few mechanisms to connect these two different types of investments.

This paper offers a new approach for systematically linking catastrophe bonds and conventional project finance to support large-scale resilience projects. The following sections describe the RE.bound Program framework for catastrophe modeling, bond structuring, and bond sponsorship; summarize key insights and lessons for extending the approach to a range of resilience applications; and offer ideas for government and other public-interest entities seeking to build resilience and mitigate disaster risk.

THE BALANCING ACT BETWEEN INSURING DISASTER RISK AND FINANCING RESILIENCE

Often the most **cost-effective solutions to disaster risk are the ones available to communities prior to a disaster to protect against a loss occurring in the first place**. Yet cities around the world are struggling to fund even basic infrastructure projects, let alone more complex investments in resilient systems. Public cash reserves and budgets for insurance are increasingly constrained, and the capital cost of large-scale resilient infrastructure, such as coastal protection projects or flood barriers, is often too high to be absorbed by local governments or utilities. Too often the benefits are diverse, diffuse, long-term, and non-monetary, making the same types of infrastructure investments unattractive to private investors.

Despite the growing interest in investing in resilient infrastructure, **the pipeline of projects remains stubbornly stuck in traditional, direct revenue models**, such as toll roads and bridges, and planning for resilience upgrades and improvements remains a public sector challenge. Most of these projects, like coastal wetlands and levee systems, are viewed as public goods that generate diffuse benefits long into the future. The risks and benefits are often broader than anticipated, only appreciated in hindsight, and are rarely captured directly to support the original investment. As a result, resilient infrastructure projects are typically supported by federal, state, or local funds, and data analysis on the risk reductions is rarely done at a level of detail required to support access to capital market financing.

Like investors in energy efficiency, resilience project developers need to be able to quantify the savings from improvements before designing a financing mechanism to capture this value. For example, after decades of property-level data collection and modeling, an investor in a large-scale energy efficiency project can, with reasonable confidence, assume the risk of providing capital that is paid back through savings or benefits over time. In the case of resilience projects, the data on interventions that create measurable risk reductions are not as readily available or as easily extrapolated across projects. Everything is site and context specific; for example, a seawall reinforcement can have wildly different risk reduction profiles in different locations. This is very different from energy efficiency projects, for example, where the electricity savings from new lightbulbs are consistent across many applications.

So how can cities and communities systematically evaluate and monetize the benefits of resilient infrastructure projects as part of their overall risk management strategy? Catastrophe models and novel bond instruments offer one approach.

HOW CATASTROPHE BONDS CAN BRIDGE THE GAP BETWEEN PROTECTION AND RECOVERY

Catastrophe bonds or 'cat bonds' are financial instruments designed to help manage the financial risks associated with potentially devastating natural disasters.[1] For example, if a hurricane strikes, the aim of a catastrophe bond is not to limit physical damages on the ground, but instead to reduce the economic disruption of financial losses. A defining aspect of cat bonds, compared to Treasury Bonds or municipal bonds, is that they are designed to be 'triggered' in the event of a disaster. This means that when a disaster reaches a predetermined threshold (such as $500 million USD in losses or a storm surge

[1] For an easy-to-read overview and history of the cat bond market from Hurricane Andrew to Hurricane Katrina, see Michael Lewis' In Nature's Casino (New York Magazine, August 2007).

height of 10+ feet above a datum) during a bond term (usually three to five years), the bond sponsor (the insurance purchaser) keeps a portion of the bond value to pay off losses and investors lose some—or potentially all—of their principal invested.

There are several types of triggering events for a wide range of potential disasters, including hurricanes, floods, earthquakes, and typhoons. **Common types of triggers are loss-and-damage based triggers**, which set a threshold based on the total insured or total economic losses experienced by a single firm (indemnity) or an industry (indexed), and parametric triggers, which are based on independent predetermined indicators, such as wind speed or storm surge height measured at specific locations.

Cat bonds provide attractive rates of return to investors to compensate for the risk of a triggering event. While cat bond investors take on considerable financial risk, this risk is generally uncorrelated with the risks inherent to other types of investments, making cat bonds attractive to institutional-type investors. As of the first quarter of 2015, the cat bond market was worth ~$25 billion and grew 25% per year over the last decade (compared to 10% for the rest of the insurance sector).[2] Cat bonds represent a portion of the broader insurance-linked security market, in which an estimated additional $40 billion of private capital is invested in insurance-related financial risks.

The role of public sector entities in the cat bond market continues to grow. The Government of Mexico was an early public sector leader in developing a cat bond program, covering first earthquake and then hurricane risk. Cat bonds are now regularly used by government-sponsored insurance programs, including the California Earthquake Authority, Florida Citizens Property Insurance, Louisiana Citizens Insurance, and the Texas Windstorm Insurance Association. The World Bank issued its first-ever cat bond in June 2014.[3] Most recently, New York's Metropolitan Transit Authority (MTA) and Amtrak have both integrated cat bonds into their insurance strategies.

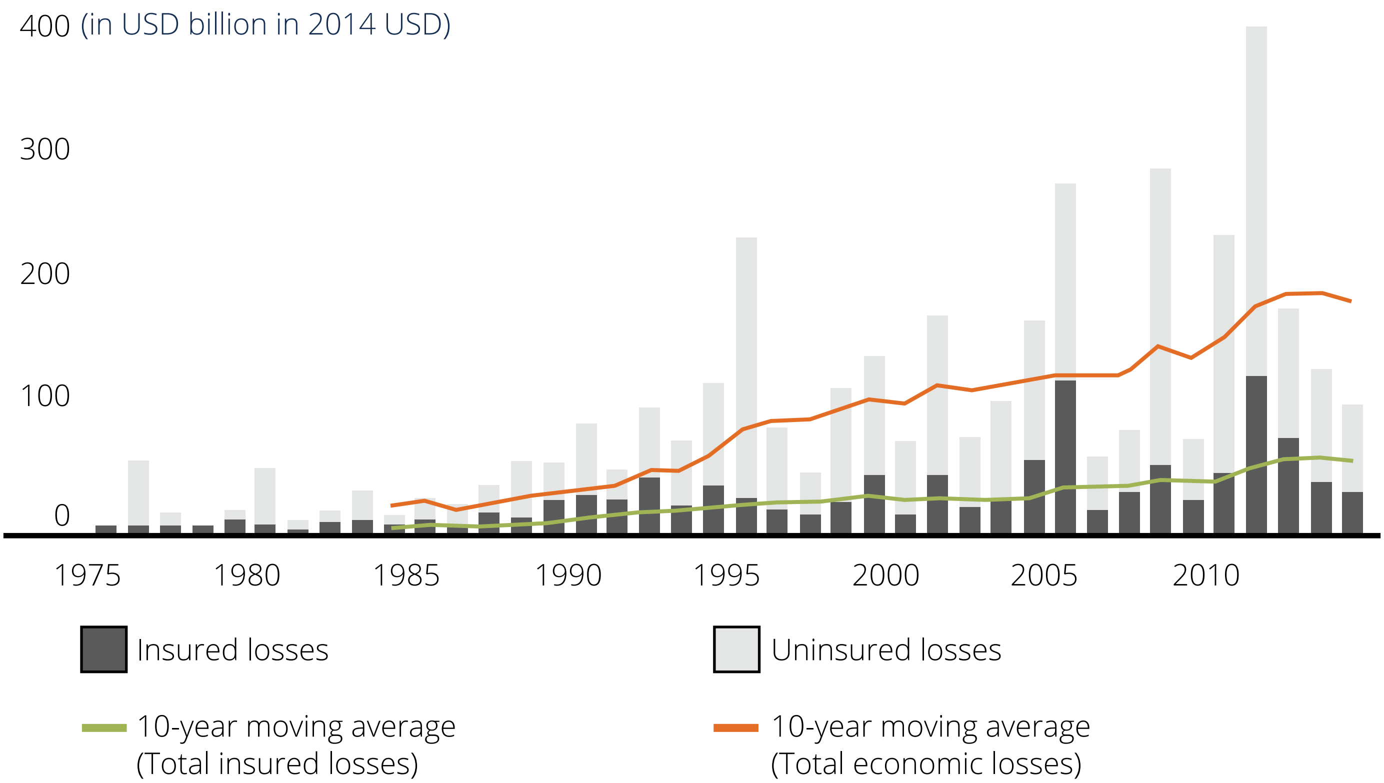
Cat bonds are typically structured with catastrophe models that are widely used in the insurance industry to evaluate the risk of a disaster and the potential resulting damages. However, these analyses are disconnected from other parallel efforts by infrastructure developers and the impact investing community to monetize more abstract benefits of resilience projects. These parallel efforts are often framed in terms of potential savings or avoided losses, but are often not grounded in a valuation method that is accepted in established markets. Connecting these two types of analyses offers an opportunity to link physical protection measures to financial insurance benefits.

[2] See the International Council on Science (ICSU) "Road to Paris" series for a summary of the Cat Bond market landscape by Leigh Phillips Cat Bonds: Cashing in on Catastrophe (ICSU, November 2014).

[3] World Bank Issues its First Ever Catastrophe Bond Linked to Natural Hazard Risks in Sixteen Caribbean Countries (World Bank Group, June 2014).

Simply put, catastrophe bonds become more valuable investments when the probability of a triggering event and/or the estimate of its total financial loss to investors goes down. For example, a resilience project designed to divert millions of gallons of floodwater can create both social value (i.e. avoided basement flooding and reduced mold related health impacts) and environmental benefits (i.e. reduced combined sewer overflows and improved ecosystem services). Separately, the same project has a measurable *financial* benefit from lower risk to investors in cat bonds that have already been issued with a fixed coupon. The result of an effectively integrated insurance and resilience project finance strategy is that a community is physically protected from the worst outcomes on-the-ground, while residents, governments, and private insurers reduce their potential financial losses, and while investors' bond holdings improve in value over time.

Natural catastrophe losses: Insured vs uninsured losses, 1975-2014



Source: Swiss Re Economic Research & Consulting and Cat Perils

Figure 1. Swiss Re Economic Research & Consulting Report "The USD 1.3 trillion disaster protection gap: innovative insurance tools exist to support governments to be better prepared." (Swiss Re, October 2015)

Insurers have long championed risk reductions including seat belts to reduce the human and economic costs of automotive accidents, fire codes for urban buildings, and workplace safety standards, among other measures.[4] As Figure 1 shows, the total economic losses from natural catastrophes have spiked in recent years, and the vast majority of those losses have been uninsured. In other words, governments and individuals are absorbing a growing share of the costs for disaster recovery. By connecting cat bonds to investments in physical risk reduction projects, the insurance industry has the opportunity to catalyze investments in resilience projects, similar to how health insurers are now focusing on options for expanding preventative care.

A NEW APPROACH TO HELP COMMUNITIES *RE.BOUND*

The RE.bound Program reflects a novel approach for **integrating catastrophe bonds and infrastructure project finance** that builds on the work of the RE.invest Initiative.[5] Using the detailed engineering conceptual designs from selected RE.invest partner cities as a starting point for analysis, RE.bound brought together a team of risk experts, insurance industry modelers, and investment bankers and analysts to:

1. **Modeling**
   Model the physical and financial risk reductions associated with specific resilient infrastructure projects

2. **Bond Design and Structuring**
   Assess options for designing and issuing a new type of resilience bond that integrates elements of traditional catastrophe bonds with features of social impact bonds to capture insurance savings that can be converted into a resilience rebate

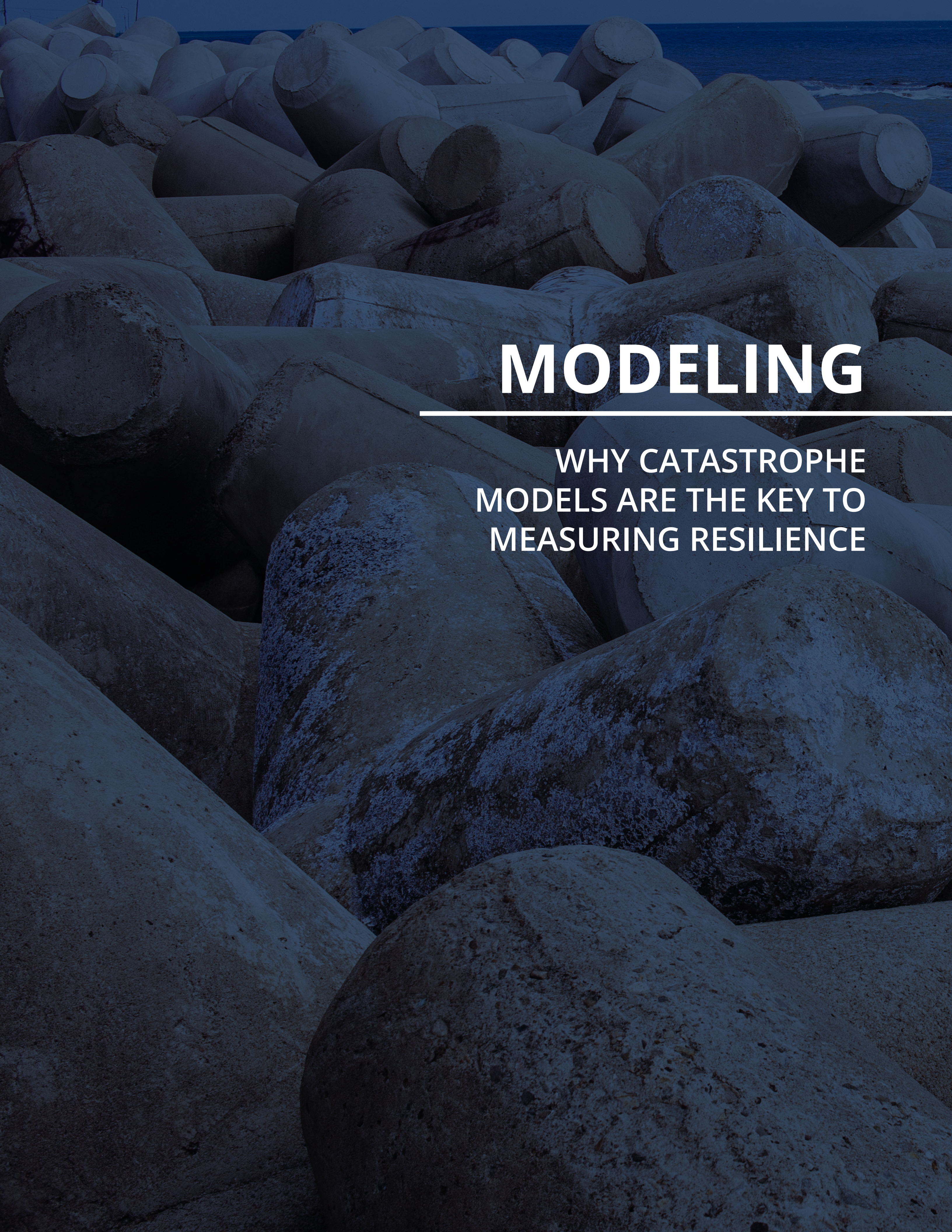
3. **Sponsorship**
   Explore how these new resilience bonds can support public sector interests and mobilize capital for diverse on-the-ground risk reduction projects

[4] For additional background on insurance industry risk management programs, see CERES Insurance Industry Initiatives Reports and Resources (CERES, May 2015).

[5] The RE.invest Initiative was a 2-year, $3 million Rockefeller Foundation supported collaboration among eight U.S. cities and leading engineering, law, and finance firms to design and finance resilient infrastructure systems through new public-private partnerships. More at www.reinvestinitiative.org.

