MarshMcLennan

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CLIMATE AND NATURAL DISASTER RISK

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Businesses of Marsh McLennan

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Overview of Regulated Entities

The central role of government-sponsored enterprises Fannie Mae and Freddie Mac (the Enterprises) and the Federal Home Loan Banks (the FHL Banks) in housing finance implies significant exposure to risk. With risks from climate change now increasing, it is time to examine this risk to the Enterprises and the ways it can be managed.

Fannie Mae and Freddie Mac have played a central role in the United States' housing system since their establishment in 1938 and 1970, respectively. Today, the Enterprises provide secondary market liquidity and reliable access to competitive funding to thousands of banks, savings and loan associations, and mortgage companies that consumers rely on for home financing. The Enterprises' guarantee of mortgage payments makes the secondary mortgage market one of the deepest and most liquid fixed-income markets in the world.

The US housing finance ecosystem revolves around the Enterprises. Originators can reach many more borrowers as a result of the reliable source of funding the Enterprises provide. Investors in both mortgage-backed securities and mortgage servicing rights deploy massive amounts of capital into the system because of the Enterprises' guarantee. The FHL Banks – together with the Enterprises referred to as the “regulated entities” – also provide significant funding to community lending institutions that are deeply involved in housing finance at the local level. The result is low-cost and widely available mortgages for American consumers.

The regulated entities also play a central role in fostering access to credit and affordable housing. Their business and risk profiles are unquestionably shaped by mechanisms such as affordable housing goals and conforming loan balance caps. The result is a commitment to serve underserved borrowers through economic cycles.

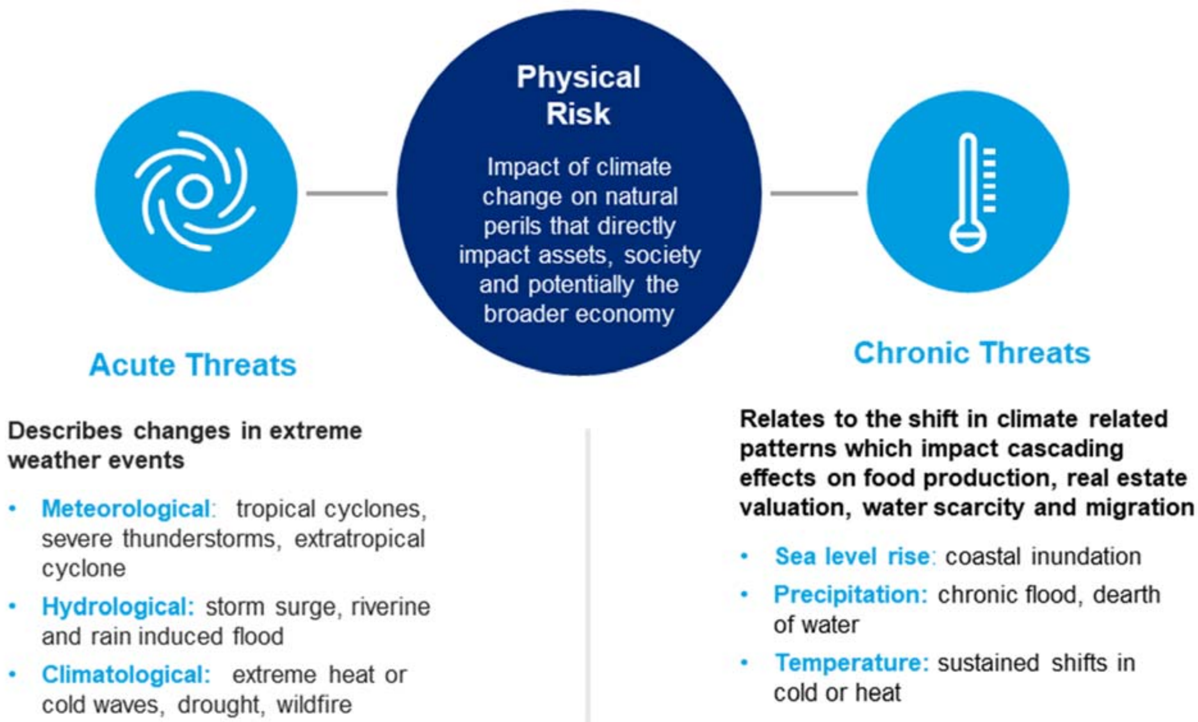
This central role implies significant exposure to risk. The Enterprises currently guarantee payment on or are otherwise exposed to $5.5 trillion of single-family mortgages, or 48 percent of outstanding housing debt, and $837 million in multifamily mortgages, or 49 percent of outstanding multifamily debt. These guarantees assure housing for millions of Americans. While the Enterprises have several risk-reducing features in their business models, such as homeowner's insurance requirements, mortgage insurance (MI) requirements, and credit risk transfer, none of these mechanisms directly consider the long-term impacts of climate change. However, credit risk within the regulated entities has a growing exposure to climate change due to the long-term exposure of 30-year mortgages – and their known exposure to earthquake and flood risk. In this paper, we explore how climate change and natural disasters expose the Enterprises to risk and how such risk can be managed.

2

Identifying Climate and Natural Disaster Risk

The impact of climate change on natural disasters that directly affect assets, society, and potentially the broader economy is referred to as physical climate risk. The scale of climate change will vary significantly by location and peril. Certain regions are likely to experience a more gradual and marginal evolution, while others will feel the effects more suddenly and potentially catastrophically. Physical risk is further divided into two categories (See Exhibit 1.). Acute threats are caused by extreme weather events. Chronic threats are the result of shifts in climate patterns, which have cascading effects on food production, real estate valuation, and water scarcity – and can possibly lead to population migration.

Exhibit 1: Physical climate risks over time



While one region could experience major physical changes, the impacts on other regions could be restricted to more modest economic or recreational impairments. The resilience of the regional infrastructure and its performance under climate change will be crucial to the health of the local housing market, given the impact electrical, water, and sewer systems have on quality of life. In addition, major components of power grids, transportation infrastructure, water supply, and sewers are vulnerable to climate change, and the damage or loss of these components could take years to recover. For the Enterprises, the scale of material losses will be informed by the peril, the region, and the category of physical risk – whether it is acute, chronic, or an accumulation of severe acute threats.

The interconnections of a range of societal variables in conjunction with the severity of impact of the physical risk event will ultimately give rise to consequences that have not yet been contemplated – or, at least, that have not yet been recorded. Seven key social variables are spatial footprint, infrastructure repair, supply chain, liability of utilities, economy and employment, home price depreciation, and population migration. (See Exhibit 2.) Because of their diverse and widespread geographical footprint, the Enterprises typically would not risk significant impairment unless there is a series of catastrophes that have an impact on the majority of these seven variables.