The primary audiences for this paper are risk managers and leaders in federal, state, and local governments that bear the brunt of the costs of disasters and are responsible for protecting communities that suffer directly. Governments are the de facto 'insurers of last resort.' By transferring catastrophe risk to the private sector and leveraging insurance to finance projects that help communities increase their resilience over time, RE.bound offers a pathway to improving both physical and economic resilience for communities around the world. Governments and public utilities that are currently struggling to fund innovative resilient infrastructure projects through public procurement processes can leverage the RE.bound approach to pursue higher quality projects, generate investment-grade data, and more effectively access private capital. **Most importantly, communities who suffer the most from disasters can benefit from better access to both insurance and protection.**

The aim of this paper is to provide public sector stakeholders with a strong grounding in the three main building blocks of resilience bonds—**insurance, resilience projects, and rebates**—and the opportunities associated with integrating local priorities for insurance and resilient infrastructure development. The following sections describe each of the main components of the RE.bound Program—modeling, bond design and structuring, and sponsorship. The final section highlights key insights, lessons, and opportunities for international development finance institutions, federal disaster agencies, and local governments seeking to promote resilient economic development. Taken as a whole, the RE.bound Program offers a template for public sector leaders to apply traditional private sector catastrophe modeling to leverage additional financing for building resilience in vulnerable communities.



MODELING

WHY CATASTROPHE MODELS ARE THE KEY TO MEASURING RESILIENCE

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Resilience is not simply the opposite of disaster. Without tools to effectively measure benefits and capture them to payback project investments, governments around the world are reliant on public funding for large-scale risk reduction projects. Given the pressures on limited public funds, most projects remain unfunded. **Measuring and monetizing the benefits of resilient infrastructure investments are critical steps toward accessing additional sources of capital**. Catastrophe models offer a unique platform for taking this step.

The RE.bound Program tested a new approach for measuring risk reductions. It applied catastrophe models from the insurance industry to measure project-based risk reductions for a sample of public sector resilience projects. These models are trusted by investors, who use them to help price risks in existing capital markets. As a result, the **RE.bound modeling approach enables project-based risk reductions to be measured in ways that are accepted by investors and well established in both capital and insurance markets.**

Instead of relying on uncertain forecasts or waiting decades to measure a project's social and environmental performance, RE.bound used the insurance industry's own approach to estimating risk, which relies on quantitative models and simulations, and applied it to generate up-front measures of project-based risk reductions. The aim of this approach is to enable governments and communities to identify and prioritize projects that are likely to generate risk reductions that can be readily translated into resilience dividends and revenues.

It is important to emphasize that this modeling approach is very different from conventional benefit-cost analyses, environmental benefit analysis, or other types of socio-economic assessments underlying social impact bonds. Social impact bonds aim to turn future social and environmental project benefits into revenues. In contrast, catastrophe modeling offers a way to assess a project's insurance benefits separate from monetizing its environmental and social benefits and to do so well in advance of its implementation. By focusing on the direct financial benefits of resilience projects—rather than hard-to-measure physical benefits or abstract proxies for social and environmental benefits (e.g., ecosystem services or community cohesion)—RE.bound demonstrates how catastrophe modeling can serve as a resilience planning tool to open up access to a broad pool of private capital.

THE VALUE OF CATASTROPHE MODELS

Catastrophe models are sophisticated tools that have been developed specifically to quantify the risks from potentially catastrophic events. Instead of just looking at the historical record of events for a specific peril, catastrophe models generally use a much larger, computer-simulated set of events, which aims to capture the entire range of possible scenarios for this peril. These models can therefore give a much more complete picture of the range of potential losses a peril could cause for a given set of exposure. Perils that can be evaluated using catastrophe models range from earthquakes to hurricanes to acts of terrorism.

Catastrophe models provide the information required for risk—and changes in risk—to be priced in the insurance industry and the capital markets. This is fundamentally different from other strategies for pricing non-market benefits of resilience projects or social impact projects.

These models can be used to evaluate expected damages from the perspective of a variety of stakeholders, including cat bond investors, insurance companies, reinsurers, private property owners, and public authorities. For cat bond investors, catastrophe models are used to evaluate expected financial risks of the bonds based on (1) the underlying perils, such as potential hurricane damages, and (2) the design attributes of the cat bonds themselves, including bond coverage, trigger type, and other elements described in the following section on bond design. This use of catastrophe models is widely accepted within capital markets, and the model results, including the financial expected loss on the bonds, are key inputs in underwriters' and investors' analyses to price new cat bonds.

THE RE.BOUND MODELING APPROACH

Evaluating the financial benefits of physical risk reductions—and generating data to support effective resilience bond design—requires applying catastrophe models in specific ways. It can be accomplished through a comparative analysis of catastrophe model results from at least two scenarios: a base case, representing expected losses before a resilience project is in place; and a resilience case, after a project is complete and has generated risk reductions. Pricing these project-generated risk reductions generally involves five steps:

1

Identify

the model inputs or assumptions that may be modified to re-present physical risk reductions provided by resilience projects within the catastrophe model

2

Evaluate

base case, or pre-project, risk metrics with the catastrophe model

3

Modify

the model inputs or assumptions to represent the resilience case in a way that captures the physical risk reductions from the resilience project

4

Re-evaluate

risk metrics based on the updated model inputs

5

Compare

the two sets of risk metrics (corresponding to pre- and post-project results) to determine the financial value of project-generated reductions in physical catastrophic risks

Step 1 involves a strategic analysis to identify modifications to model inputs or assumptions that can be used to represent the resilience project design and are feasible for catastrophe modelers to implement. This involves associating key features and design parameters of the resilience project with catastrophe model components that can be efficiently modified. For example, in the case of a seawall or coastal protection system, two essential design parameters are the location of the protection (to identify the protected area) and the level of protection provided, or height of protection above a specified datum. Together these two design specifications can shape a resilience case that shows how the protection from storm surges below the height of a new coastal defense system results in reduced economic losses.

It is important to note that not all risks can currently be modeled using commercially available catastrophe models. Hurricane-linked wind and coastal surge risks are relatively well understood by modelers and accepted by investors. In contrast, model coverage of inland (riverine) flooding and rainfall related risks is less complete, and there are greater challenges associated in modeling projects designed to mitigate against high-frequency flood events. However this is an active area of research with new models in development and soon coming to market. In addition, all catastrophe models are regularly refined and updated to incorporate the latest scientific and technological capabilities and to address the needs of users. In the context of resilience bonds, the RE.bound approach can be applied to any specific resilience project designed to address a peril that can be effectively modeled.

Step 2 is similar to analyses that would be undertaken to issue conventional cat bonds before a resilience project has been implemented. **Step 3** involves making the modifications to the model inputs and assumptions identified in Step 1, and **Step 4** is similar to the analysis undertaken in Step 2. Finally, **Step 5** involves a thoughtful comparison of model outputs to appropriately reflect the financial benefits generated by the resilience project. This step necessarily involves consideration of the distribution of benefits (avoided losses) and various stakeholder interests, including potential public sector resilience bond sponsors, public and private beneficiaries of the resilience project, resilience project developers, and potential resilience bond investors.

The risk measures—and the project-based risk reduction—generated using the approach outlined in this paper are consistent with the information used to price risk in the capital markets (via conventional cat bonds). As a result, they provide an anchor for pricing the financial value of risk reductions and for capturing a portion of that value via resilience bonds.

Importantly—and unlike social impact bonds—the RE.bound approach allows the benefits to be defined and priced up-front, without ongoing obligations to measure and defend social benefit metrics on a progressive basis. As catastrophe models typically calculate risk measures based on a large set of simulated events, which often represent up to one million years of data, they are able to capture project-based risk reductions much more comprehensively than project performance data collected in the years immediately after a project is completed. Performance measurement and evaluation are important for a variety of reasons; however, from an investor-confidence perspective, the RE.bound approach offers an important added benefit. The financial instrument does not depend on or require ongoing measurement of project outcomes, beyond verification of project completion. While models may be updated post-event and risks may be reevaluated and repriced at any time, the results of such reevaluation will not change the cost of resilience bond premiums or the corresponding value attributed to resilience projects—dramatically reducing uncertainty for both investors and sponsors.

IMPLICATIONS FOR RESILIENT INFRASTRUCTURE INVESTMENT

The RE.bound modeling approach discussed above has a number of important implications for investing in resilience. **First,** the ability to reliably measure the financial value of project-generated physical protections provides a new lens for evaluating resilience projects. This lens can be used in a variety of ways. It offers a rational basis for prioritizing projects within an organization's capital plan, for evaluating pending proposals, and for accelerating development of those projects that provide the largest risk reductions.

This lens can also be used to inform project design standards. While there are limits to the types of projects and the level of precision that can be evaluated with commercially available catastrophe models, the potential to explicitly measure financial benefits of alternate project designs allows these benefits to be directly compared with their respective costs. As a result, design standards can be set in a way that optimizes a project's financial performance by maximizing net financial benefits or by equating marginal financial benefits to marginal development costs. Design standards can also be set to specifically support value capture via resilience bonds in order to help fund project development activities.

Second, the RE.bound modeling approach provides the data required to price physical risk reductions in existing markets. The pricing approach represents a pure market mechanism that relies exclusively on existing markets for financial products. As a result, there is no need to develop and defend abstract proxies for the value of social benefits. Moreover, it allows project benefits to be defined up-front, rather than projected forward with ongoing requirements to measure the benefits over time. This ability to define benefits early in the project development process can be particularly useful for prioritizing and capitalizing projects.

Third, the approach tested through RE.bound represents the financial value of risk reductions in a manner that facilitates value capture. Resilience bonds provide a coherent mechanism for capturing a portion of the financial value created by resilience projects. Even if a resilience bond program is not ultimately adopted, data generated through the RE.bound modeling approach can provide clarity and additional flexibility for public entities investing in resilience. It can also help identify other finance strategies to capture a portion of the value created by resilience projects.

Taken as a whole, the ability to use resilience bonds empowers public entities to take a proactive approach to meeting insurance compliance obligations while funding investments in resilience. For example, under the Stafford Act, federal disaster assistance often includes a compliance requirement to purchase and maintain additional insurance. While the concept of leveraging insurance to invest in resilience is not new, until now it has remained in the realm of abstract ideas because there has not been a coherent mechanism to both measure and capture the value. Resilience bonds, enabled by the RE.bound modeling approach, crystallize this concept in a financial mechanism that should enable resilience investments to be directly linked to insurance purchases.

KEY RESULTS AND PROJECT EXAMPLES

In order to validate the modeling approach described above, members of the RE.bound team and collaborating organizations identified and jointly developed three project-specific case studies, based on the prior infrastructure design work of the RE.invest Initiative and parallel infrastructure planning efforts. These cases focused on anticipated or potential infrastructure projects providing flood protection in three cities: Hoboken, Norfolk, and Miami Beach. The key design attributes of each are summarized below:

Coastal Protection (Hoboken, NJ):
The City of Hoboken is exposed to tidal surge risks from both the north and the south. Through the Rebuild by Design competition, Hoboken was awarded federal funding for comprehensive flood defenses comprised of hard and natural infrastructure to provide protection up to a 500-year storm event.

Flood Barriers (Norfolk, VA):
The City of Norfolk is a historic, coastal city subject to significant tidal surge and inland flood risks. The City is pursuing a range of projects designed to provide protection against surge events with intensities up to a 500-year storm.

Seawall Upgrades (Miami Beach, FL):
As a barrier island with ~63 miles of seawall along its interior (bayside) coast, the City of Miami Beach faces significant risks from hurricanes and rising sea-levels. The City is exploring options to upgrade existing seawalls for greater flood protection, but design standards have not yet been set.

The RE.bound Program used two modeling scenarios to estimate the risk reduction created by the coastal protection and flood barrier projects: (1) the pre-project evaluation was conducted using default model settings; (2) the post-project evaluation ignored all storm surge below the different levels of protection which might be provided by the project depending on the final design standard. The following sections provide a detailed picture of the approach and results for preliminary catastrophe modeling undertaken within the RE.bound Program for each project type. It is important to note that the model results provided here are preliminary and have not been sufficiently developed to satisfy market requirements for an actual bond issuance.

Coastal Protection System (Hoboken)

BACKGROUND

Hoboken, New Jersey is an older U.S. city with historical infrastructure dating back to the mid-1800s. The City is prone to flooding due to its location on the Hudson River, low topography, and prevalence of impervious surfaces. In 2012, storm surge from Superstorm Sandy inundated low-lying areas of the city with between 4-6 feet of flood water. Through the Rebuild by Design Competition, Hoboken was awarded $230 million in federal funding to implement its winning 'Resist, Delay, Store, Discharge' proposal. These funds have been approved for use to build the comprehensive coastal protection and flood defense components of the plan, to provide storm surge protection up to the 500-year surge level. Modeling results from RMS indicate that this 500-year surge level is equivalent to a surge height of approximately 12.3 feet above NAVD88 at The Battery tidal gauge, New York.

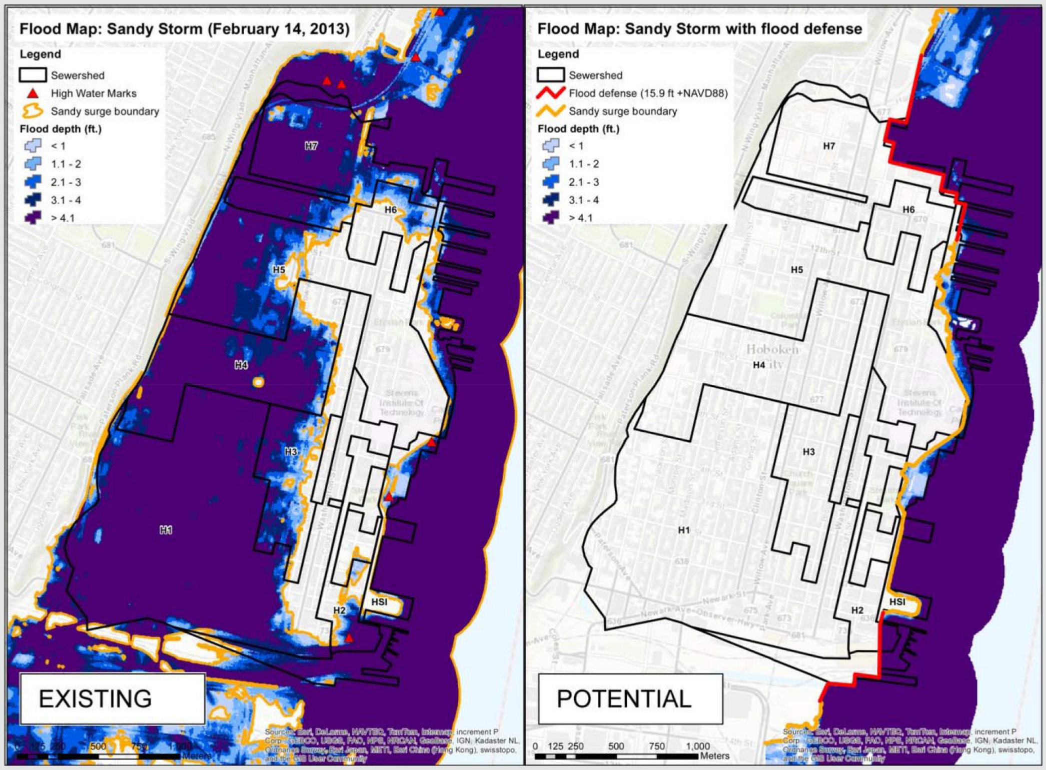

Figure 2. Hoboken flood map with and without flood defenses (Rebuild by Design, 2014).

KEY TAKEAWAYS

- Modeled economic losses from storm surge are large (see Tables 1 and 2).
- Preliminary results from RMS on risk reductions indicate that projects providing protection below eight-feet above datum are unlikely to have a significant impact on surge losses. Each foot of protection above eight-feet provides significant additional value.
- Lack of insurance coverage is a major financial risk for both the City and the State. RMS industry level assumptions around insurance coverage in the U.S. and the mix of property types in the City of Hoboken suggest that as little as 15% of average annual storm surge losses to the City of Hoboken may be insured, with the remainder either uninsured or covered at the federal level through the National Flood Insurance Program.
- These results provide a strong foundation for exploring insurance via a resilience bond that includes a rebate to support project finance.

KEY MODELING ASSUMPTIONS

In order to understand the risk to a particular city or community, it is important to understand the exposure (i.e. the assets and/or population) at risk on a detailed level, including location, usage, types of loss, value, construction and other characteristics such as the number of stories a building has. The risk modeling results outlined herein form an initial step in understanding the nature of the risk to Hoboken from hurricane driven surge events and are based on RMS' proprietary view of insurable exposure and insurance coverage within the U.S. for the City of Hoboken. *Note: The model results provided here are preliminary and have not been sufficiently developed to satisfy market requirements for an actual bond issuance* *(continued on next page).*

Key assumptions used in this analysis are outlined in brief below. See pages 17-19 for a more complete description.

- RMS has assessed the risk to the City of Hoboken from hurricane driven storm surge events using the RMS® North Atlantic Hurricane Models version 15.0. Storm surge originating from other severe weather events such as *nor'easters* is not included in this analysis. Modeled losses include loss due to damage to property and contents and direct business interruption.

- This analysis is based on the RMS industry view of insurable exposure in the City of Hoboken for residential, commercial and industrial assets on a variable resolution ranging from 100m in urban coastal areas up to 10km in very flat rural areas. It therefore does not include publicly owned assets, such as infrastructure or all types of government buildings.

- Modeled losses presented in this analysis are based on modeled surge levels above NAVD88 at a resolution of up to 100m. Modeled surge levels at The Battery tidal gauge, New York are chosen as a reference point in Table 2 and Figure 4, and are highly correlated to water levels along the Hoboken coastline.

RMS Summary Results — City of Hoboken

Return Period*	RMS Base Case Modeled Economic Surge Loss (Millions $)
50 years	<$1
100 years	$361
200 years	$985
500 years	$1,745
Average Annual Loss**	$12.7

Table 1. Summary of base case modeled losses by return period (RMS, 2015).

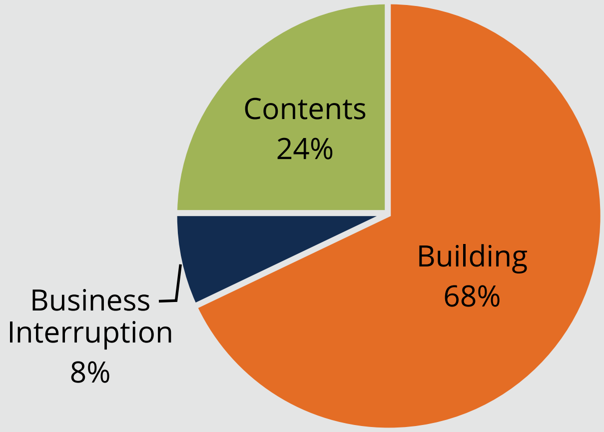

Figure 3. Base case modeled annual average losses by loss type (RMS, 2015).

Return Period*	Modeled Economic Surge Loss (Millions $)			
	8-foot Surge Protection	9-foot Surge Protection	10-foot Surge Protection	11-foot Surge Protection
50 years	<$1	<$1	<$1	<$1
100 years	$361	<$1	<$1	<$1
200 years	$985	$985	$907	<$1
500 years	$1,745	$1,745	$1,745	$1,733
Average Annual Loss**	$12.7	$11.9	$9.4	$6.4

Table 2. Modeled losses by return period, assuming different levels of surge protection. Events with surge levels less than the specified amount of feet, as modeled at The Battery tidal gauge, are assumed to cause no loss (RMS, 2015).

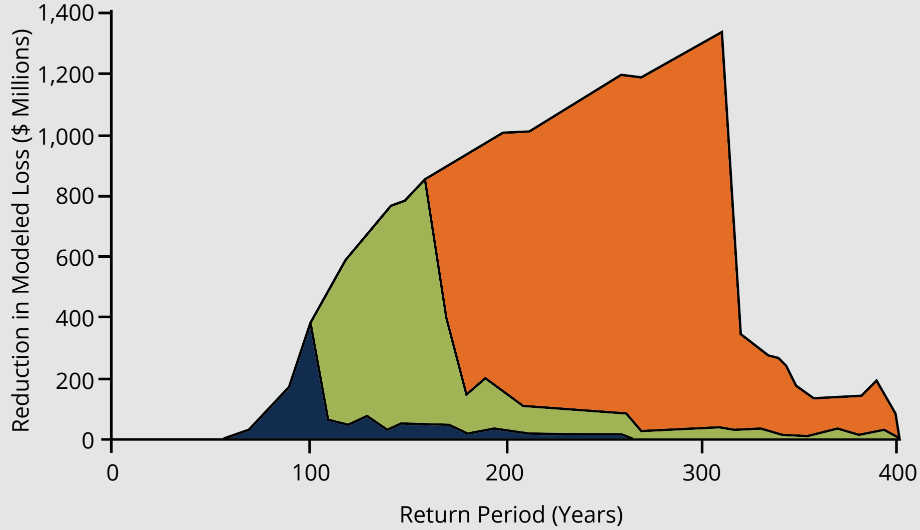

Figure 4. Reduction in modeled losses for alternate levels of protection (RMS, 2015).

* A return period (or recurrence interval) is a period of years and the modeled loss associated with a particular return period, for example 100 years, is the loss that on average is expected to be exceeded every 100 years.
** The average annual loss is the loss that would be expected to occur on average in a year. The figure represents an average over time and when looking at storm surge losses for individual years it would be expected that no or very little loss occurs during most years, but a very large amount of loss occurs during each of the rare remaining years.

RMS Modeling Approach and Assumptions

The information set forth on the previous page, and any other RMS model results referenced in this document, are subject to the RMS Disclaimer and readers are encouraged to review these results in conjunction with the RMS Disclaimer

Modeled Area: City of Hoboken, New Jersey
ZIP Code 07030

Modeled Exposure
An RMS® Industry Exposure Database (IED) contains an estimated inventory of insurable properties and values, grouped by peril, line of business, and coverage type.

Figure 5. Modeled area for the City of Hoboken (shaded grey). The position of The Battery tidal gauge is also indicated by a red circle.

In order to obtain loss results that are as accurate as possible for the localized coastal areas of interest in this study, and which reflect realistic spatial patterns of surge hazard, the analysis is based on a higher resolution version of the RMS IED for U.S. Hurricane. Exposure is represented using a grid with cell sizes varying from 100m in urban coastal areas to 500m in non-urban areas and up to 10km in very flat areas. It contains residential (including personal and commercial residential), commercial and industrial lines of business and has a data vintage of 2011. This higher resolution version of the IED is not currently commercially available. The modeled loss results presented in this paper might therefore differ significantly from the loss results obtained when using the commercially available RMS IED for U.S. Hurricane, where exposures are defined at ZIP-code resolution and an alternative grouping for lines of business is used.

Since the exposure calculated in all RMS IEDs only estimates the total value of insurable properties, it will not include publicly-owned assets such as infrastructure or all types of government buildings. Generally speaking, general services and properties used for education are accounted for in the inventory, but large government building complexes (such as capital buildings, courts, etc.) are not. Automobile exposures are also excluded.

RMS Model Version
RMS North Atlantic Hurricane Models version 15.0 (incorporates the MIKE21 hydrodynamic surge model).

RMS Model Settings
The model offers a choice between long-term and medium-term hurricane event rates. The long-term view assesses hurricane activity using the long-term historical average, based on the post-1900 historical record. The medium-term view represents a five-year forward looking forecast of likely hurricane activity on a regionalized basis. All modeled loss results in this paper are based on the long-term view. Post-event loss amplification has been included in all modeled losses.

Modeled Economic Losses
Total modeled economic loss to the industry, based on the RMS IED, is prior to the consideration of any insurance cover. As the RMS IED only contains an estimated inventory of insurable properties and values in the commercial, industrial and residential lines of business, modeled economic losses do not include potential losses from non-insurable and automobile exposure.

Modeled Insured Losses
The subset of the economic loss which is covered by insurance policies, and accounts for the financial terms of the underlying policies; in particular attachment points, limits and deductibles.

Windstorm insurance policies in the U.S. primarily provide cover against losses from wind damage, rather than storm surge flooding. Surge losses may be paid out under wind policies, however, when either:

1. there is partial surge coverage (mainly for the commercial lines),
2. where wind and water interact such that surge damage cannot be separated from wind damage,
3. or where surge losses are not explicitly excluded in property insurance forms but wind and water interact such that surge damage cannot fully be separated from wind damage (known as 'leakage', mainly for residential lines).

Only a fraction of the full modeled economic surge losses is therefore considered in the calculation of insured losses from storm surge. Assumptions around partial coverage and coverage leakage are made to account for the different industry practices and insurance penetration of surge policies (compared to wind policies), and to give a more realistic estimate of surge losses which are paid for by the insurance industry. It should also be noted that modeled surge losses covered by the NFIP are not included in the modeled insured surge losses.

Modeled loss to NFIP

The NFIP coverage for a location depends on the FEMA flood zone as well as the community in which the location is situated. Participation in the NFIP is known to vary significantly geographically (NFIP participation is mandatory for V- and A-zones, but not for moderate risk zones such as X, where take-up rates tend to be lower). RMS models losses to the NFIP by estimating NFIP take-up rates at a FEMA flood zone level which may not reflect the variation at the community or city level.

Non-Modeled Losses

The RMS North Atlantic Hurricane Models do not include storms that at no point during their life-cycles affect land as a hurricane (i.e. Category 1 or greater), although these types of storms may be able to cause significant storm surge. Storm surge caused by other severe weather systems such as nor'easters is also not modeled. Contingent business interruption, off-premises power losses, and an insurer's claims adjustment expenses are not included in modeled losses.

Surge hazard

Surge hazard is modeled at the tidal gauge closest to the city. For Hoboken, NJ, this is the New York tidal gauge 'The Battery' maintained by the National Oceanic and Atmospheric Administration (NOAA). Its location is indicated by a red circle in the map above. Modeled surge heights are given in feet above the NAVD88 datum.

Flood barriers (Norfolk)

BACKGROUND

The City of Norfolk is an independent coastal city located at the mouth of the Chesapeake Bay near the southern border of Virginia. The City was originally built on fill material and is today experiencing subsidence (due to settlement and compaction), sea-level rise, and chronic tidal flooding. Based on a comprehensive City-Wide Coastal Flooding Study by Fugro (2012), the City is exploring options for implementing multiple flood barrier projects across neighborhoods with chronic flooding and recurring damage. Engineering proposals include: tidal gates, berms, elevated roadways, floodwalls, bulkheads and related storm water system upgrades designed to mitigate flood related losses.

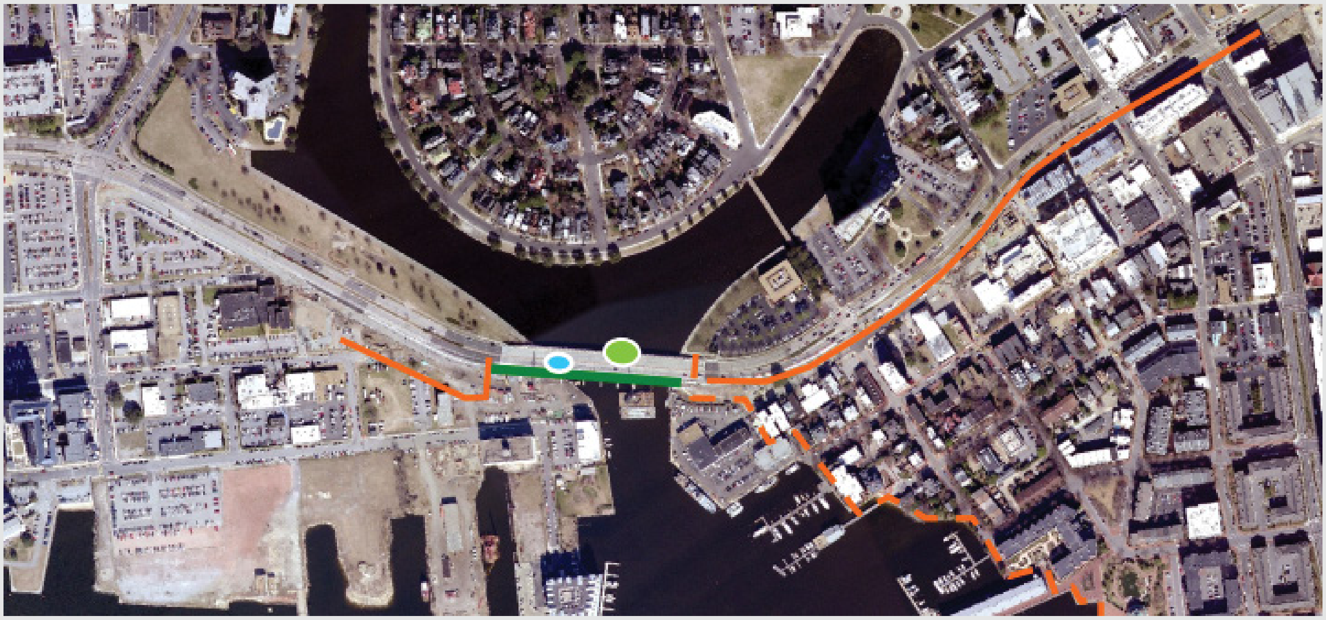

Figure 6. Proposed locations of tidal barrier (floodwall), pump station, and closure walls/berms in the Hague District of the City of Norfolk (Fugro, 2012).

KEY TAKEAWAYS

- Modeled economic losses from storm surge are large (see Tables 3 and 4).
  - A 100-yr storm in terms of preliminary modeled surge losses is associated with >$600 million in losses.
  - Hurricane Isabel (2003) and Superstorm Sandy were less than a 50-year storm in terms of preliminary modeled surge losses for Norfolk.
- Preliminary results on risk reductions indicate that projects providing protection at a surge height of less than seven-feet above NAVD88 are unlikely to have a significant impact on surge losses, but the difference between eight and nine feet of protection is large.
- Lack of coverage is a major financial risk for City and State. RMS industry level assumptions around insurance coverage in the U.S. and the mix of property types in the City of Norfolk suggest that as little as 23% of average annual storm surge losses to the City of Norfolk may be insured, with the remainder either uninsured or covered at the federal level through the National Flood Insurance Program.
- These results provide a strong foundation for exploring insurance via a resilience bond that includes a rebate to support project finance.
- Because the city is considering multiple non-contiguous segments of flood barriers, additional modeling is required to evaluate the level of protection that is possible.

KEY MODELING ASSUMPTIONS

In order to understand the risk to a particular city or community it is important to understand the exposure (i.e. the assets and/or population) at risk on a detailed level, including location, usage, types of loss, value, construction and other characteristics such as the number of stories a building has. The risk modeling results outlined herein form an initial step in understanding the nature of the risk to Norfolk from hurricane driven surge events and are based on RMS' proprietary view of insurable exposure and insurance coverage within the U.S. for the City of Norfolk. *Note: The model results provided here are preliminary and have not been sufficiently developed to satisfy market requirements for an actual bond issuance.*

Key assumptions used in this analysis are outlined in brief below. See pages 24-26 for a more complete description.

- RMS has assessed the risk to the City of Norfolk from hurricane driven storm surge events using the RMS® North Atlantic Hurricane Models version 15.0. Storm surge originating from other severe weather events such as nor'easters is not included in this analysis. Modeled losses include loss due to damage to property and contents and direct business interruption.