Exhibit 2: The full spectrum of climate change risk for government-sponsored enterprises

Variable	Limited	Minor	Moderate	Major	Massive
Spatial footprint	Neighborhood to community	City	Metro regions	State(s)	Super regional
Infrastructure repair	Limited	Weeks to months	Quarters	Years	Irreversible damage
Supply chain	Negligible	Price increases	Lack materials	Breakdown	No available sources
Liability of utilities	None	Tougher legislation	Increased utility costs	Bankruptcy	Government takeover
Economy and employment	Strength on rebuilding	Stagnation / reduced growth	Reduced employment opportunities	Recession with interest rate implications	Depression
Home price depreciation (HPD)	Negligible	Temporary HPD / incidental defaults	Extended HPD / moderate defaults	Multi-year and widespread HPD – widespread defaults	Severe HPD amid lack of demand - widespread defaults
Population migration	None	Temporary relocation for affluent	Affluent homeowners relocate	Increased migration of all demographics	Permanent population reduction

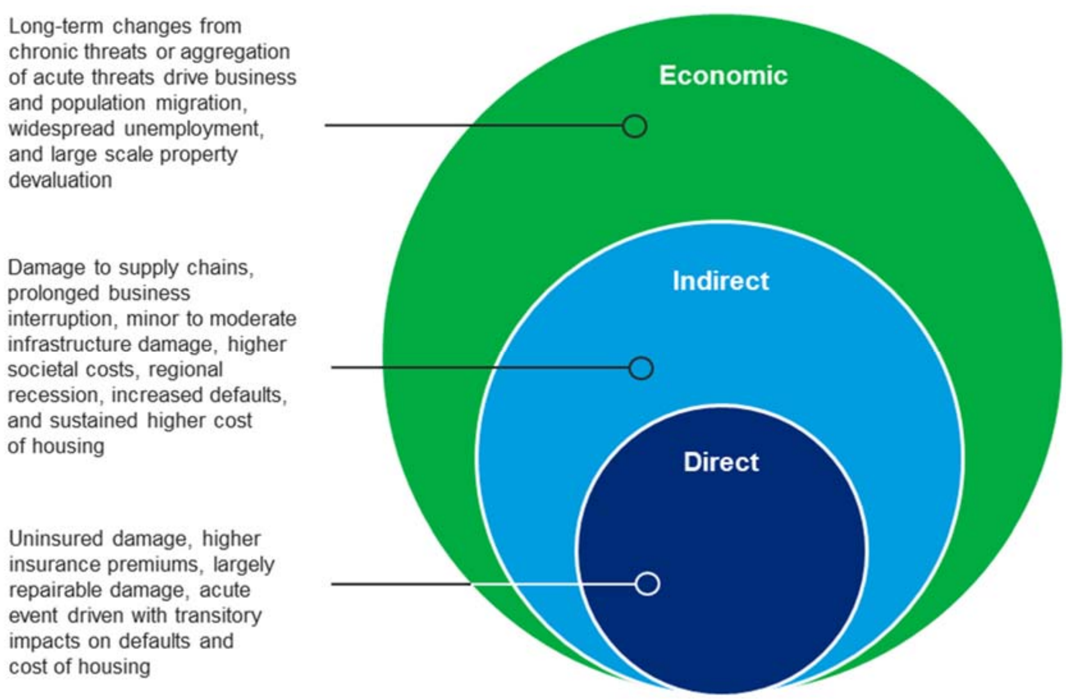
Surveying the three manifestations of physical risk – chronic risks, acute risks, and the accumulation of severe acute risks – indicates a multitude of plausible ways by which major and massive impacts can transpire, identified in Exhibit 2. Combining the type of physical climate risk in concert with the seven societal variables results in a taxonomy of potential impacts on the Enterprises, with the scale growing from the direct to the indirect and ultimately to the economic scale.

Direct impacts. These are typical for catastrophes and natural disasters that currently occur across the United States. Common financial consequences are uninsured damage and higher insurance premiums for insured perils. Direct impacts are largely reparable, and there are transitory impacts on loan defaults and the cost of housing.

Indirect impacts. These can have a larger scale. Supply chains can be impaired, and prolonged business interruption claims can follow minor to moderate infrastructure damage. These higher societal costs can result in a regional economic recession, accompanied by increased loan defaults and a sustained higher cost of housing. Even with this larger scale of impact, however, the stress to the Enterprises' portfolios is anticipated to be limited.

Economic impacts. These have the scale and severity to have a significant impact on the Enterprises. Long-term changes from chronic threats can drive the migration of both population and businesses. The migration of population and the exodus of commerce can cause widespread unemployment and large-scale property devaluation and increased default.

Exhibit 3: The rippling financial impacts of climate change

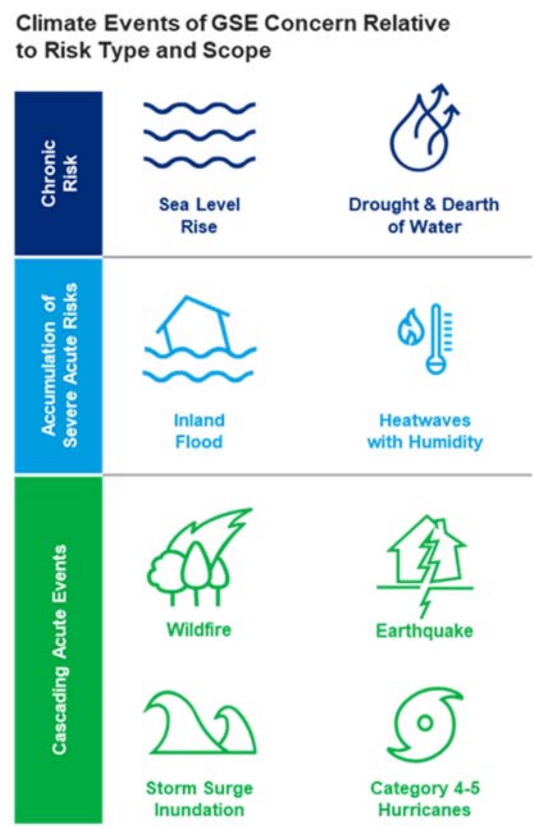


What perils can give rise to economic impacts severe enough to drive large-scale property devaluation? In contrast to the full range of natural disasters the US economy currently faces, the perils that concern to the Enterprises are largely related to whether certain areas remain inhabitable.

Among chronic risks, the irreversible rise of sea levels will render some coastal property uninhabitable. While many wealthy coastal communities have loan limits above conforming

Enterprise limits, it does not mean the Enterprises are free of the consequences of sea-level rise. Before the seas rise enough to trigger economic impacts such as population migration and large-scale property devaluation, challenges with ingress and egress for these communities could result in direct and indirect impacts to the Enterprises. For example, a coastal community threatened by rising seas may only be able to use roads during low tides to move in and out of the community. In the years to come, cars may ultimately be unable to enter the community; if boats become the only means of transportation, there could be a corresponding permanent devaluation of property. In contrast, another chronic threat to the Enterprises is repeated long-lasting droughts that lead to a comprehensive dearth of water in a region. As reservoirs and aquifers deplete, the lack of water for human consumption and industrial use could rapidly cause longer-term economic impacts.

Exhibit 4: Short- and long-term consequences



An accumulation of severe acute risks of increasing frequency can also give rise to concern for the Enterprises. In regions experiencing statistically significant increases in rainfall (due to rainfall covering larger areas or being heavier and more severe in nature), floods could be more frequent in the future. These events could increase the degree of economic disruption. A lack of timely investments in rainwater removal systems may result in an increased frequency of flooding, which could depreciate home values across a metropolitan region.

Longer heatwaves and higher humidity for longer periods of the year are a concern across the southern United States. If high humidity prevents people's bodies from cooling properly, outdoor activities might no longer be possible, hurting economies that require outdoor activity.