- This analysis is based on the RMS industry view of insurable exposure in the City of Norfolk for residential, commercial and industrial assets on a variable resolution ranging from 100m in urban coastal areas up to 10km in very flat rural areas. It therefore does not include publicly owned assets, such as infrastructure or all types of government buildings.

- Modeled losses presented in this analysis are based on modeled surge levels above NAVD88 at a resolution of up to 100m. Modeled surge levels at Virginia Key tidal gauge are chosen as a reference point in Table 4 and Figure 8. However, given the complex geographical shape of the Norfolk coastline, the degree of correlation between water levels at different points along the coastline and at Virginia Key tidal gauge may be

RMS Summary Results — City of Norfolk

Return Period*	RMS Base Case Modeled Economic Surge Loss (Millions $)
50 years	$171
100 years	$611
200 years	$971
500 years	$1,496
Average Annual Loss**	$16.8

Table 3. Summary of base case modeled losses by return period (RMS, 2015).

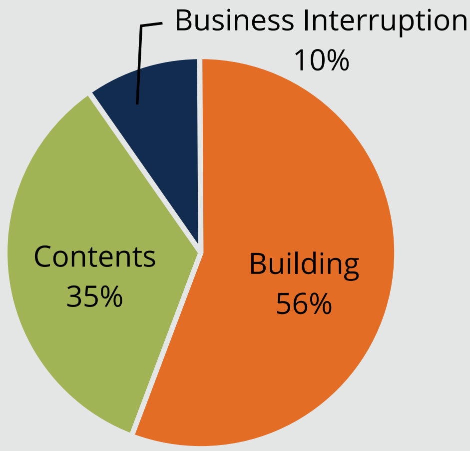

Figure 7. Base case modeled annual average losses by loss type (RMS, 2015).

Return Period*	Modeled Economic Surge Loss (Millions $) 7-foot Surge Protection	8-foot Surge Protection	9-foot Surge Protection	10-foot Surge Protection
50 years	$65	<$1	<$1	<$1
100 years	$610	$464	<$1	<$1
200 years	$942	$941	$677	<$1
500 years	$1,495	$1,489	$1,474	$1,059
Average Annual Loss**	$16.2	$12.8	$8.6	$5.0

Table 4. Modeled losses by return period, assuming different levels of surge protection. Events with surge levels less than the specified amount of feet, as modeled at Virginia Key tidal gauge, are assumed to cause no loss (RMS, 2015).

Figure 8. Reduction in modeled losses for alternate levels of protection (RMS, 2015).

* A return period (or recurrence interval) is a period of years and the modeled loss associated with a particular return period, for example 100 years, is the loss that on average is expected to be exceeded every 100 years.
** The average annual loss is the loss that would be expected to occur on average in a year. The figure represents an average over time and when looking at storm surge losses for individual years it would be expected that no or very little loss occurs during most years, but a very large amount of loss occurs during each of the rare remaining years.

RMS Modeling Approach and Assumptions

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Modeled Area: City of Norfolk, Virginia
ZIP-codes: 23502, 23503, 23504, 23505, 23507, 23508, 23509, 23510, 23511, 23513, 23517, 23518, 23523, 23529

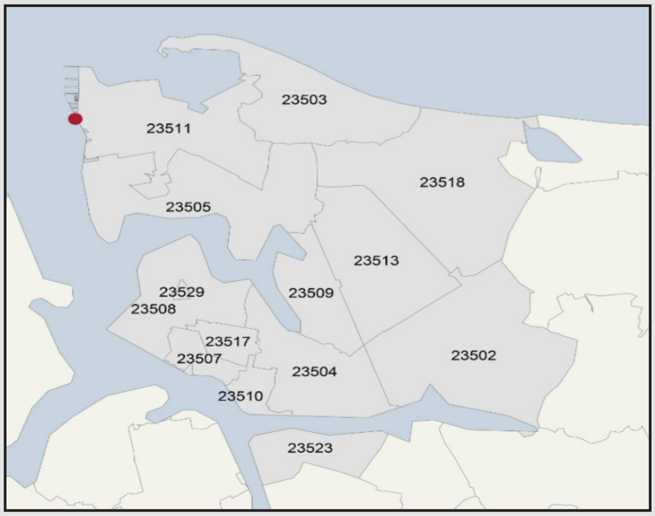


Figure 9. Modeled area for the City of Norfolk (shaded grey). The position of Virginia Key tidal gauge is also indicated by a red circle.

Modeled Exposure
An RMS Industry Exposure Database (IED) contains an estimated inventory of insurable properties and values, grouped by peril, line of business, and coverage type.

In order to obtain loss results that are as accurate as possible for the localized coastal areas of interest in this study, and which reflect realistic spatial patterns of surge hazard, the analysis is based on a higher resolution version of the RMS IED for U.S. Hurricane. Exposure is represented using a grid with cell sizes varying from 100m in urban coastal areas to 500m in non-urban areas and up to 10km in very flat areas. It contains residential (including personal and commercial residential), commercial and industrial lines of business and has a data vintage of 2011. This higher resolution version of the IED is not currently commercially available. The modeled loss results presented in this paper might therefore differ significantly from the loss results obtained when using the commercially available RMS IED for U.S. Hurricane, where exposures are defined at ZIP-code resolution and an alternative grouping for lines of business is used.

Since the exposure calculated in all RMS IEDs only estimates the total value of insurable properties, it will not include publicly-owned assets such as infrastructure or all types of government buildings. Generally speaking, general services and properties used for education are accounted for in the inventory, but large government building complexes (such as capital buildings, courts, etc.) are not. Automobile exposures are also excluded.

RE bound
INSURING FOR RESILIENCE

RMS Model Version
RMS North Atlantic Hurricane Models version 15.0 (incorporates the MIKE21 hydrodynamic surge model).

RMS Model Settings
The model offers a choice between long-term and medium-term hurricane event rates. The long-term view assesses hurricane activity using the long-term historical average, based on the post-1900 historical record. The medium-term view represents a five-year forward looking forecast of likely hurricane activity on a regionalized basis. All modeled loss results in this paper are based on the long-term view. Post-event loss amplification has been included in all modeled losses.

Modeled Economic Losses
Total modeled economic loss to the industry, based on the RMS IED, prior to the consideration of any insurance cover. As the RMS IED only contains an estimated inventory of insurable properties and values in the commercial, industrial and residential lines of business, modeled economic losses do not include potential losses from non-insurable and automobile exposure.

Modeled Insured Losses
The subset of the economic loss which is covered by insurance policies, and accounts for the financial terms of the underlying policies; in particular attachment points, limits and deductibles.

Windstorm insurance policies in the U.S. primarily provide cover against losses from wind damage, rather than storm surge flooding. Surge losses may be paid out under wind policies, however, when either:

1. there is partial surge coverage (mainly for the commercial lines),
2. where wind and water interact such that surge damage cannot be separated from wind damage,
3. or where surge losses are not explicitly excluded in property insurance forms but wind and water interact such that surge damage cannot fully be separated from wind damage (known as 'leakage', mainly for residential lines).

Only a fraction of the full modeled economic surge losses is therefore considered in the calculation of insured losses from storm surge. Assumptions around partial coverage and coverage leakage are made to account for the different industry practices and insurance penetration of surge policies (compared to wind policies), and to give a more realistic estimate of surge losses which are paid for by the insurance industry. It should also be noted that modeled surge losses covered by the NFIP are not included in the modeled insured surge losses.

Modeled loss to NFIP

The NFIP coverage for a location depends on the FEMA flood zone as well as the community in which the location is situated. Participation in the NFIP is known to vary significantly geographically (NFIP participation is mandatory for V- and A-zones, but not for moderate risk zones such as X, where take-up rates tend to be lower). RMS models losses to the NFIP by estimating NFIP take-up rates at a FEMA flood zone level which may not reflect the variation at the community or city level.

Non-Modeled Losses

The RMS North Atlantic Hurricane Models do not include storms that at no point over their life-cycles affect land as a hurricane (i.e. Category 1 or greater), although these types of storms may be able to cause significant storm surge. Storm surge caused by other severe weather systems such as nor'easters is also not modeled.

Contingent business interruption, off-premises power losses and an insurer's claims adjustment expenses are not included in modeled losses.

Surge hazard

Surge hazard is modeled at the tidal gauge closest to the city. For Norfolk this is the tidal gauge "Virginia Key" maintained by the National Oceanic and Atmospheric Administration (NOAA). Its location is indicated by a red circle in the map above. Modeled surge heights are given in feet above the NAVD88 datum.

Seawall upgrades (Miami Beach)

BACKGROUND

Miami Beach is a coastal city in Miami-Dade County, Florida, located on a series of natural and man-made barrier islands between the Atlantic Ocean and Biscayne Bay; the latter separates the Beach from Miami city proper. Along the bayside and canals, the City is supported by 63 miles of seawall, of which only three miles are publicly owned. To date nearly all of the seawalls have been deemed structurally deficient. As a low-lying island, Miami Beach experiences significant and regular tidal flooding. Through the RE.invest Initiative, the City worked to identify an engineering solution and mechanism to protect against chronic city-wide tidal flooding and coastal erosion, to address long-term sea-level rise and the threat of more severe storm surges. The proposed engineering solution included a new seawall to be constructed on the outside of the existing seawall. The new wall also integrates a barrier system to better manage subsurface hydrological flows.

Figure 10. City of Miami Beach GIS Tidal Flood Areas Map (RE.invest Initiative, 2015).

KEY TAKEAWAYS

- Modeled economic losses from storm surge are large, from 10% of total value (10 year return period) to 27% of total value (500 year return period) (see Table 5).
- Preliminary results on risk reductions indicate that seawall upgrades that raise the seawall cap minimum elevation from 3.2 feet NAVD88 to 5.7 feet NAVD88 can provide significant benefits, particularly in reducing loss from frequent, low intensity surge events.
- The suitability of this resilience project for a resilience bond is not clear from preliminary modeling and additional analysis is required.

Swiss Re Summary Results — City of Miami Beach

Event Frequency (Return Period in Years)	Probability of Occurrence	Modeled Economic Surge Loss-Base Case (Millions $)	Modeled Economic Surge Loss-Upgraded Case (Millions $)
10-year storm	10.00%	$81	$4.4
50-year storm	2.00%	$163	$158
100-year storm	1.00%	$194	$193
200-year storm	0.50%	$220	$219
500-year storm	0.20%	$247	$245
Average Annual Loss		**$14.4**	**$11.8**

Table 5. Modeled losses by return period, assuming different levels of surge protection (Swiss Re, 2015).

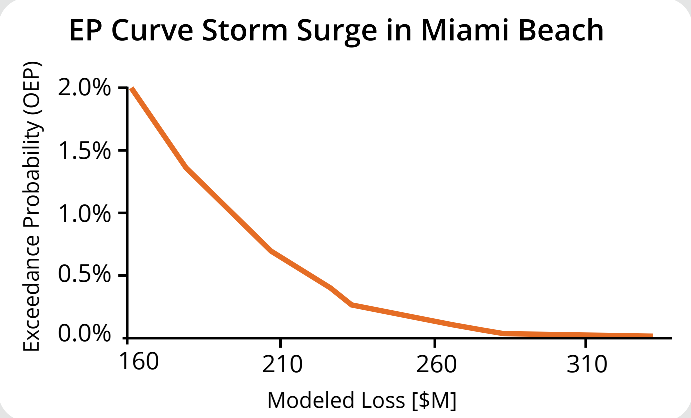
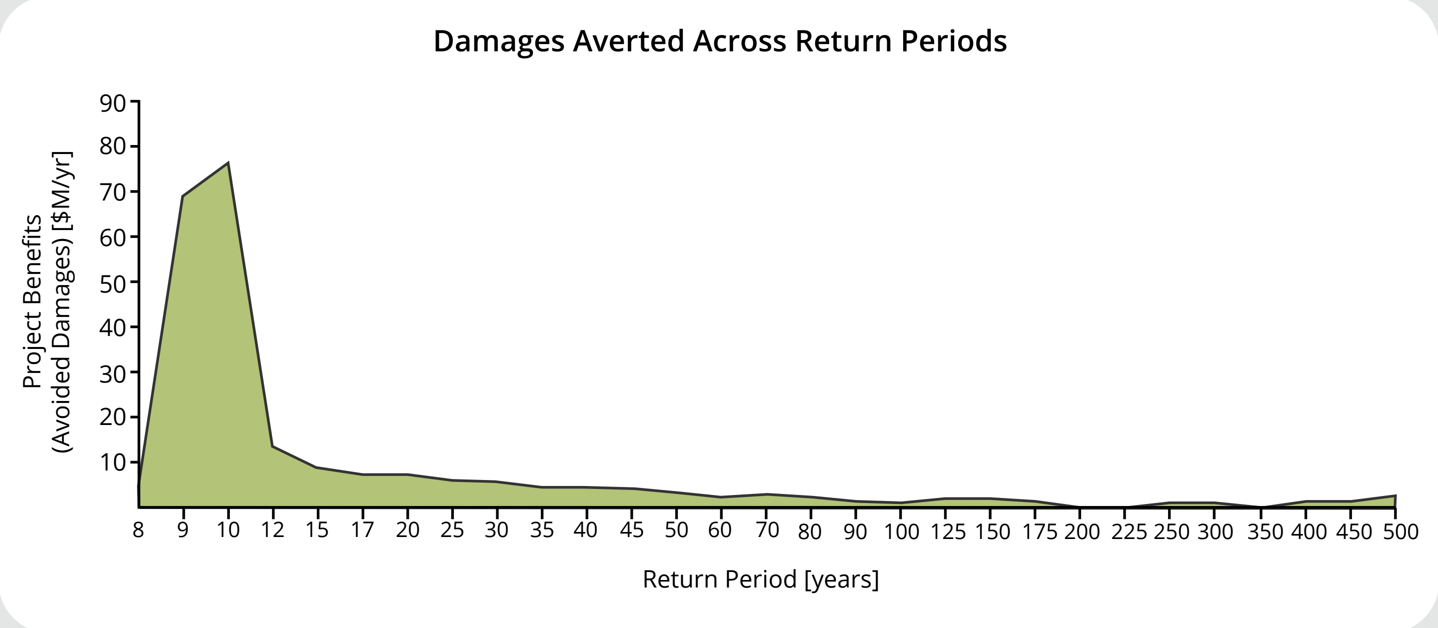


Figure 11. Exceedance probability curve for Miami Beach storm surge. This figure illustrates the probability distribution of damages to Miami Beach's city-owned assets from extreme (low probability) storm surge events. The distribution is based on the current conditions in Miami Beach, with the existing seawall (Swiss Re, 2015).

Figure 12. Damages averted across return periods (Swiss Re, 2015).



Swiss Re Modeling Approach and Assumptions

Miami Beach, Florida
Covered Area
ZIP Codes 33139, 33140 & 33141

Insurable city-owned assets
The schedule of asset values (SoV) for the city of Miami Beach serves as the underlying asset base for modeling. The SoV, representative of expected exposure in July 2016, contains 96 assets, with a total value of USD 910 million. The asset types include public office buildings, theaters and entertainment facilities, wastewater treatment plants and public housing. The geographic resolution of the provided portfolio is at postal code level.

Swiss Re Model Version(s)
The Swiss Re Next Generation (NG) Tropical Cyclone North Atlantic (TCNA) model is used. Released in 2010, the Swiss Re NG TCNA model couples tropical cyclone wind fields, generated using the Holland (1980, updated 2008) model, with the Sea, Lake and Overland Surges from Hurricanes (SLOSH) model, and a high resolution digital elevation model to determine water heights at various locations.

Swiss Re Model Settings
The Swiss Re NG TCNA model is run using near term event frequencies to consider the impact that the Atlantic Multidecadal Oscillation is having on North Atlantic hurricane activity. Post-loss amplification is included.