Among the less likely ways the Enterprises could be affected are cascading impacts on the heels of a natural disaster. Wildfires, earthquakes, and category 4-5 hurricanes with accompanying storm surges are not, in and of themselves, conventionally regarded as events large enough to influence the Enterprises. However, cascading events after such a natural disaster can increase the threat of indirect and, potentially, economic impacts. Will the increased frequency, duration, and severity of wildfires make pre-emptive power outages commonplace – and will populations begin to move due to a lack of reliable power? Will storm surge inundation from a major hurricane combine with excessive rainfall to cause a large-scale environmental disaster that renders certain regions uninhabitable? A single earthquake is not thought to have enough geographic scope to cause economic depression and population migration, but what if a series of large earthquakes occurs over a several year period? These questions indicate areas ripe for further investigation – though from a modeling perspective they are very challenging to quantify, because they involve cascading and systemic failures across multiple aspects of society. Section 3 contains several case studies that help to frame the range of impacts that could eventually rise to a level of concern for the Enterprises.

3

Assessing Risk Through Natural Disaster and Climate Change Scenarios

Case Study #1: Long-lived series of earthquake aftershocks

In order to supplement current views of seismic risk, Guy Carpenter has been exploring the impact of aftershock hazard on property and casualty loss estimation. Traditional probabilistic seismic hazard analysis (PSHA) methodologies have limited views of hazard to consideration only of the mainshock – that is, the largest shock. But recent large earthquakes and public planning scenarios suggest that this approach can ignore other, major impacts. In the earthquake sequence in 2010 and 2011 in Canterbury, New Zealand, the largest earthquake (the mainshock) on Sept. 4, 2010 was M7.1 and caused $6 billion of damage in 2011 US dollars. However, the most economically damaging shock was the relatively shallow M6.2 aftershock on Feb. 22, 2011 within 8 kilometers of Christchurch, which caused significantly more economic damage ($15 billion) and loss of life, according to SwissRe *sigma*.

The US Geological Survey's HayWired Earthquake Scenario (2018) for public planning provides an opportunity to expand the modeling of seismic catastrophes. Building on recent lessons learned, the scenario includes a two-year aftershock sequence that can supplement the results of traditional catastrophe modeling of earthquakes. It is estimated that there is a one-in-five chance of an aftershock of M6.4 occurring in the weeks or months following the M7.0 mainshock. Using the spatial-temporal information from the HayWired scenario, a range of losses can be built around the mainshock risk assessment for a more holistic view. Risk specialists across the Marsh McLennan businesses are capable of extending the spatial-temporal models to addresses the broader economic consequences of the scenario and potential impact on the Enterprises, including:

- The Enterprises' gross modeled mortgage credit default losses
- Net modeled losses after the application of the in-force credit risk transfer programs
- Net modeled losses after alternative structures to the credit risk transfer program (e.g., attachment and detachment levels)

Case Study #2: Water scarcity in the United States

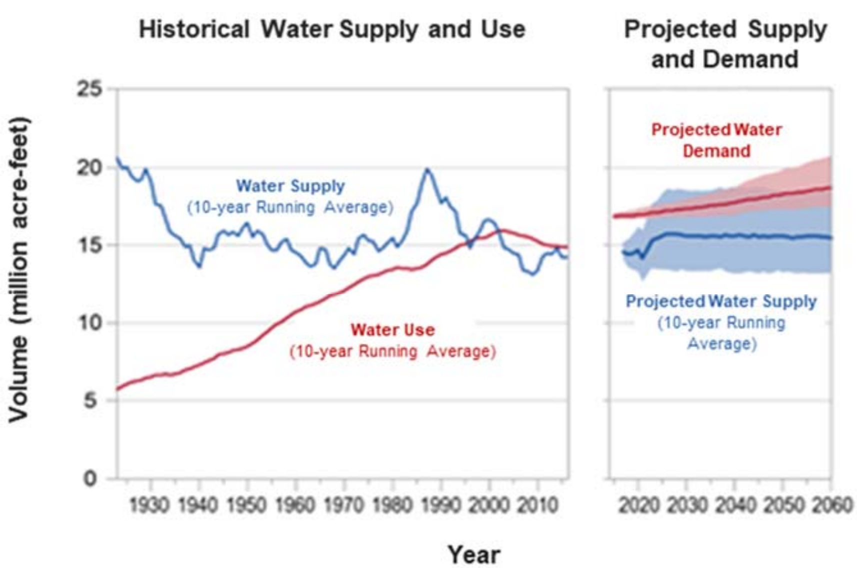
The threat from water scarcity can be conveyed by looking at two regions that are causing considerable concern.

The Desert Southwest

The Colorado River Basin provides water to nearly 40 million people and irrigation to 5.5 million acres of land across seven states in the Southwest. A landmark study issued in 2012 by the US Bureau of Reclamation highlights the projected imbalance of water supply and demand up to the middle of the 21st century. (See Exhibit 5.) Most scenarios predict water demand far outpacing supply. By 2060, the mean estimate of water shortfall is a trillion gallons, the amount needed to supply 6 million households with water for a year.[1] The predicted increase in demand is largely due to high expectations of population growth in the driest states of the country on the Colorado River Basin. The population of the Intermountain and Desert Southwest, the most arid regions of the country, is expected to grow by 45 percent between 2010 and 2040, outpacing other regions.

Exhibit 5: Historical and projected future supply and use of Colorado River Basin water

(Source: Adapted from US Bureau of Reclamation Colorado River Basin Water Supply and Demand Study)



[1] Barnett, T. P., and D. W. Pierce, 2009: Sustainable water deliveries from the Colorado River in a changing climate. Proceedings of the National Academy of Sciences, 106, 7334–7338, doi:10.1073/pnas.0812762106.

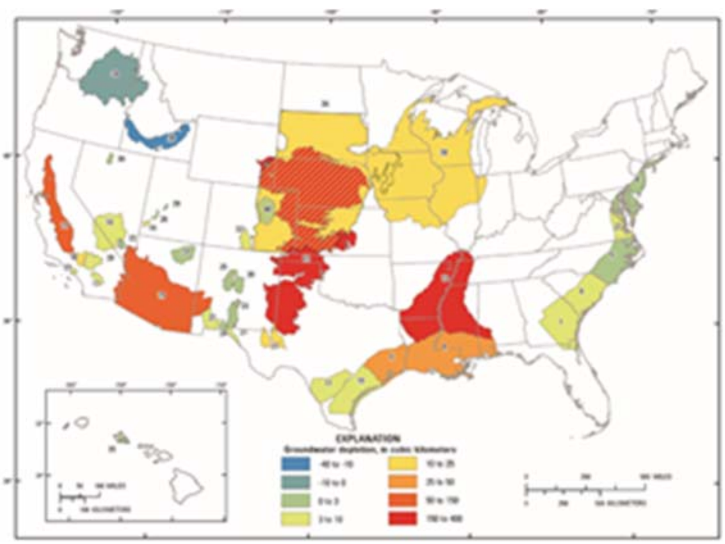
The Great Plains

Groundwater decline and depletion are another significant long-term threat to water supply in both heavily irrigated agricultural regions and metropolitan regions of the United States. The most comprehensive study of aquifer usage was conducted a decade ago by the US Geological Survey. (See Exhibit 6.) The regions with the most-dramatic groundwater depletion are highlighted in red: They coincide with semi-arid regions and zones of intensive agricultural production, most notably in the Great Plains. Cumulative US groundwater depletion from 1900 to 2000 was noteworthy, at 800 cubic kilometers. From 2001 to 2008, it increased another 25 percent. The greatest depletions this century have been in the Central Valley of California, and the lower Mississippi River Valley extending into the Gulf Coastal Plain.

Since the agriculture and power generation industries are the most intensive consumers of water, a continuation of these trends will likely increase their production costs and reduce their profits. It could also potentially result in outsized economic impacts, including declining home values. The vast majority of studies on home valuation assess the impact of water quality, rather than availability, on home prices. Not surprisingly, clean water exhibits a positive effect on property values, whereas localized studies of groundwater contamination show a negative influence on home values. Further work is needed to assess the potential economic impact to the regulated entities as the footprint of water scarcity is broad and the consequences far reaching.

Exhibit 6: Groundwater depletion in 40 top groundwater aquifers since 1900

(Source: USGS Scientific Investigations Report 2013-5079)



Case Study #3: Levee or dam failure

Dam failures across the United States in recent years – including Oroville, CA (2017), Spencer Dam, NE (2019) and Edenville Dam, MI (2020) – highlight the critical impact of aging infrastructure on catastrophic flooding outcomes. Nearly a third of dams are owned by governments or public utilities, while states are responsible for 80 percent of inspections. The average age of all dams in the United States is close to 60 years. A subset of high-hazard dams (at least 100 years old) is highlighted below in Exhibit 7. Follow-on studies from the Oroville Dam failure by the Army Corps of Engineers have warned that the Prado Dam is at high risk of failure and would have an inundation footprint from Newport, CA to Anaheim, CA. Major public work efforts are reinforcing the Isabella Dam, 40 miles northeast of Bakersfield, CA. The Association of State Dam Officials estimates that there are 15,500 dams with high-hazard potential, and that it would cost $70 billion to rehabilitate them and make them safe. The potential consequences to the regulated entities at present remain unknown, but levee and dam failures will likely expose lack of adequate insurance and highlight the protection gap of uninsured and underinsured borrowers.

Exhibit 7: Location of high-hazard dams built prior to 1919

(Source: US Army Corps of Engineers)

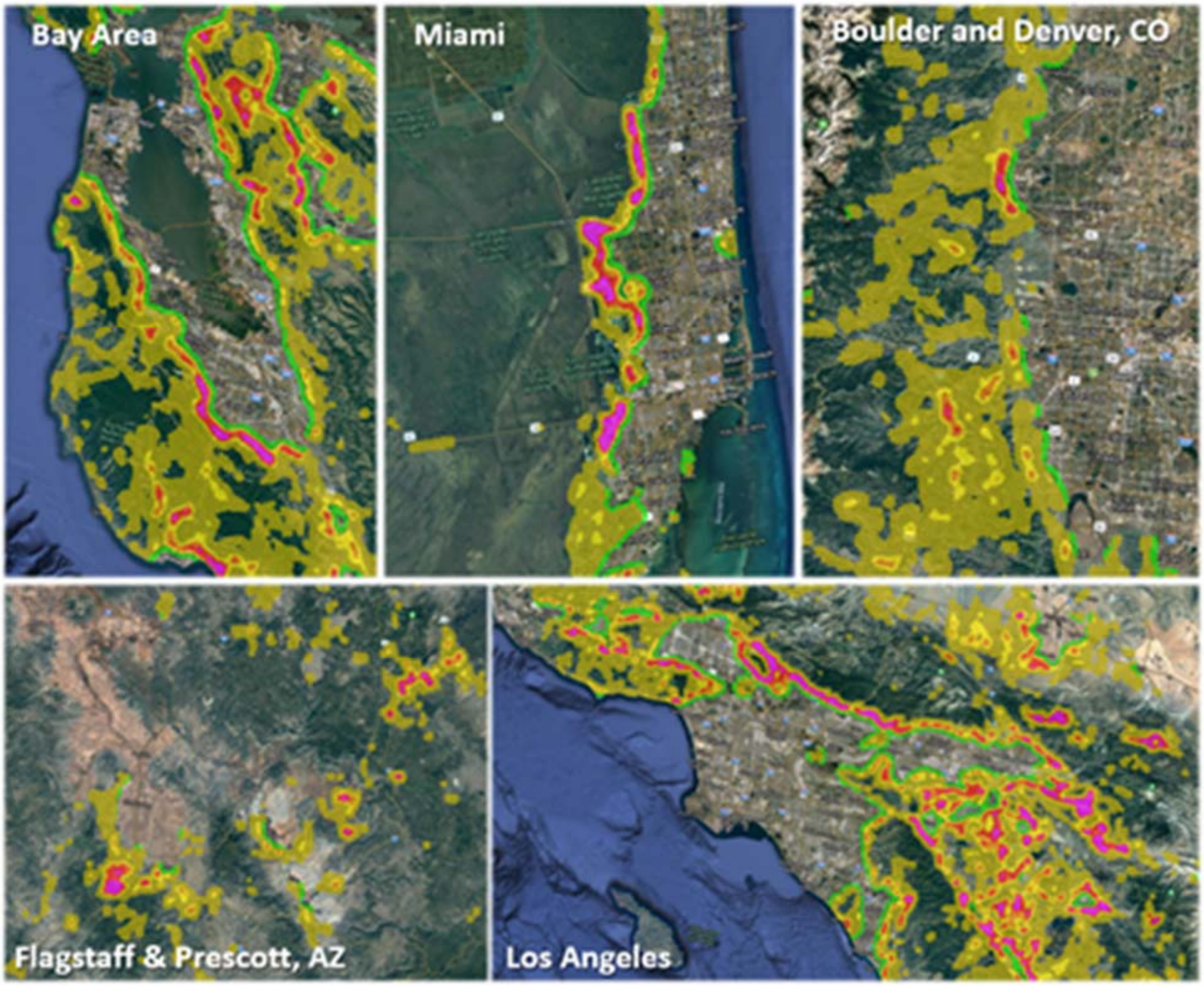
Case Study #4: Urban conflagration of wildfires

The combination of climate change and development in areas of wildland urban interface (WUI) brings an elevated risk to human populations in the United States. Once wildfires move from wildlands into urbanized environments, they can spread rapidly from building to building, often driven by very strong seasonal winds such as the Santa Ana winds in Southern California. This phenomenon is known as "urban conflagration." The confluence of very dry fuels, local seasonal winds, and humans living in vulnerable environments and igniting fires could precipitate a wildfire disaster on an unprecedented scale. The potential impacts of such a disaster spread far beyond a loss of structures: They could range from disruption due to power utility outages pre-event to the destruction of entire communities by urban fire spread.

The risk of such a devastating scenario is widespread. Guy Carpenter's *Urban Conflagration Index* indicates that fires could affect tens of thousands of homes in a single large event on the fringes of most major metropolitan areas in California, as well as locations further afield such as Boulder, CO, Miami, FL and Prescott, AZ. (These are represented by the pink and red shading in Exhibit 8.) The larger the scale, the more pronounced the societal and environmental impacts. These could include widespread home price devaluations and mortgage defaults, as well as a disruption of societal norms in the form of water supply contamination, increased health risks from air pollution, a reduction in tourism, and issues related to insurability.

Exhibit 8: Areas of significant housing density at risk of large wildfires

(Source: Guy Carpenter Urban Conflagration Index)



4

Modeling Techniques and Data Requirements

The quantification of climate change risk begins with understanding existing physical risks (both acute and chronic) and the potential for the risk profile to change. To understand the geographically diverse risks to which the Federal Housing Finance Agency (FHFA) is exposed, different quantification methods are required to align with the current best understanding of the science, available data, and best practices of the risk transfer industry. Present-day risk evaluation consists of the following techniques: profiling based on first-principle insight, hazard mapping of known perils, scenario modeling, catastrophe modeling, and economic modeling. Numerous data providers and capabilities exist for each of these tools, so they can be used to address different types of risk insight and transfer. (See Exhibit 9.)