Modeled Losses
Total, or ground up, modeled loss to the portfolio is produced, without the consideration of any insurance or reinsurance conditions. Please note that since the resiliency measure focused on was a sea wall, only the sub-peril of storm surge was analyzed. The impacts of wind and rain are not considered.

BOND DESIGN & STRUCTURING

RESHAPING CATASTROPHE BONDS AS RESILIENCE BONDS

BOND DESIGN & STRUCTURING

RESHAPING CATASTROPHE BONDS AS RESILIENCE BONDS

Building on the risk reduction modeling process and results described in the previous section, the second step in the RE.bound Program was to explore options for designing and structuring a new type of resilience bond to help communities improve their resilience to natural disasters. This section focuses on the **three main building blocks of resilience bonds: (1) insurance, (2) resilience projects, and (3) rebates** (generated from insurance savings). These basic building blocks can be further broken down into nine key elements, which differentiate resilience bonds from cat bonds.

The discussion in this section is intended to provide a point of departure for designing effective resilience bonds. Its aim is to describe those elements that are most fundamental for *reshaping* cat bonds as resilience bonds, not to provide a comprehensive treatment of bond structure. It is worth emphasizing that the insurance benefits of resilience bonds are generally similar to those available through conventional cat bonds. The distinguishing features of resilience bonds reflect their goal of capturing a portion of the insurance value created by resilience projects in the form of a rebate.

It is also worth emphasizing that **there is no one-size-fits-all design for either cat bonds or resilience bonds.** Rather there are common underlying elements that all bond designs share. This section focuses on providing an overview of these elements, recognizing that all bonds must be tailored to local risks, resilience project opportunities, and insurance priorities. Bond design decisions will ultimately be driven by these factors and the specific interests of sponsors.

Cat bonds were originally developed to provide insurance companies with an alternative to traditional reinsurance; however, their cost effectiveness and flexibility has made these types of bonds an attractive insurance option for large asset holding entities who could be devastated by natural disasters. **As a result, cat bonds are increasingly being used by public or quasi-public entities to complement traditional insurance or reinsurance.** Examples include:

- New York Metropolitan Transportation Authority's (MTA) 2013 cat bond issuance
- Mexico's 2009 and 2012 cat bonds issued using the World Bank's MultiCat platform
- Florida Citizens Property Insurance cat bond program
- The California Earthquake Authority's cat bond program
- Louisiana Citizens Insurance's cat bond program
- Texas Windstorm Insurance Association's cat bond program
- Amtrak's October 2015 cat bond issuance

With these programs, the cat bond sponsors (insurance purchasers) are buying insurance to help offset the financial costs of recovery when a disaster strikes. They are buying financial protection; however, they still remain exposed to all the physical risks that disasters impose on communities—population displacement, infrastructure failures, service disruptions, critical supply shortages, health-care impacts, and mortality. Financial insurance cannot protect against these risks, it can only reduce their financial consequences for asset owners and the indirect impacts on the broader community. **Every cat bond sponsor has an interest in protecting against physical risks**, and mobilizing investments into projects that provide real, on-the-ground protection from perils, such as storm surge and flood. Transitioning from cat bonds to resilience bonds can offer sponsors additional value by providing financial protection plus resilience rebates to support investments into physical protection, including resilient infrastructure projects. Figures 14 and 15 diagram the major components and cash flows associated with a conventional cat bond and with new resilience bonds respectively.[6]

Conventional cat bonds are financial instruments that provide insurance to sponsors and provide a return to investors. As indicated in Figure 14, cat bond sponsors enter into a re/insurance contract or a similar derivative contract and make premium payments to the bond issuer in exchange for a payout if disaster strikes. The issuer is typically a business entity created specifically for the purpose of issuing the cat bonds—a so-called special purpose vehicle or SPV. The cat bond transaction is typically structured by an issuance group, which generally includes one or more investment banks, (re)insurers or insurance brokers to structure, underwrite, and market the bonds, and a risk modeling firm to evaluate the downside risk to investors. Cat bonds are issued to investors by the SPV (issuer). Proceeds from the bond sales are deposited into a collateral account, where the funds are invested in securities with very low risks (e.g., in secure structured notes, such as IBRD notes issued by the World Bank, or in money market funds that invest in U.S. Treasury Bills). During the term of the bond, the issuer collects both premiums from the sponsor and interest earned in the collateral account and distributes regular coupon payments to investors.

What happens next depends on whether a disaster strikes that meets the conditions specified as a 'trigger event.' If there is no trigger event during the bond term, then the investors get their money back at the bond's maturity date. This return of principal, combined with the coupon payments, provides investors with a return on investment. On the other hand, if a trigger event does happen during the bond term, then the investors lose all or a portion of their principal investment, depending on the severity of the event. This money is used to make a payout to the cat bond sponsors.

[6] For a summary of how conventional cat bonds are structured, see the World Bank's MultiCat Program: http://treasury.worldbank.org/bdm/pdf/MultiCat_ProductNote.pdf (World Bank, 2011).

The return on investment provided to cat bond investors must compensate investors for the chance that they will lose their money. A key feature of cat bonds is that the rate of return generally scales with the probability that a trigger event will occur or, more specifically, with the expected loss. In other words, **a 'riskier' bond comes with a higher premium for sponsors and higher rate of return to investors.**

The relationship between the return on investment to cat bond investors (i.e., measured as the interest spread between the collateral account yield and the coupon paid to investors) and the risk that the investors will lose their money (i.e., frequently measured as the bond's expected loss) is illustrated in Figure 13. Note that the risk to cat bond investors is generally defined by independent risk modeling firms that use catastrophe models to evaluate the chances of a trigger event occurring. The use of catastrophe models to measure the risk to cat bond investors and the ability to price that risk directly in the capital markets provides a relatively transparent mechanism for pricing insurance coverage provided to sponsors, the underlying risk of catastrophic events, and risk reductions provided by resilience projects.

Theoretical Value of Risk Reduction

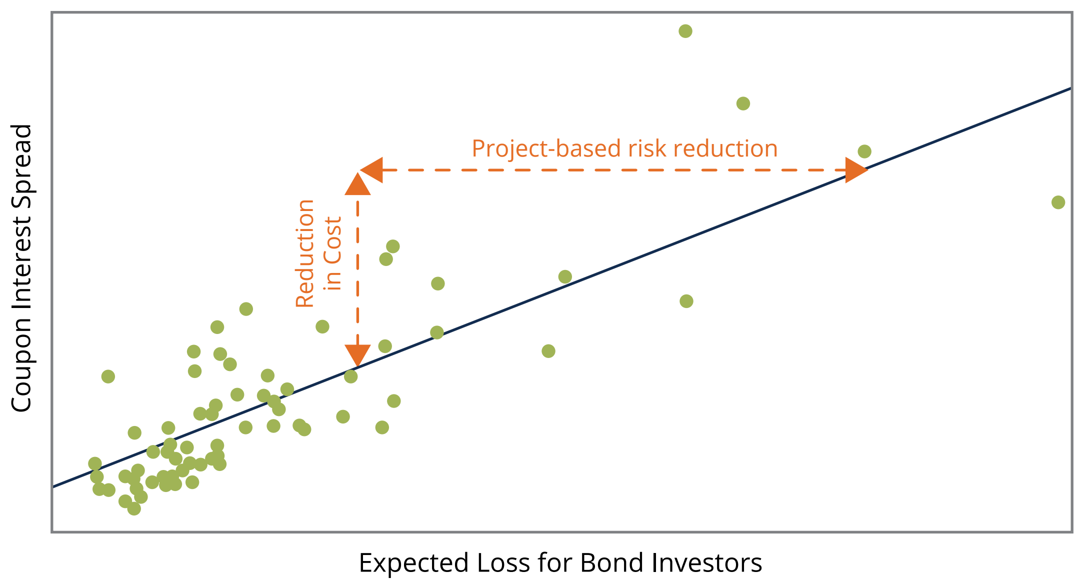


Figure 13. Cat bond coupon as a function of expected loss. Plotting the coupon spread of historically issued cat bonds as a function of expected loss to investors illustrates the fundamental linkage between these bond parameters and highlights the relative transparency of risk pricing in capital markets. The trend line included in this figure suggests that a reduction in expected losses—e.g., resulting from a resilience project—should result in a reduced coupon, which can be captured as a rebate within Resilience Bond structures. Source: Miu Pricing Report (RMS, 2015).

In principle, resilience bonds can be structured similarly to conventional cat bonds except that they explicitly anticipate the impact that resilience projects can have on the chances of a trigger event occurring. **In effect, resilience bonds are priced at two levels: one based on the chance of a trigger event *without* the resilience project; and one based on the chance of a trigger event *with* the resilience project.** Assuming that the resilience project reduces the chance of a trigger event, then resilience bond investors should be willing to accept a lower coupon after the project is completed. The difference in the coupon pricing represents the financial value that a resilience project provides by reducing the expected loss of bonds placed in the capital markets. Resilience bonds explicitly measure this value so it can be captured it in the form of a resilience rebate.

This conceptual framework for structuring resilience bonds is illustrated in Figure 15. Notice that the basic relations between sponsors, issuers, investors, and the collateral account are similar to those in conventional cat bonds. The difference is that resilience bonds explicitly evaluate the impact of the resilience project on the investor's expected loss. Assuming that the resilience project reduces the expected loss to investors, then the project can create a resilience rebate from the reduced cost of coupon payments to investors. This can be implemented in two steps. The first step is to model project impacts on the expected loss for bond investors, for example, using the RE.bound approach discussed in the previous section. This is indicated in Figure 15 by the arrows connecting the resilient infrastructure project to the risk modeling and to the issuer. The second step is to create a rebate by capturing the cost savings from the reduction in coupons paid to investors. This is shown in Figure 15 by the arrows connecting the sponsors and investors to the resilience rebate.

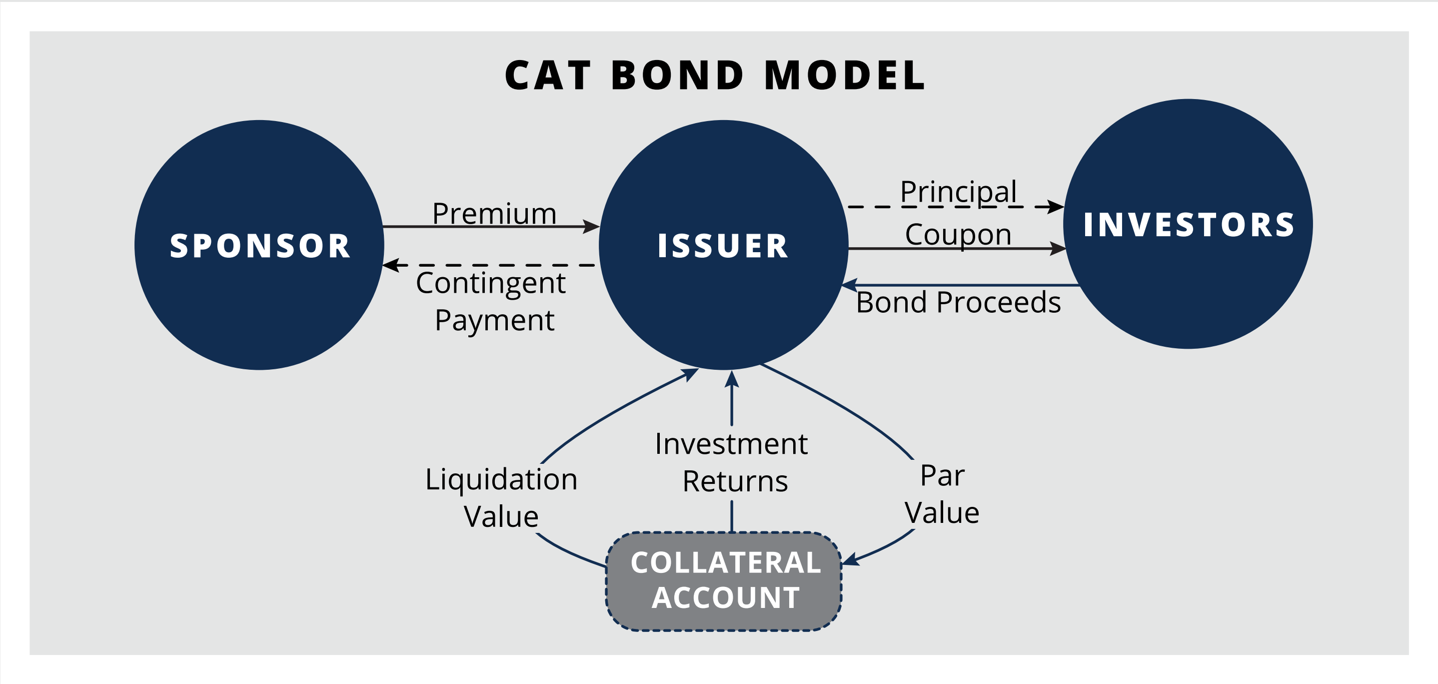


Figure 14. Generalized catastrophe bond structure.

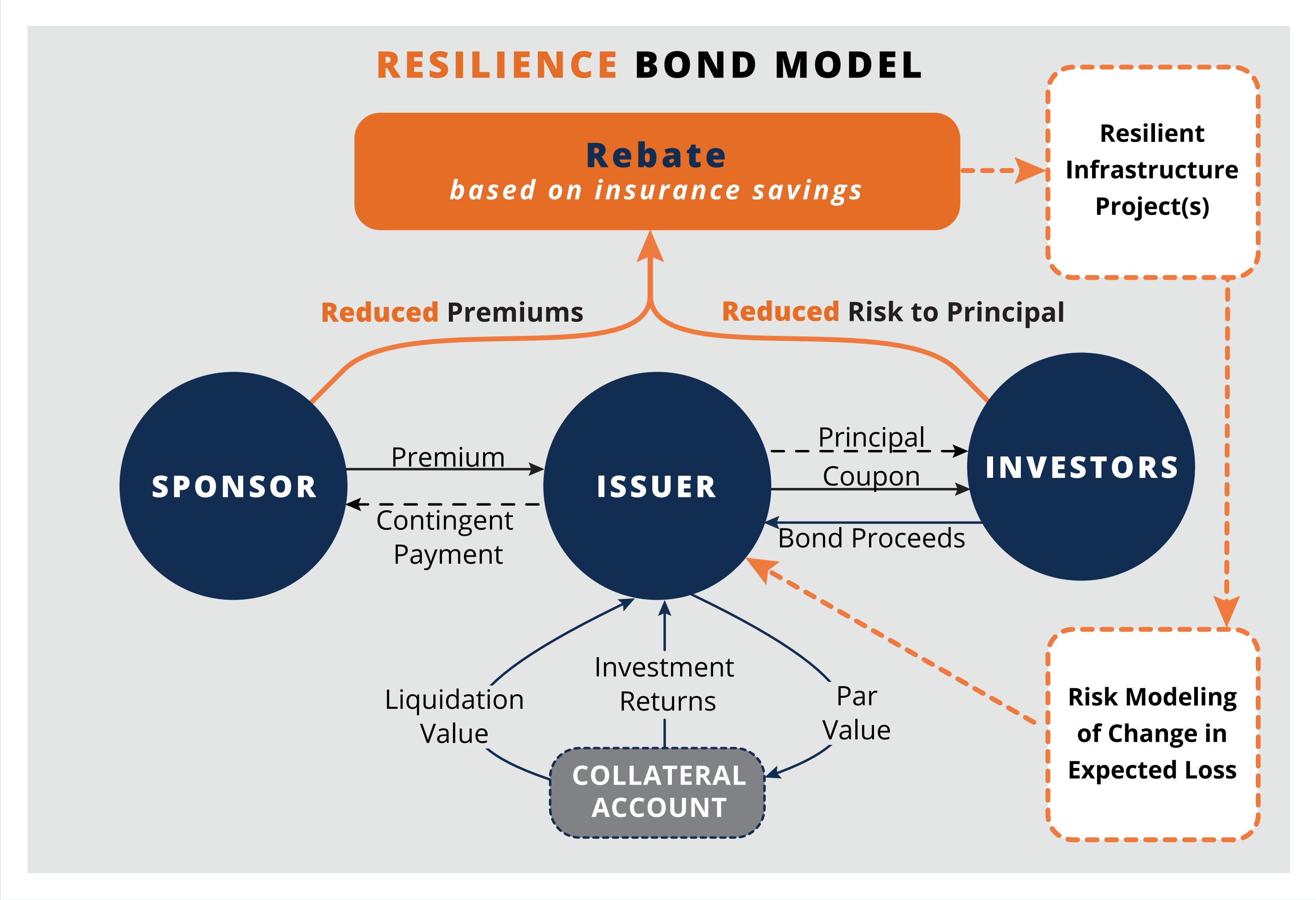


Figure 15. Proposed resilience bond structure.