Exhibit 9. List of industry use cases for different risk quantification tools

Industry Use Case	First principle insight	Hazard mapping	Scenario modeling	Catastrophe modeling	Economic modeling
Data profiling	●	●			
Underwriting	●	●	●		
Risk accumulation	●	●	●		
Physical risk stress testing		●	●	●	●
Reinsurance risk transfer	●	●	●	●	●
Capital modeling				●	●

First-principle insight: distance to coast

The physical and geographic characteristics of each location in a portfolio can provide valuable insight into its risk profile. By aggregating metrics of physical and geographic parameters, indicators can be developed of potentially untenable concentrations of risk. While these aggregations do not provide complete insight into the risk profile of a portfolio, they are often the first step in understanding it. They can also serve as key differentiators when considering risk-based transactions.

With the proliferation of remote sensing technology, commercial data providers have emerged to provide data points that assist in quantifying observable characteristics. Freely available open-source data provided by the USGS, the National Oceanic and Atmospheric Administration (NOAA), and other government-related scientific bodies also form datasets for specific locations. These include elevation, land use, land cover, satellite imagery, and the location of water bodies.

Understanding risk profile based on physical and geographic characteristics, while not a replacement for more comprehensive and more complex solutions, can help the FHFA identify trends and hotspots requiring detailed investigation.

Hazard mapping

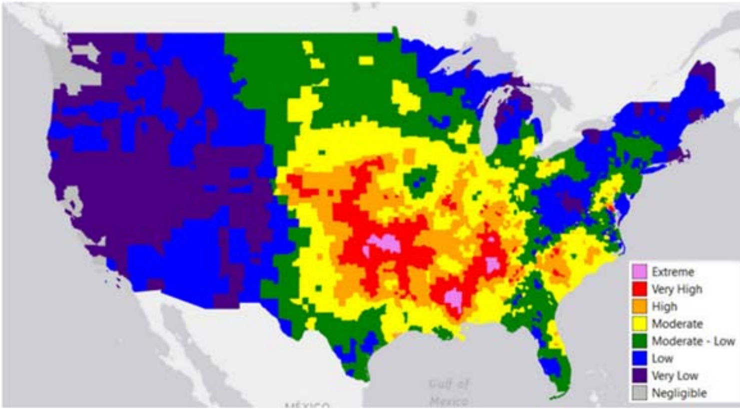
Hazard maps are an effective way to provide quantitative risk-differentiating metrics for specific locations. Ultimately, this risk differentiation can aid in the understanding of risk aggregation, inform location-level risk valuation, and support the development of site-specific reliance strategies.

Hazard maps are the product of detailed geographic information system (GIS) and engineering analysis and can help assess climate risk down to a specific property. In addition to quantifying existing hazards, commercial vendors and open-source providers are beginning to create hazard maps that reflect the impact of possible climate change scenarios. These maps help various industries understand the regional and site-specific impacts of specific perils resulting from different climate stresses.

Resolution is an important consideration when examining the utility of hazard mapping for a specific portfolio of risks. Hazard-map analysis can be applied in many resolutions, and the appropriate degree of precision will generally depend on the peril under consideration. Flood hazard mapping, for example, such as digital flood insurance rate maps (DFIRM), is most informative when the risk is shown down to individual structures, because flood hazard varies significantly with differences in elevation. Conversely, severe convective storm (SCS) hazard mapping, such as Guy Carpenter's STORMi map, assigns risk categories for different SCS sub-perils at the county level. (See Exhibit 10.) Different resolutions are necessary to accommodate the differences in underlying data sources and the semi-random nature of the observations informing the risk metric.

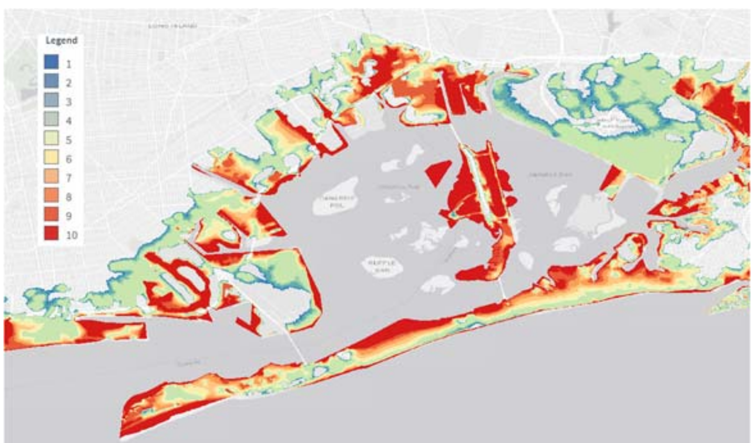
The quantification in hazard maps is generally driven by geographic characteristics. While hazard maps feature some mitigation, site-specific mitigation is generally absent. For example, known levees are mapped within the DFIRM database, but elevated houses are not. It is therefore important to pair the physical risk with detailed loan-level and exposure information.

Exhibit 10: Guy Carpenter's STORMi categorizing areas of severe convective storm severity



The rise in sea level will continue to threaten coastal communities for decades to come. The rise has the potential to increase the risks resulting from acute storms, widen the area impacted, and increase the severity of storm surges. In addition, chronic problems caused by the rise in sea level, such as infrastructure disruption due to "sunny day flooding," will continue to burden local economies.[1] Sea level rise maps help practitioners identify the most significantly impacted regions, so that they can prioritize mitigation efforts and estimate costs under different climate change scenarios.

Exhibit 11. Guy Carpenter's Sea Level Rise Risk Score summarizes different climate change scenarios in a single value that (re)insurance analysts utilize for risk management purposes.



Scenario modeling: wildfire footprint

Hazard maps do not account for correlation between locations. This is a limiting factor when examining how physical risks, such as flooding, may affect a region or a portfolio of risks, because not all locations will experience the same level of damage. Scenario modeling and mapping is a useful tool to examine how a portfolio of risks will respond to specific chronic and acute physical risks. This GIS-based exercise usually involves overlaying a particular hazard

[1]M. Hino, S. T. Belanger, C. B. Field, A. R. Davies, K. J. Mach, High-tide flooding disrupts local economic activity. Sci. Adv. 5, eaau2736 (2019).

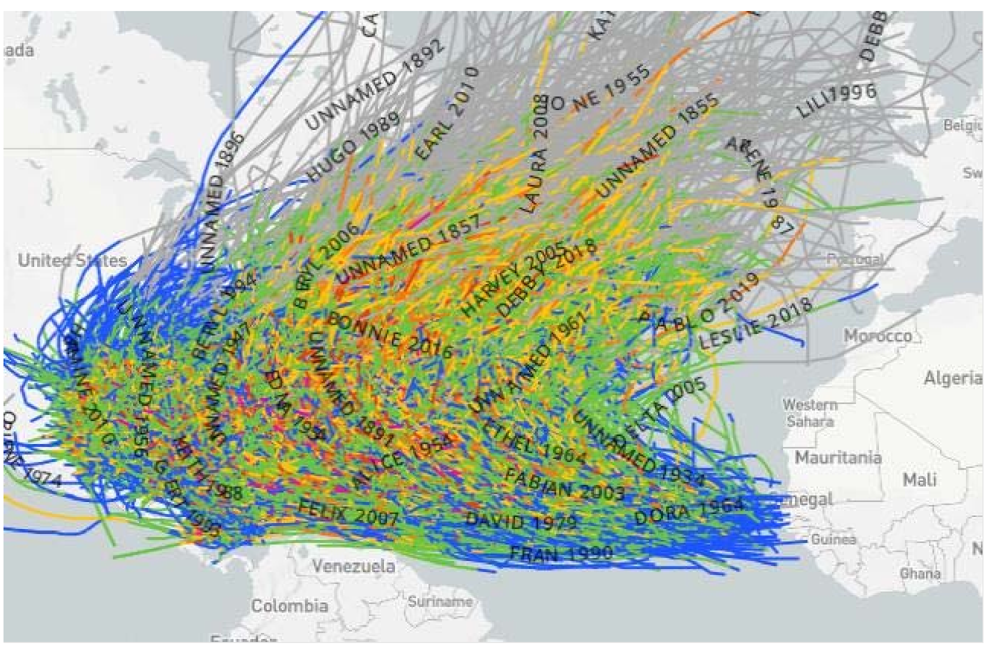
scenario footprint onto a portfolio of risks to identify which locations will be directly impacted. Loss estimation can also be incorporated into the modeling to estimate the financial impact of a particular scenario.

Scenario models represent either historic or hypothetical events and are used for a variety of risk quantification exercises. Historic event reconstructions provide valuable benchmarks for the resilience of a schedule of risks. Hypothetical events, such as the Realistic Disaster Scenarios published by Lloyds of London, are used to stress test portfolios and reinsurer balance sheets. Scenario modeling is also used to investigate event types that are expected to become more prevalent in a changing climate.

Catastrophe modeling

Catastrophe models are a collection of acute physical risk scenarios (called a stochastic catalog) that have calibrated the frequency and severity of the events to historic observations. Their most common application is for probabilistic portfolio-level risk analysis, and they are one of the primary tools used to quantify physical risk for risk transfer solutions. However, advances in technology, specifically around computational efficiency, have made possible greater application of catastrophe models along the value chain of risk quantification and transfer value. For example, the National Flood Insurance Program (NFIP) is currently leveraging a number of catastrophe models in their Risk Rating 2.0 initiative aimed at aligning their rating methodology with current industry best practices.[2] Major commercial model vendors include AIR Worldwide, RMS, KatRisk, and CoreLogic, each of which provides its own suite of models addressing acute physical risk. Major perils include hurricanes, earthquakes, floods, wildfires, and severe convective storms.

Exhibit 12. Map of all historical events used to build and calibrate catastrophe models stochastic catalog.



2 https://www.fema.gov/flood-insurance/work-with-nfip/risk-rating. Accessed March 26, 2021

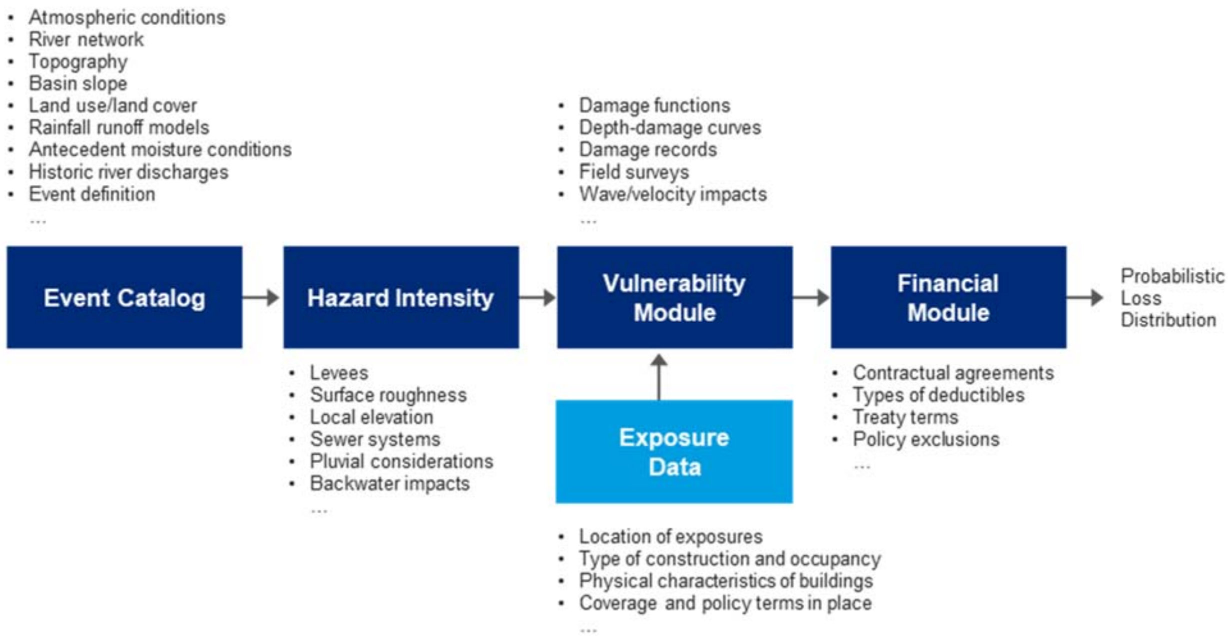
In addition to a catalog of hypothetical events, catastrophe models include a financial engine, which translates physical damage into structure and portfolio-level loss. This component is critical for indemnity-based risk transfer, as it allows both parties to correlate the loss magnitude to a certain probability. After a major catastrophic event, costs for material and labor generally increase as a function of availability. Catastrophe model providers include this in their loss estimates, by including loss adjustment factors calibrated on historical observations of increases in rebuild costs after events in different regions.

Catastrophe model vendors have experience in adjusting modeled frequencies to account for specific climate regimes. The most common adjustment accounts for different sea surface temperature scenarios and provides valuable insight into potential financial losses at different stages in the La Niña-El Niño cycle. While specific scenario adjustments for near-term views are possible, comprehensive adjustments for different climate regimes have been stymied by the uncertainty over future projections of climate and its influence on the frequency and severity of specific perils.

The modeling of potential financial losses varies among perils, because different physical attributes have different sensitivities to the unique damaging element of each peril. In addition, while historical datasets used for calibration are generally consistent between model vendors, differences in modeling methodology can lead to significant differences.[3] To ensure the model loss estimates are appropriate for the exposure of the regulated entities, it is crucial to tailor model results to a mortgage finance view of risk, which is usually derived from an investigation into historical losses. Different model vendors take different views on the sensitivity of specific building characteristics. Marsh McLennan assists clients in understanding these views, so that they can make informed choices when they select the most appropriate combinations of perils and geographic factors for their specific goals. If necessary, they can make adjustments to align stochastic loss estimates with historical experience.

[3] Franco, Guillermo, et al. "Evaluation Methods of Flood Risk Models in the (Re)Insurance Industry." Water Security, vol. 11, Dec. 2020, p. 100069. ScienceDirect, doi:10.1016/j.wasec.2020.100069.

Exhibit 13: Modeling Catastrophe. Anatomy of a catastrophe model with necessary inputs for each section from Franco et al. 2020. Used to identify components suitable for adjustment to align historical experience. This process is justified through extensive analysis into historical portfolio losses.