RESILIENCE BOND

BUILDING BLOCKS & DESIGN ELEMENTS

THE 3 MAIN BUILDING BLOCKS

- **INSURANCE**
  - SPONSOR
  - COVERAGE
  - TIMING
  - TRIGGER
  - MARKET RISK MANAGEMENT
- **RESILIENCE PROJECTS**
  - PROJECT ELIGIBILITY
  - QUALIFYING RISK REDUCTIONS
- **REBATES**
  - REBATE MECHANISM
  - REBATE MANAGEMENT

THE 9 DESIGN ELEMENTS

The **9** main design elements are described **individually** in the following pages.

INSURANCE

SPONSOR

Resilience bond sponsors purchase insurance and have an interest in **reducing physical damages from disasters**. Sponsors pay premiums and receive payouts if a disaster strikes. Sponsors also decide which projects qualify for coupon reductions and how potential rebates are used. Bonds can be co-sponsored by multiple parties with shared interests.

COVERAGE

Coverage describes the **insurance purchased by resilience bond sponsors**. Bond coverage can be tailored to complement existing insurance and risk management programs. In order to enable effective rebates, coverage must encompass the risks being reduced by resilience projects.

TIMING

Resilience bonds should be **coordinated with the timelines and development milestones of specific resilience projects**. This can be done in a variety of ways. Examples include short-term, single issue bonds with price resets and longer-term sequences of resilience bonds.

TRIGGER

Bond triggers specify when **sponsors receive insurance payouts**. There are at least 4 trigger types. **Indemnity** and **industry loss** triggers pay when financial losses are documented, but payouts may be delayed by accounting processes. **Parametric** and **Modeled Loss** triggers can provide rapid response funds, but may not provide payouts when losses are incurred if the threshold parameter value isn't reached.

MARKET RISK MANAGEMENT

Capital market dynamics create opportunities for risk reductions to be improperly valued in investor pricing. Various strategies are available to mitigate these risks, depending on other aspects of the bond design. Bond designs should include appropriate measures to protect Sponsors from these market risks.

Resilience bonds are intended to provide a **reduction in insurance costs** that can be captured as a resilience dividend or "rebate" **(SEE REBATES)**

RESILIENCE PROJECTS

PROJECT ELIGIBILITY

Resilience bonds must **specify which projects are eligible to generate potential rebates.** This specification should both identify eligible projects and indicate which project parameters will be used to measure risk reductions.

QUALIFYING RISK REDUCTIONS

Resilience bonds must **specify how project generated risk reductions will be qualified under the bond program.** This includes developing a risk modeling plan to quantify the risk reductions. It also includes protocols to define when a project is completed.

A unique feature of resilience bonds relative to cat bonds is their **direct connection to real, on-the-ground risk reduction projects.**

REBATES

REBATE MECHANISM

Resilience bonds must **pre-specify the mechanics of rebate transactions**, including how coupon reductions will be translated into rebates and who will receive them.

REBATE MANAGEMENT

The use of **rebate funds must be specified in advance.** This includes allocating funds among capitalizing resilience projects, reducing premiums, and increasing coverage as well as defining the detailed use of funds within each of these categories.

Reductions in bond coupons may be captured and used in a variety of ways to **support local resilience priorities.**

INSURANCE-BASED ELEMENTS OF RESILIENCE BONDS

The insurance design elements of resilience bonds are nearly identical to those of cat bonds. Like cat bonds, the aim of resilience bonds is to provide financial protection, in the form of catastrophe insurance. **The main difference is that resilience bonds are also intended to provide a reduction in insurance costs** that can be captured as a resilience dividend or 'rebate' to support investments in projects that provide physical protection against catastrophic events. As a result, high-quality modeling is a prerequisite for effective structuring to validate baseline risk and exposure and to quantify potential project based risk reductions. Five main elements from traditional cat bonds are described below: **sponsors, coverage, timing, triggers, and market risk mitigation.**

1 Resilience Bond Sponsors

Sponsors of resilience bonds are parties with interests in both purchasing insurance and mobilizing investments to reduce physical risks from catastrophic events. Like purchasers of conventional insurance, resilience bond sponsors pay insurance premiums in exchange for a payout if disaster strikes. Unlike purchasers of conventional insurance, or sponsors of conventional cat bonds, resilience bond sponsors can recognize a portion of the insurance value created by resilience projects in the form of resilience rebates.

Resilience bonds are different products than municipal bonds or corporate bonds issued by the sponsors. Sponsors are entering into an insurance contract with the SPV issuer of the resilience bond. Sponsors are **not responsible for repaying bond principal**, and resilience bonds are **unlikely to compromise sponsor balance sheets** or available debt capacities. Sponsors are **only responsible for premium payments**—just like any other insurance purchase.

Resilience bonds can be structured with a single sponsor or with multiple co-sponsors. An intermediary (in addition to the SPV issuer) would typically be used to facilitate the issuance of resilience bonds with two or more co-sponsors. The role of this intermediary is to collect premiums from the co-sponsors and to distribute any payouts to the co- sponsors if a bond is triggered by a catastrophic event. Premiums and payouts can be allocated among resilience bond co-sponsors in a number of ways. Factors affecting this allocation may include the co-sponsors' relative risk exposures, their particular insurance needs, or their broader resilience priorities.

2 Bond Coverage

Bond coverage describes the type of insurance provided by resilience bonds. Similar to traditional insurance, **resilience bonds provide payouts when particular events occur**; however, payouts are limited in a number of important ways. First, similar to traditional insurance, sponsors must specify the particular perils or hazards that are to be covered. Perils covered by recent cat bonds provide clear precedents for what risks resilience bonds can address. For example, storm surge, wind, tornado, winter storm, earthquake, and excess mortality are all associated with recent cat bond issuances. Second, sponsors will generally need to specify the sources of damages, or exposures, to be covered. Exposures may include, for example, the sponsors' physical assets, business operations, supply chains, or personnel that may be affected when disaster strikes. Again, this is no different than traditional insurance.

Finally, sponsors need to decide how severe an event should be before the resilience bond provides an insurance payout. Severity can be defined in terms of threshold levels of monetary damages or total losses from an event to the insurance industry. Threshold severities can also be based on physical measurements of the event itself. Examples include the storm surge height, wind speed, or earthquake magnitude or ground motion acceleration. These threshold options are referred to collectively as bond 'triggers' (discussed further below), because events that achieve a specified threshold will trigger insurance payouts to the sponsors. Note that triggers are typically defined so that a payout occurs if the intensity of an event exceeds a threshold value, and higher event intensities often increase the size of the payouts until the bond funds are exhausted.

Once a resilience bond is triggered, the total payouts are limited by the bond size, or the quantity of bonds issued to investors. The size defines the total value of funds available for payouts if disaster strikes, and therefore it represents the upper limit of insurance provided to the sponsors. In principle, resilience bonds can be issued in a wide range of sizes, from several million U.S. dollars up to over a billion dollars; typically, issuances between one hundred and several hundred million dollars are the most common in current cat bond markets. The right size for sponsors will depend on a variety of factors, but generally speaking, resilience bonds can be scaled in three ways:

1. they can be scaled so that premiums fit within the available budget for insurance purchasing;
2. they can be scaled so that they meet particular insurance requirements; or
3. they can be scaled to offer a specific level rebate to help finance particular resilience projects.

In practice, all three of these scaling factors will likely influence sponsor decisions on the bond size. Moreover, the sponsor will also have to consider how much demand the bond is likely to be able to attract in the investor community, in order to ensure that the entire bond can be placed in the market successfully.

In these ways, the coverage provided by resilience bonds is **limited at the lower end by the trigger and at the upper end by the bond size**. These limits are important because sponsors will need to rely on other strategies to cover disaster recovery costs that don't fall within these boundaries. Adjustments to bond triggers and sizes enable resilience bonds to be tailored to target particular segments of the sponsor's risk exposure and complement a sponsor's broader insurance and risk management portfolio. Note that tailoring insurance instruments to target particular segments of risk is common in traditional insurance policies.

One aspect of coverage that is unique to resilience bonds is its implication for **coupon pricing and reductions from resilience projects**. This is because resilience projects often reduce risks in very particular ways. As a result, resilience bonds' coverage must be defined to encompass risks that resilience projects will actually reduce. This can create unique trade-offs with respect to insurance benefits and potential rebate benefits of resilience bonds. Striking an appropriate balance between these two types of benefits will require a number of decisions that will be driven by local factors and the particular interests of the sponsors.

3 Bond Timing

Resilience bonds are specifically intended to capture a portion of the insurance value created by resilience projects. As a result, resilience bonds are **most effective when they are coordinated with project development timelines and milestones**. A point of consideration is that bond issuance and resilience project development timeframes are unlikely to be naturally aligned. Cat bonds are typically issued with three to five year terms, whereas large-scale resilience projects, particularly major infrastructure projects, can take a decade or more to complete in multiple phases and can remain in service for half a century or more.

One way to coordinate the timing of resilience bonds with project development is to issue the bonds shortly before a resilience project is initiated and design it to mature several years after initial construction (of a given phase) is completed. A bond designed in this way could be initially priced with a coupon reflecting the baseline risk (before any project-generated risk reductions), with an opportunity for the coupon to 'reset' to a lower level once the project is completed. Another option is to issue multiple resilience bonds over time in a sequence of consecutive issuances. The first resilience bonds in a sequenced program would be priced with coupons that reflect the baseline risk, while bonds issued after project completion would have coupons that reflect the project-based risk reductions, which would be re-evaluated in advance of each new issuance.

Both the short-term, single issue *reset* option and the longer-term, *multi-issue sequence* option allow for consecutive resilience bonds to be issued over time through forward-looking programs. This enables sponsors to continue receiving insurance benefits of resilience bonds and to continue generating rebates from a portion of the insurance value created by the project. In this way, **resilience bond programs can recognize and incentivize the types of long-term risk reductions that resilience projects can provide.**

More generally, timing alignment can be addressed by recognizing the variety of incentives that resilience bonds can provide during different phases of project development. For example, during the predevelopment phase, before key project design decisions have been made, resilience bond programs can be structured to provide the promise of rebates over multiple bond issuances for projects that deliver measurable risk reductions. They can also focus attention on design features that affect the magnitude risk reductions and even inform design criteria or standards for project approval. Further, resilience bonds can inform project finance decisions by providing a path to monetizing the insurance value created by the project.

The options described above for coordinating resilience bond timing with project development timelines are not mutually exclusive, but each involves a number of trade-offs. The right approach for each resilience bond program will be driven by local factors and by the specific interests of the sponsors.

4 Triggers

Bond triggers are criteria that provide an unambiguous way to determine the insurance payout to sponsors from the bond. Resilience bond triggers are generally similar to triggers used for conventional cat bonds. There are four basic types: **indemnity triggers, industry loss triggers, parametric triggers, and modeled loss triggers**. Hybrids of these are also possible.

Bonds with indemnity triggers provide payouts to sponsors when their financial losses (or recovery costs) from a covered event reach a specific dollar amount. For example, with a resilience bond that covers storm damages, a sponsor could receive a payout if it experiences direct storm losses over $200 million. Such indemnity bonds require particularly good data regarding the sponsor's exposure and generally require insurance adjustor data to verify the losses realized. **Bonds with industry loss triggers provide insurance payouts when aggregate losses realized by the insurance industry, as estimated by an independent party such as Property Claim Services (PCS)**, reach a specific dollar amount. For example, a sponsor could receive a payout if a storm drives insurance industry losses in excess of $1 billion dollars.

Bonds with parametric triggers provide payouts when a physical measure of the event itself reaches a specified threshold value. For example, a sponsor could receive a payout if a particular tide gauge registers a maximum storm surge height greater than ten feet above datum. Bonds can also have triggers that provide payouts when a mathematical combination of parameter values meets a particular level. Continuing the storm surge example, a sponsor could receive a payout if the surge heights measured across a (potentially large) number of tide gauges reaches an average value of ten feet above datum. The mathematical computations for such triggers can become quite complex, where **modeled loss triggers represent the most complex type**. In this case, available parametric data are input into a catastrophe model and the bond provides a payout when the modeled loss output exceeds a threshold amount. For example, a sponsor might get paid if modeled surge losses from a particular storm exceed $1 billion.

Selecting the trigger type for a resilience bond involves balancing a number of tradeoffs. For example, a key advantage of parametric and modeled loss triggers is that events can be evaluated quickly resulting in fast payouts to provide rapid response funds. On the other hand it is important to know that sponsors may incur catastrophic losses without receiving a payout using these types of triggers because the specified parameter did not meet the threshold level or because the modeled loss didn't match actual losses. This risk cuts both ways, and parametric triggers can also create payouts in cases when a threshold was met but significant losses were *not* incurred. In both cases, this risk is referred to as 'basis risk.' Basis risk is an important consideration for all bond sponsors. It can generally be minimized by adopting indemnity-type triggers, which are based on actual losses incurred; however, this requires costs to be tallied and verified before sponsors receive a payout. As a result, both indemnity and industry loss triggers are often associated with delayed payouts. Such delays can take years to resolve, particularly if bond investors dispute the financial accounting. Generally speaking, the premium costs for resilience bonds will tend to decrease with the trigger's transparency to investors, as more transparent triggers will increase investors' understanding of the degree of uncertainty in the estimated probability of a trigger event occurring.

5 Market Risk Mitigation

Resilience bonds face unique market risks relative to conventional cat bonds, because of the challenges of pricing both near-term changes in risk and long-term benefits associated with many types of resilience projects.

The *bond timing* section above introduced two approaches for coordinating the issuance of resilience bonds with resilience project construction timelines—a short-term reset and longer-term sequence of issuances. While both of these approaches can be effective, they each face market risks when it comes to accurately valuing financial benefits of physical risk reductions within capital markets. It is important for potential sponsors to have a clear understanding of these market risks and adopt appropriate mitigation strategies as part of any transaction.

Resilience bonds structured according to the short-term reset approach may face pricing challenges because investors will naturally tend to anticipate risk reductions. This creates an opportunity for risk reductions and project benefits to be effectively undervalued by investor pricing. A number of strategies could be used to address these market risks.

Resilience bonds structured in longer-term sequences face different sets of market risks, such as the potential impacts of evolving capital market conditions over time. For example, if the market price associated with a particular level of risk decreases over time, then the cost of insurance will go down, but so will the value attributed to the project benefits and the rebate. Alternatively, if market prices for risk increase over time, then the financial value of physical protections will also increase. This reflects increasing project benefits; however, resilience bond sponsors could find themselves 'locked-in' to higher program costs reflecting the higher market value of the insurance benefits and resilience rebates. A variety of strategies can be used to address these market risks. For example, resilience bond programs can integrate a variety of 'off-ramps' to future bond issuances or define upper and lower bounds on the rebate value that may be realized through future bond issuances that protect both sponsors and project financing from risks associated with evolving market conditions.

PROJECT-BASED ELEMENTS OF RESILIENCE BONDS

A unique feature of resilience bonds relative to cat bonds is their direct connection to real, on-the-ground risk reduction projects, such as a coastal protections, flood barriers, or other resilient infrastructure investments designed to address specific perils. There are two main design elements related to resilience project specifications that are fundamental to designing effective resilience bond programs: **defining eligible projects and qualifying their risk reductions**.

6 Eligible Project Definition

In the context of resilience bonds, project definition includes at least two aspects. First, the **specific projects, or types of projects, eligible to generate rebates within the resilience bond program must be defined**. Eligible projects can be defined in terms of specific capital projects already underway, such as a seawall under construction at 'Location L', funded by 'Source S', being built by 'Contractor C', to be completed by 'Date D.' Alternatively, projects can be defined in terms of general features, for example, a coastal protection within 'Area A' designed to provide protection against storm surge up to at least a 'Surge Height H', as measured at 'Tide Gauge G.'

In addition to defining the **projects themselves, the project parameters that will be used to quantify risk reductions must be defined**. In the case of surge risk reductions, the primary specifications required for modeling potential risk reductions are detailed location data and a defined height above datum or a corresponding event level of protection, such as a 500-year surge level. Taken together, these definitions provide a clear basis for quantifying risk reductions. They are also important for informing sponsorship, coverage, timing, and trigger decisions.

For example, as noted above, in the case of coastal protections from storm surge, the geographic locations and effective heights of protection (e.g., relative to a reference datum) may be sufficient to quantify the risk reductions. However, for more complex resilience programs, such as infrastructure retrofits to reduce seismic risks, more detailed inputs may be required to generate risk reduction estimates. Separate from project design specifications, additional data and analyses to identify which assets will be protected, who will benefit from the project, how much they benefit, and under what conditions the benefits will actually accrue are also prerequisites for modeling risk reductions and developing locally-appropriate bond design options.

7 Qualifying Risk Reductions

With respect to resilience bonds, qualifying a risk reduction relates to both measuring and verifying project benefits. Measuring the risk reductions involves a number of staged activities, starting with defining an appropriate risk modeling plan. **The plan should reflect the insurance needs of the sponsors, the data available regarding sponsor exposures, expected risk reductions from the resilience projects, the basic structure of resilience bonds, and information needs of capital market investors.**

Once defined, the risk modeling plan can be developed iteratively through several cycles of data collection, data processing, and model runs. Modeling is complete when the plan has been fully implemented and when the risk—both the baseline risk and project-based risk reductions—has been quantified to the satisfaction of both the resilience bond sponsors and the resilience bond issuers. Note that the modeling results are critical for informing resilience bond design decisions discussed above, as well as for defining and communicating risks for Investors.

The modeling section above provides several examples of risk modeling developed within the RE.bound Program. These examples illustrate the path an interested party (potential sponsor) can take to quantify risk reductions and explore bond design options. While the modeling results for these examples are preliminary and would not be sufficient for an actual bond issuance, they provide a point of departure for the types of analyses that would be required to enable resilience bond transactions. The details of any modeling plan developed to support resilience bond transactions will reflect local factors, the interests of the sponsors, the capabilities of available risk modeling tools, the requirements of the bond issuers and underwriters, and the needs of investors.

Once the risks and risk reductions have been properly quantified, protocols must be developed to verify project completion according to the design specifications. It is critical to complete these verification and validation steps before rebates are distributed. This is important for ensuring that investors are appropriately compensated for the risks they accept and to support investor confidence more broadly. It is also important for sponsors to receive clear validation that the resilience projects they have implemented actually deliver the intended benefits. Verification and validation protocols should be spelled out before resilience bonds are issued in order to provide clarity for all parties, including investors, sponsors, and project developers, and to limit future conflicts. As with all structuring decisions, the design of these protocols should be driven by local factors and by sponsor and investor interests.

REBATE-BASED ELEMENTS OF RESILIENCE BONDS

The third and final building block of effective resilience bonds is the **reduction in bond coupons that may be captured as a resilience dividend or rebate.** The main design elements related to resilience rebates focus on ensuring the integrity of rebate capture, distribution, and use. They include the rebate mechanism and protocols for rebate management.

8 Rebate Mechanism

Resilience bonds generate rebates by capturing a portion of the insurance savings created by resilience projects. This central feature of resilience bonds can be implemented in a number of ways. In order to ensure integrity of the rebate, the mechanisms by which funds are generated and distributed must be defined prior to the issuance of any resilience bond.

The primary decision associated with creating the rebate mechanism is specifying who receives rebate funds. For example, rebates could be credited directly back to resilience bond sponsors, they could be collected by the issuer or a broker, or they could be distributed to an independent or 3rd party 'depository' that is empowered to receive and distribute rebate funds according to specified rebate management protocols. While the use of an independent depository may require some effort to formalize up-front, it can significantly simplify the processes for issuing resilience bonds and utilizing rebates. The advantage of an independent depository is that it effectively insulates participants in the resilience bond transaction (e.g., sponsors and issuers) from the processes and liabilities associated with rebate fund management. It provides a defined space in which rebate management processes can be specified and implemented, and it allows sponsor obligations and project funding opportunities to be equitably balanced within multi-sponsor bond configurations. Decisions regarding the nature and designation of a rebate recipient are likely to be highly political and will need to be negotiated among sponsors and relevant project implementers to ensure confidence in resilience bond transactions and any associated project financing.

A second aspect of the rebate mechanism is the specific way transactions are organized to generate rebate funds within a resilience bond program. For example, reductions in coupons could simply be credited to sponsors' premium payments, enabling sponsors to issue side payments to rebate recipients in the amount of the insurance savings. In principle, resilience bond issuers could collect fixed premiums from sponsors and issue rebates according to the difference between premiums and coupons paid. An alternative would be for an independent resilience trustee to collect fixed payments from the sponsors, pay premiums to the issuer, and make resilience rebate payments from the difference between the fixed payments received and the premiums required by the issuer after the coupon is reset. These (and potentially other) alternative rebate mechanisms involve a number of trade-offs, and the right mechanism for any particular resilience bond program will be driven by local procurement requirements, public agency rules on the receipt and distribution of funds, and other relevant legal factors.

9 Rebate Management

The ability to create resilience rebates sets up a series of decisions regarding how rebates should be used. At a high level, rebates can be allocated in at least three ways:

- They can be used to advance resilience projects, if directed to a dedicated and protected project fund.
- They can be used to reduce insurance costs for sponsors, if returned to the 'general fund' on the balance sheet of the sponsors.
- They can be used to increase insurance coverage for sponsors, if they are directed to pay premiums for additional insurance.

These uses are not mutually exclusive, and other applications are also possible. Rebates can be segmented, with portions allocated to each of these uses, and the allocation of rebates can change over time. For example, rebates generated during the first 15 years of a resilience bond program can be used to fund pre-defined projects, while future rebates (i.e., after the 15th year) can be allocated to reduce insurance costs and increase coverage.

Once the general allocation of rebate funds is decided, the specific use of funds should be predefined to ensure integrity of the system. Rebates allocated to advancing resilience projects can be used in a variety of ways. For example, annual rebates can be used to pay ongoing costs for project operations and maintenance; they can be used to pay upfront capital costs associated with future project expansions or future phases of the project; they could be securitized to pay initial capital costs; or they could be used to fund additional projects that further advance community resilience.

Similarly, rebates allocated to increase coverage or decrease insurance costs could be used in multiple ways. For example, increased coverage could be secured by applying rebates to increase the size of the resilience bond program moving forward, or could be used to secure other, more conventional insurance coverage. Rebates allocated to reduce insurance costs could be earmarked for special uses related to local resilience programs, for example, or could be credited back to the general fund of the sponsors. Like all bond design decisions, decisions regarding both the general allocation and specific use of rebate funds will be driven by sponsors' priorities and interests.

Taken together, the nine design elements described here constitute the core insurance, project, and rebate building blocks required to structure any resilience bond. The next sections provide a hypothetical example and describe the key steps that governments and other public sector entities can take to explore local applications of resilience bonds in their communities.

HYPOTHETICAL

RESILIENCE BOND PROGRAM

Designing an effective resilience bond program involves a number of moving parts. In order to provide an illustration of how all the pieces might come together, below is a hypothetical resilience bond program designed for the fictitious City of At-Risk, in the State of Concern. Any perceived similarities between this hypothetical illustration and any actual cities or projects are coincidental, and all pricing is purely illustrative. Actual resilience bond pricing will vary widely depending on a number of factors.

At-Risk has recently become aware of the potential impacts to its community of storm surge events. The city reviewed the schedule of values used for its insurance program, along with those for other quasi-public entities operating in andaround the city. This review revealed the following exposures of insurable assets within the city limits:

$75 MILLION IN ASSETS OWNED BY THE CITY OF AT-RISK

$125 MILLION IN ASSETS OWNED BY UNDERWATER ELECTRIC, THE LOCAL ELECTRIC UTILITY

$400 MILLION IN ASSETS OWNED BY SWAMPED WATER AND SEWER, THE LOCAL WATER UTILITY

$1.2 BILLION IN ASSETS OWNED BY SUBMARINER TRANSIT, THE LOCAL TRANSIT / PORT AUTHORITY

The city further commissioned a catastrophe modeling study, which indicated that losses to these assets are, on average, expected to exceed $300 million every 50 years, including the costs of service disruptions. In response to these insights the city is undertaking a coastal protection project, with support from federal public assistance grants.

These grants are associated with various insurance coverage compliance requirements. The proposed projects total $110 million and include a combination of hardening measures and natural protections designed to protect the city from storm surge up to the 200-year surge level. Construction of these coastal protections is expected to take two years, and the city is pursuing a resilience bond program to support the implementation of additional phases of the project in future. The nine key elements for this resilience bond program are summarized below.

INSURANCE

SPONSORS
(Premiums Allocated By Exposure)

City of At-Risk: Lead Sponsor ($0.5-1 million per year)

Underwater Electric: Co-sponsor ($1-2 million per year)

Swamped Water & Sewer: Co-Sponsor ($3-4 million per year)

Submariner Transit: Co-Sponsor ($10-12 million per year)

COVERAGE

$200 Million resilience bond designed to payout if 50-year surge level is exceeded.

TIMING

First bond to be issued within 3 months of construction start date.

4 year bond term, with a potential coupon reset after year 2 (tied to project completion), generating savings in years 3 and 4 of initial bond term.

Rebates in years 5 through 20 may be generated through additional bond issuances. These subsequent bonds may also satisfy ongoing sponsor insurance compliance requirements.

TRIGGER

A parametric trigger defined in terms of surge height measured at the closest NOAA tide gauge (several back-up gauges are also specified).

Initial trigger set to a height of 5.5 feet above datum (~50-year surge level).

After project completion, trigger is reset to a height of 10 feet above datum (~200-year storm level), which would likely overtop coastal protections.

MARKET RISK MANAGEMENT

The bonds are issued with an initial coupon of 7% and a reset coupon of 4.5%, which includes explicit compensation for the potential decrease in investor returns in years 3 and 4 of the bond term.

Sponsors are protected from future increases in market rates by their ability to terminate the bond program at any time (after the first bond matures).

REbound
INSURING FOR RESILIENCE

RESILIENCE PROJECTS

PROJECT ELIGIBILITY

The coastal protection project undertaken by the City of At-Risk is the only project eligible to generate coupon reductions & receive rebates.

The project is eligible to create coupon reductions (insurance savings) and therefore generate rebates after verification of project completion/delivery by the contractor, but not before year 3 of the bond.

QUALITY OF RISK REDUCTIONS

Project-based risk reductions are evaluated by the issuer's catastrophe modeling firm prior to issuance based on the final pre-construction engineering specifications established for the project.

Project completion will be verified by the execution of final completion documents by the contracted construction firm.

REBATES

REBATE MECHANISM

Rebates will be issued as a side payment from the sponsor and co-sponsors based on the insurance savings, computed as the difference between the initial coupon and the reset coupon.

The hypothetical coupon rates above, combined with the $200 million bond size indicate a rebate of ~$5 million per year ($200M * [7%-4.5%]).

Rebates will be paid to a publicly-administered account or fund pre-designated by the sponsors to support additional project finance.

REBATE MANAGEMENT

The coastal protections have an expected useful life of 50 years.

During the first 20 years of the bond program, rebates based on the captured insurance savings are estimated to generate ~$70 million in eligible project finance (assuming a 3% interest rate) that can be applied to any phase of project implementation based on the prior agreement of the sponsors.

During years 21 through 50, the value of project-based risk reductions will be allocated to reducing insurance costs and expanding coverage.

SPONSORSHIP

HELPING GOVERNMENTS LEVERAGE INSURANCE FOR RESILIENCE

SPONSORSHIP

HELPING GOVERNMENTS LEVERAGE INSURANCE FOR RESILIENCE

Traditionally, cat bonds have been a tool for insurers, reinsurers, and other buyers to protect themselves against extreme losses. As governments and public authorities increasingly turn to the capital markets for catastrophe insurance, there are several considerations that are unique to public sector entities with potential sponsorship interests. The nine bond design and structuring elements described in the previous section comprise the core building blocks that any public or private sector sponsor would need to carefully evaluate before pursuing a resilience bond. In addition, public entities, who are considering both resilience projects and new catastrophe insurance to complement their existing risk management strategies (e.g., self insurance, cash reserves, participation in regional risk pools, conventional insurance programs, etc.), need to take several additional prerequisite steps to create high-quality bond opportunities. This section describes three main public sector sponsorship considerations:

Resilience Bonds are best suited for cities, utilities, or other large asset holders that have initial resilient infrastructure project ideas or related capital plans; however, the topics and questions below are relevant for any community seeking to better understand how to balance between investments in protection and insurance. Each of these topics is discussed in depth below, and together they are intended to serve as a general framework for interested parties seeking to champion integrated resilience and insurance strategies.

1 Sharing Risk

Exploring co-sponsorship options with other at-risk parties

2 Filling Data Gaps

Characterizing public assets and setting insurance priorities

3 Engaging Technical Support

Securing third-party financial, technical, and legal advice to ensure effective pre-transaction analysis

SHARING RISK—WHO SHOULD CONSIDER SPONSORING RESILIENCE BONDS?

As described in the previous sections, **sponsors of resilience bonds are parties with interests in both purchasing insurance and mobilizing investments to reduce physical risks from catastrophic events.** Based on this definition, any large public or private asset holders—cities, public utilities, universities, hospital systems, or other public anchor institutions—with insurance needs can be a resilience bond sponsors or co-sponsors.

Like purchasers of conventional insurance, sponsors agree to pay insurance premiums in exchange for a defined payout in the event of a disaster. Because both cat bonds and resilience bonds are insurance products—not municipal bonds or corporate bonds issued by sponsors—sponsors are only responsible for paying insurance premiums, not for repaying bond principal. Sponsors should consult with their counsel, but it is unlikely that these types of bonds would compromise their debt limits or credit ratings. Resilience bonds offer the additional benefit of generating project funding, via the rebate structure, outside of a public authority's balance sheet. For cash-strapped cities and utilities this mechanism may open up new avenues to help fund specific resilience priorities.

In order to maximize the public benefits that resilience bonds can create, an interested party should consider not only its asset base, risk exposure, and insurance needs, but also shared or interdependent assets and the potential to spread costs and benefits among other local and regional stakeholders. Resilience bonds naturally lend themselves to situations with multiple co-sponsors. **Risks from catastrophic events are typically shared among many affected parties**, each of whom could benefit from both the insurance benefits and resilience benefits that resilience bonds enable. In particular, financial risks from catastrophes are typically born by local residents, businesses, local governments and utilities, owners of public and private assets, private insurance companies, and state and federal agencies as the 'insurers of last resort.' Most, if not all, of these parties could benefit from the transfer of financial risks to capital markets that resilience bonds can provide. Expanding the set of potential beneficiaries can also allow interested parties to rebalance their individual insurance purchases to generate greater collective benefits.