Economic modeling

Following the introduction of the Enterprises' credit risk transfer (CRT) program in 2013 came sophisticated loan-level models to quantify the potential impact of mortgage defaults on loan-level portfolios. The Enterprises maintain very detailed levels of loan-level data on loan portfolios including LTV, FICO scores, valuations, risk layers, and more that allow third-party models to stress test portfolios for loss potential before and after the application of credit risk transfer structures. Guy Carpenter licenses various economic models including CoreLogic and M-PIRe, which assist the Enterprises and reinsurers to evaluate the risk profile of reference pools in advance of CRT reference pools' issuance. These models, however, are not parameterized to account for the potential consequences of climate change the way physical models are parameterized. Nevertheless, specialized Marsh McLennan analytics teams are capable of and have the tools needed to combine physical and economic models to help assess climate change scenarios and quantify their potential impact on the regulated entities.

Data requirements

The level of insight into climate change and its impacts on natural catastrophes that different tools are able to provide depends on the quality of the exposure data provided to the different tools. Exposure data are usually divided into three categories for each risk within a portfolio: location, financials, and physical characteristics. As the name suggests, location data relate to information on the physical location of a particular risk. Often these include the address or latitude-longitude coordinates, the city, the county, the state, and the postcode. This enables the precise calculation of a number of different geographic and physical risk drivers and how they intersect. If the regulated entities are unable to provide information with this level of detail, disaggregation techniques can help to translate aggregated accumulation metrics into detailed location-specific metrics. This process, however, significantly increases uncertainty, particularly for high-gradient perils such as flood.

Financial information includes details of specific location attributes that are related to the current loan balance, the loan-to-value ratio, and property values. Such information helps to quantify losses through catastrophe models, and it results in informative metrics when aggregated to particular drivers of geographic or physical risk.

Physical attributes include details of each location and indicate likely vulnerability to different acute physical risks. Characteristics such as year built, occupancy, construction type, and number of stories inform the vulnerability module of scenario and catastrophe models. They are essential for translating physical damage into a financial loss.

When detailed data are not available, third-party data providers are used to augment an asset's physical attributes, usually for a fee. Data from these third-party vendors can come from a variety of different sources. Some vendors collect disparate publicly available information and consolidate it into digestible formats for specific use cases. Others combine remote sensing with complex visual intelligence algorithms to identify specific property characteristics. Because each physical attribute's sensitivity to risk varies according to peril, it is important to understand which attributes provide the most predictive power for financial loss. The Marsh McLennan businesses can help the regulated entities optimize their assessment of climate changes given the data available.

5

Enhancing the Supervisory Framework

Incorporating climate-related risks into the FHFA's supervisory framework and practices will become an increasingly critical element of ensuring its mission.[4] However, it is likely that a phased approach to supervision may be the most suitable approach. Climate-related risk is a relatively new field, and modeling approaches and data requirements are still rapidly evolving, so the FHFA can learn and adapt as industry practices evolve. A phased approach also allows the regulated entities build internal infrastructure and teams that can respond to incremental increases in requirements and can gather the data required.

The FHFA will need to consider several factors as it builds out its supervisory practices. There are four key aspects of a possible phased approach.

Supervision of climate-related risk management

As a start, the FHFA could achieve a significant amount by providing overall supervisory guidance to its regulated entities and incorporating climate-related risk management into its supervision of them. Supervisory guidance could outline minimum requirements and best practices, such as involving sufficiently senior executives in the risk review process, as well as appropriate pressure or penalties if entities fail to meet these requirements. The level of scrutiny and weight of penalties can be ratcheted up, as the general level of expertise on the topic rises. Other supervisory agencies have already started to indicate what its expectations might be in this area. For instance, the Federal Reserve made clear in its November 2020 Financial Stability Review that climate change poses risks for banks and that it is the responsibility of bank managers and boards to manage these risks.

Data requirements and disclosures

A key part of risk management is having the right data to understand the risks. Given the rapid evolution of modeling techniques, the FHFA could initially direct regulated entities to develop the data that each believes are required to appropriately manage its risk. Some of these data could be reported to the FHFA. Next, based on these measurements, the FHFA could require all regulated entities to report a standardized set of data to the FHFA. Once the FHFA has had time to review the data and gain confidence that the measurements are appropriate and that the underlying data are reasonably accurate, public disclosure requirements can be issued as appropriate. It will be critical to coordinate in this area with other regulatory agencies, including the US Securities and Exchange Commission (SEC), which will no doubt be making its own moves toward increased and more-standardized disclosure requirements. There will also be

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[4] Ensure the regulated entities fulfill their mission by operating in a safe and sound manner to serve as a reliable source of liquidity and funding for the housing finance market throughout the economic cycle

important non-governmental players, such as the rating agencies, which will have their own ideas on disclosure.

Climate stress tests

Testing the resilience of regulated entities to different climate pathways and assessing the impacts of climate-related risks on housing finance and affordability will be critical parts of the FHFA's supervisory activities. However, a stress test in the context of climate-related risks is a significantly different exercise from a traditional stress test to assess the impacts of financial and economic downturns on financial institutions, such as the FHFA's current Dodd-Frank Act stress tests (DFAST). Federal Reserve Governor Lael Brainard in a recent speech alluded to "the different nature of climate-related risks relative to financial and economic downturns and [their] significantly longer planning horizons."[5] She also contrasted the heavy reliance of traditional stress testing on historical data with the unprecedented nature of climate change, which limits the usefulness of historical data.

As the FHFA defines its overall approach to climate risk management and determines how climate stress testing fits into its broader framework, the experience of other regulatory agencies can help inform potential approaches. For example, the Bank of England has scheduled a climate stress test for 2021. A key consideration for the FHFA may be whether to use the results of such climate stress tests to inform any legally binding capital requirements – such as the stress capital buffer (SCB) highlighted in the recently finalized FHFA Capital Rule for the Enterprises. There are several arguments for creating such requirements to ensure that these risks are sufficiently considered and incorporated by the regulated entities. However, the lack of historical experience with these risks, their unpredictability, and their sheer complexity may mean that some time is required before they can be appropriately incorporated into capital requirements.

If the FHFA were to impose capital requirements based on climate-related risks, an additional challenge would be how best to combine these requirements with other capital requirements. Simply adding on climate-based requirements to existing requirements might not be a suitable approach, given that there is likely to be a relatively low correlation between the conditions that create extreme stress for a bank under standard tests and those that create high stress on climate risk. Approaches that combine these different conditions may be complicated to formulate and hard to justify, and they could reduce the transparency of capital requirements.

Other measures such as risk-weight differentiation

In the future, the FHFA could incorporate climate-related risks by employing supervisory practices that are more direct or stringent. For instance, it could use different risk weights for "green" and carbon-intensive activities. There is considerable international discussion of integrating climate risk into the risk weights used in capital requirements. Lending to green projects or companies, for example, would have a lower risk weight than lending to carbon-intensive ones. This could be done by keeping green risk weights at the level of current risk weights and adding a surcharge for carbon-intensive projects, or by setting green risk weights lower than the current level and carbon-intensive weights higher. Guidance published by other

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[5] Address by Governor Lael Brainard to the Center for American Progress, December 18, 2020, as taken from the Fed's website

regulatory bodies and standard setters, such as the Basel Committee on Banking Supervision (BCBS), will likely provide further clarity on the pros and cons of adopting such measures.

A more extreme approach than revising risk weights would be to create absolute prohibitions against loans to carbon-intensive activities. Regulatory agencies, such as the Federal Reserve, are unlikely to adopt such approaches in the near future. Nevertheless, this is one potential supervisory tool that the FHFA could consider over the long term.