Building community resilience to physical damages offers an alternate path for managing risks from catastrophic events. Importantly, the same stakeholders that share similar financial risk exposures would also benefit from projects to build resilience and reduce their aggregate risk. As a result, there are likely multiple shared interests in mobilizing investments in resilience projects and realizing successful risk reductions. For example, upgrades to a utility's storm water management infrastructure are likely to create spillover benefits for local transit authorities and private property holders, who will become, as a result, less vulnerable to flooding and experience fewer damages from severe weather events. In this case, all parties could experience savings in their total insurance costs if the potential beneficiaries collectively analyze options for aligning insurance and investment priorities. The simplest path to identify potential co-sponsors in this case is for an interested party, likely the public entity with the greatest exposure or liability in the event of a disaster, to convene other potential beneficiaries, exchange information on insurance coverage and needs, assess the shared benefits of a comprehensive risk reduction project, and negotiate co-sponsorship interests based on relative exposure and other priorities.

Resilience bonds can be structured with a single sponsor or with multiple co-sponsors. Identifying who should be a lead sponsor and which entities may have significant co- sponsorship interests requires reliable data on each stakeholder's exposure to specific perils. The next section describes the steps that interested parties can take to develop a preliminary characterization of the distribution of expected losses and benefits across various public and private asset holders.

FILLING DATA GAPS—WHAT PREPARATION IS ESSENTIAL FOR SPONSORS?

Within the insurance industry, private bond sponsors and issuers typically have excellent data on their assets and overall exposure. **Governments and public sector agencies rarely have similar high-quality data on public buildings and infrastructure**. Cities and public utilities with established risk management programs and existing private insurance coverage generally have a Schedule of Values (SOV) for their own insured assets. Even still, these databases can be limited in their scope and provide an incomplete picture of total exposure. In order to start the process of determining whether a resilience bond is an appropriate investment in the public interest, the first step is for any interested party to start by compiling several key pieces of data, including, but not limited to, the following:

- Asset locations and values—Schedule of Values (SOV) and/or appraisals
    - Buildings and contents
    - Other property and land holdings
    - Public infrastructure
        - Water systems
        - Electric generation and distribution assets
        - Transit systems
- Insurance holdings—Existing coverage and premium payments
    - Cash reserves
    - Risk pool contributions
    - Private insurance purchases
    - Current and anticipated compliance requirements
- Resilience project(s)—Basic design specifications
    - Location(s)
    - Level of protection
    - Area(s) protected

These data form the basis for any preliminary catastrophe modeling to characterize baseline exposure and assess if proposed resilience projects can generate a measurable and meaningful risk reduction. It is important to note that some projects may not be model-able with current catastrophe modeling technology. For example, large-scale storm water detention systems and diffuse green infrastructure projects aimed at mitigating high frequency flooding events cannot readily be incorporated into existing catastrophe models. The coverage of catastrophe models is, however, constantly expanding; resulting in capabilities to model an even larger range of risk reduction measures in the future. Estimating the financial benefits of a resilience project in terms of avoided economic losses is a valuable exercise for ensuring effective project design, regardless of whether or not initial modeling suggests that a resilience bond is worth pursuing.

ENGAGING TECHNICAL SUPPORT—WHAT DO POTENTIAL SPONSORS NEED TO DO TO ASSESS VALUE?

Resilience bonds are not for everyone. Some public authorities may not have enough public exposure to warrant catastrophe insurance. Others may not have the budget available to cover insurance premiums. Still others may not have sufficiently complete or accurate baseline data to model exposure or they may not have resilience projects that can be modeled in ways that support the development of a locally appropriate bond design or structure. Finally, some may find after an initial round of exploratory modeling that the resilience benefits of anticipated projects are far lower than expected. (This should refocus public discussions on what measurable benefits the proposed resilience projects do, in fact, create.)

For interested parties who do have the relevant data to support preliminary modeling and find that the insurance and resilience benefits are sufficient to justify moving forward with additional analysis of bond design options, an essential next step is to engage legal counsel, financial advisors, and technical experts in the process before engaging an issuer(s) for any specific transaction. Just as most cities that issue municipal bonds have a bond counsel to review potential opportunities and protect the public interest, the process of procuring resilience bonds within a larger risk management portfolio should begin by engaging a trusted team of dedicated experts.

Modeling the risk reductions of proposed resilience projects adds a layer of complexity to conventional insurance procurement processes, and likely requires the engagement of multiple public agencies and departments. As a result, securing appropriate, independent, and high-quality advisory and technical services for any transaction is essential to ensure good governance and effective use of taxpayer dollars. The RE.bound modeling and design approach described in this paper is geared toward helping interested public parties consider the potential public benefits of resilience bonds generally. Should a potential sponsor choose to move forward with the more detailed pre-transaction modeling and analysis required to assess local bond design and structuring options, seeking third-party advice is an essential steps.

INSIGHTS AND LESSONS

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Governments can no longer be expected to cover the rising costs of disasters.

> "On average only about 30% of catastrophe losses have been covered by insurance over the last 10 years. That means that about 70% of catastrophe losses – or USD 1.3 trillion – have been borne by individuals, firms and governments."[7]

Insurance is an essential component of overall resilience. Not only are communities increasingly exposed to growing risks, but they are also increasingly uninsured, underinsured, or dependent on national or international aid in the event of a disaster. The RE.bound Program offers a new approach to leveraging private insurance markets to support public interests. This approach is not only relevant for individual cities and states seeking to improve local resilience, but also for national governments and global institutions looking to mobilize private financing for vulnerable communities through international instruments, such as the UNFCCC Loss and Damage Mechanism. By integrating physical and financial protections, governments around the world have the opportunity to rebalance reactive demands for disaster aid and shift to a proactive focus on promoting local investments in resilience and risk reduction.

Returning to the analogy of life insurance and health care, diagnosing a condition or understanding overall risk and exposure is only the beginning. **Public authorities must also have treatment options available to them.** The following sections expand on the key insights generated through the RE.bound process and frame a set of opportunities to leverage the lessons learned from the program to date and ensure the integrity of the catastrophe and resilience bond market for both public sector sponsors and private investors into the future.

EXTENDING THE RE.BOUND MODEL

Beyond the specific model results and bond design elements highlighted in previous sections, the RE.bound Program lays the groundwork for cities, utilities, and other public-interest organizations around the world to build physical and financial resilience. The RE.bound model offers three major lessons to this end. First, catastrophe modeling can be effectively used alongside other planning tools to evaluate a community's financial risk exposure, need for insurance cover, and the financial benefits of potential resilient infrastructure projects. Second, traditional cat bond instruments can be modified to provide insurance cost reductions for projects that reduce risk, which can be captured in the form of resilience rebates. Third, in order to capture these rebates, public entities, such as cities and utilities, must have a clear, well-defined, and near-term pipeline of risk reduction projects that they can pursue.

[7] Source: Disaster Risk Financing: Smart Solutions for the Public Sector (Swiss Re, 2015).

Incorporating Cat Modeling into Resilience Planning and Finance

Catastrophe models can help communities understand their exposure to a wide variety of risks. The RE.bound Program demonstrated specifically how catastrophe models can fill a critical gap in assessing the value of resilient infrastructure projects. Unlike other benefit-cost analysis methods, **investment-grade models are based on widely accepted and trusted characterizations of specific risks (perils) and industry asset exposure data.** Additionally, these models allow for a sophisticated disaggregation of losses and benefits across geographies, asset holders, and exposures. Rather than attempting to monetize diffuse environmental benefits or abstract proxies for socio-economic benefits, these models are specifically designed to estimate losses in a way that enable verification and future value capture. This is very different from broad characterizations of resilience benefits or ecosystem services that are open to debate or are based on assumptions that are hard to validate in advance or verify in retrospect.

By applying catastrophe modeling technology to investigate the impacts of various resilient infrastructure (surge-protection) projects in three diverse coastal communities, RE.bound demonstrated that catastrophe models can be used to both assess levels of risk reductions provided by different projects and estimate the financial value of specific resilience investments. For example, modeling the marginal expected losses associated with each incremental foot of seawall height offers a way for a community to make more informed trade-offs based on the long-term financial consequences associated with specific design parameters.

Catastrophe models will not work for all risks nor can they be relied upon to assess every possible type of resilience project. That said, the results of the RE.bound process make clear that these models can play an important role in helping governments set priorities and balance resilience investments with insurance purchases. More importantly, the examples in this paper show how even preliminary modeling can help advance the public interest by properly valuing the financial benefits of resilient infrastructure investments.

Modifying Catastrophe Bonds to Enable a Resilience Rebate

Second, **RE.bound shows how traditional cat bond instruments can be modified to provide insurance savings that can be captured as resilience rebates**. The basic bond design and structuring elements outlined in this paper offer a strong foundation from which interested parties can explore their own insurance and resilience rebate opportunities. Just as a seawall in one location cannot simply be duplicated in a different context, there is no one-size-fits-all bond design. Each resilience bond must be designed and tailored to a potential sponsor's interests. That said, the RE.bound process demonstrates that the generalized approach to linking insurance and resilience project finance is viable for a wide range of risks, sponsor types, and project applications. This result offers opportunities for sponsors of current cat bond programs to connect capital planning strategies with future bond issuances to create insurance cost reductions and potential resilience rebates.

Crafting Well-Defined Resilience Projects to Deliver Insurance Benefits

In order to assess and capture any resilience rebates, public entities—such as cities and public utilities—must have a clear, well-defined, and near-term risk reduction project(s) that they can implement within a reasonable timeframe of bond issuance. Resilient infrastructure projects and resilience bonds will not happen on their own. Local governments and public utilities must invest in thoughtful predevelopment both to design new infrastructure solutions and evaluate their insurance priorities. To that end, the final sections of this paper offer a set of ideas that federal and local governments can pursue to encourage vulnerable communities to invest in both insurance and resilience.

SHAPING THE MARKET FOR RESILIENCE BONDS

Expanding infrastructure investment and improving insurance coverage are twin policy problems. Public sector authorities have historically funded and maintained public transportation, water, energy, and telecommunications networks. Public expectation has also long driven governments at all levels to step forward in the aftermath of catastrophes to support devastated communities and absorb the costs of recovery and rebuilding.

In the face of growing long-term risks like climate change, these expectations are poorly matched with declining public budgets. The myriad urgent budget demands placed on public officials mean that investment in long-term priorities, including both infrastructure investment and insurance, are more often than not deferred.

Despite this grim picture, **there are tremendous opportunities to move from a reactive to proactive policy landscape and reframe the role that public sector authorities and funding programs can play in reducing disaster risk and building overall resilience.** Each of the following ideas builds directly on the results of the RE.bound Program, and the brief descriptions below are intended to catalyze national and global policy discussions on options for making better and more efficient use of public funds to expand physical and financial protections for vulnerable communities.

Incorporate risk-reduction based design criteria into Federal infrastructure & disaster recovery funding programs

Following Superstorm Sandy in 2012, the U.S. Department of Housing and Urban Development (HUD), in collaboration with the Rockefeller Foundation, developed the Rebuild by Design program. This innovative competition created a new platform for targeting disaster recovery funds to projects designed to ensure long-term resilience. The design solutions that emerged ranged from large-scale coastal protections to natural infrastructure systems to reduce local flooding. All of the resulting projects and awards included detailed descriptions of the resilience benefits of the proposed projects, but none captured insurance savings or the types of financial benefits highlighted by the RE.bound Program. Since then, HUD has also launched a National Disaster Resilience Competition to allocate nearly $1billion USD in federal assistance to eligible disaster-affected states and jurisdictions (anticipated award date in early 2016). Adding catastrophe model risk reduction measures to complement the traditional cost-benefit metrics required for federal funding in these types of competitions and grant programs can not only help inform and improve projects at the design stage, but it can also open doors to leveraging additional private financing as projects move toward implementation.

Reframe federal insurance compliance requirements to encourage proactive investments in risk reduction projects

National governments benefit when state and local governments have appropriate levels of insurance. With the growing number of uninsured or underinsured individuals, communities, and asset holders, governments are facing increasing pressure to make significant budget decisions on a disaster-by-disaster basis. This is unsustainable policy. In the U.S., federal disaster assistance is governed by the Stafford Act and associated with various obligations to purchase or expand insurance coverage in proportion to the assistance received; however, cash-strapped recipients of this assistance are regularly granted waivers from their compliance requirements. Federal agencies should reevaluate the administrative waiver process to enable qualifying catastrophe insurance and risk reduction projects to count toward compliance requirements. Two options in lieu of approving waivers based on a lack of available or affordable insurance are (1) to offer a ‘resilience match’ as a funding incentive to supplement local budgets for insurance premiums or (2) to designate a small percentage of any disaster assistance package for the purchase of insurance aligned with specific risk reduction measures.

Use insurance as a driver to get resilience projects across the finish line

Resilience projects are often complex, involving multiple sectors and stakeholders. As a result, these infrastructure projects can take even longer to plan and execute than already drawn out timelines for conventional infrastructure planning, permitting, and construction. Insurance mechanisms, including resilience bonds, can serve as a financial incentive to help local governments set clear objectives for project completion in order to recognize the potential value of reduced insurance costs and associated rebates. For example, if a four-year bond is designed with an anticipated reset beginning in year three, after the point of project completion, a delay in construction or operation would result in a lower financial benefit across the bond term due to a delay in the coupon reset. Not only can strategic investment in resilience bonds increase the value of public sector coverage—lower premiums or more total coverage for the same premium—a thoughtfully structured bond that aligns the timeline for insurance procurements with target dates for project implementation, can help local officials push resilience projects across the finish line.

Create a pathway for communities to 'graduate' to different risk levels within government-subsidized insurance programs

Local governments and public authorities should get credit for protecting themselves. Currently, many risk designations—such as flood hazard maps for programs like the U.S. National Flood Insurance Program (NFIP)—are highly political and not updated with sufficient frequency to motivate proactive or urgent action to reduce risk. As a result, these programs impose high burdens on low-income policyholders and communities, who are locked into indefinite insurance obligations. Conversely, meaningful options for reducing overall risk and exposure are often costly regional solutions, like large-scale flood defense systems, not protections that are available to individual property owners. As the cost of disasters continues to increase, public insurance programs themselves present massive government liabilities. Currently, program administrators are limited in their risk management options, and many programs facing insolvency have only one option: to raise the cost of premiums. Pricing at-risk asset holders out of insurance markets simply shifts the responsibility for catastrophic losses onto other public sector resources. One potential pathway to both improve the solvency of subsidized insurance programs and encourage proactive investments in local risk reduction is for relevant federal authorities to create a pilot program in collaboration with select communities already pursuing large scale risk reduction projects to establish a replicable pathway to enable other participants to measurably reduce risk, validate the risk reductions, and eventually "graduate" to lower risk tiers or designations within mandated insurance purchase programs, such as the NFIP.

Taken together, these ideas and the insights from the RE.bound process offer a wide range of opportunities for governments, insurers, and communities to shift from reactive debates on disaster assistance to proactive strategies on insuring for resilience.

CONCLUSION

CONCLUSION

The result of a successful resilience project is often something that never happens. A storm struck, but the community was not devastated. Invisible successes pose tremendous public investment challenges.

The RE.bound Program offers a new path forward for monetizing these successes, limiting the growing pressure on federal disaster recovery funds, making better use of taxpayer dollars for disaster response, and leveraging the capital markets to both expand insurance coverage and increase protection for vulnerable communities.

Put simply, 'an ounce of prevention is worth a pound of cure.' While resilience bonds have not yet been proven in the market, the RE.bound model provides governments around the world with a new option to support proactive investments in prevention and to generate real resilience dividends.