6

Impact on Affordable Housing

Natural disasters have had a disproportionate impact on low-income communities, which disproportionately include Black, Indigenous, and People of Color (BIPOC) populations. The greater vulnerability of low-income communities to disasters is a dual function of their location (often in more disaster-prone areas) and the relative lack of access to financial resources for community members. Climate change threatens to increase the frequency and/or severity of many disaster types, exacerbating this dynamic. One of the main causes for the over-representation of BIPOC in low-income groups is the banking industry's historical practice of redlining, which barred many BIPOC families from homeownership and has had lasting effects on wealth creation.

To address these inequities going forward, the FHFA has two broad decisions to make. First, should the Enterprises' exposure to low-income communities be allowed to increase? Second, should the Enterprises' support or implement special lending programs that boost the resilience of low-income communities?

The Enterprises already have some exposure to low-income communities, mainly via the multifamily lending portfolio, but the two segments of the housing stock most utilized by lower-income Americans generally are not addressed. Many low-income families choose to live in single-family rental homes, which receive only very limited and poorly fitting support compared to the other segments of the housing market. This unexpected gap reduces the Enterprises' ability to address a large segment of the housing market – one bigger than the apartment segment.

In addition, there has been a long, ongoing discussion, even at the Congressional level, about the potential for the Enterprises to extend their lending into the market for manufactured homes. Doing so would significantly increase the Enterprises' exposure to low-income communities, potentially enabling more interventions that could address historic inequalities and curtail the generation of such inequalities in the future. Another contribution to low-income communities could come from targeted lending to mobile homes and mobile-home parks. Many of these are vulnerable to climate-related hazards, so lending to mobile homes and parks would help to address climate injustice.

Regardless of the interest or ability of the Enterprises to expand their lending in low-income communities, several actions can be considered that would improve community resilience.

Preserve assets. The Enterprises could develop a lending program for certain low-income homeowners that includes a principal component that is earmarked for asset hardening. Ideally this component should be subsidized or interest free. It could include raising homes in a flood plain on stilts, adding tie downs or wind-resistant cladding to homes in wind zones, and incorporating earthquake retrofits in earthquake zones.

Retreat options. The Enterprises could provide affordable refinancing for existing loans on properties in high-risk areas. They could work in concert with other agencies, such as the Department of Housing and Urban Development (HUD), to support relocation of owners to less-vulnerable locations.

CBCI. Community-based catastrophe insurance is another novel mechanism the Enterprises could help employ at community level rather than household level. In such programs, community-level resilience enhancements could be partially financed that would have a greater impact on community resilience than home-specific efforts. These programs could yield significant long-term economic benefits in relation to their up-front costs.

Much of the low-income housing at risk is not covered meaningfully by current programs, but extending them to the single-family rental market and manufactured housing market could address much of this gap. For the areas currently covered and any others added, the primary strategies will be the ones already outlined: preserve, retreat, and CBCI. But the correct solution will likely vary from community to community, so it will be important to work with local government and community groups to find the solution with the most just and workable outcome.

7

Risk Management Strategies

By relying on a comprehensive and quantitative view of the climate and natural disaster risks to the housing sector, the FHFA and the regulated entities will be able to define better tolerances for these risks and put in place risk management strategies. Risk management in this context should contemplate the full range of options.

Avoidance. This includes policies, procedures, and tools that enable the Enterprises to avoid taking on unacceptable climate and natural disaster risks.

Reduction. These are mitigation approaches that reduce the impact of climate and natural disaster risks.

Transfer. Shifting climate and natural disaster risks to another party can spread the risk so that it can be borne more effectively.

Acceptance. Based on a thorough understanding of properties and their circumstances, the regulated entities can make an informed decision to take on and retain climate and natural disaster risks.

A combination of these approaches should result in a more resilient housing system with regulated entities that are better positioned to fulfill their core mission responsibilities. In the context of the FHFA request for input, this response will focus on several key ways in which climate and natural disaster risk can be reduced or transferred.

Insurance protection

In the event of a natural disaster, mortgagors’ first line of defense against potential credit losses is traditional property insurance. This is well recognized by the regulated entities, and requirements for property and flood insurance are built into the guidelines for selling and servicing properties. Proper and comprehensive insurance typically provides significant resources for a mortgagor to repair damage without impacting their ability to remain current on the mortgage.

However, significant gaps exist under the current guidelines, resulting in situations in which mortgagors are uninsured or underinsured against climate change and natural disaster perils – the insurance protection gap. This is a significant global economic risk, and the US Federal Insurance Office has established a subcommittee of the Federal Advisory Committee on Insurance focused on this specific topic. The subcommittee submitted recommendations in December 2019. Where these gaps exist, the regulated entities have significantly higher exposure to potential credit losses following a natural disaster. Exhibit 14 shows the regulated entities’ insurance requirements and potential protection-gap exposures.

Exhibit 14: Identifying insurance gaps

Segment	Peril	Existing Insurance	Protection Gap
Single family	Flood	Required in FEMA special hazard zones	• Properties outside hazard zones • Insufficient limits on insured properties • MI physical damage exclusion on >80 LTV loans
	Wind	Required	• Significant wind deductibles in high-hazard areas • MI physical damage exclusion on >80 LTV loans
	Fire	Required	• MI physical damage exclusion on >80 LTV loans
	Earthquake	Optional	• No protection on majority of properties • Insufficient limits on insured properties • Significant deductibles where insured • MI physical damage exclusion on >80 LTV loans
Multi-family	Flood	Required in FEMA special hazard zones	• Properties outside hazard zones • Insufficient limits based on guidelines
	Wind	Required	• Ability to cover deductible with cash flow / reserves
	Fire	Required	• Ability to cover deductible with cash flow / reserves
	Earthquake	Required based on seismic risk assessment	• Properties outside required areas • Ability to cover deductible with cash flow / reserves
REO	Flood	None	• Self-insured with no protection
	Wind		
	Fire		

The scale of the overall insurance protection gap requires a combination of approaches from relevant private and public stakeholders. The FHFA and the regulated entities can consider a number of approaches to reduce this gap and provide greater protection for the potentially impacted population while also reducing potential risk. They can, for example, strengthen insurance requirements for earthquakes and floods and adjust mortgage rates to reflect natural disaster risk and facilitate the purchase of appropriate insurance coverage. They can also allow catastrophe insurance protection for high loan-to-value loans with MI and catastrophe (re)insurance protection for Real Estate Owned (REO) portfolios.

Credit risk transfer

Fannie Mae and Freddie Mac established credit risk transfer (CRT) programs in line with the FHFA conservatorship scorecard objective for “the Enterprises to reduce taxpayer risk through increasing the role of private capital in the mortgage market.” Beginning with small, nascent transactions executed in the capital and (re)insurance markets, to date more than 200 CRT transactions have been completed, transferring more than $130 billion of risk on over $3.5 trillion of single and multi-family mortgages. The private capital, bankers, brokers, and other service providers supporting the CRT programs have "bought-in" to the CRT role in the evolution of the Enterprises. That has resulted in a deep and broad market for the efficient transfer of mortgage credit risk across multiple types of transaction and execution. It is also important to note that reinsurance CRT is frequently placed on a forward basis, so that future credit risk is protected, further reducing pro-cyclicality.

The CRT programs are designed to protect the regulated entities against unexpected credit losses on defined portfolios of guaranteed mortgage loans. The structures provide protection for all credit losses incurred by the regulated entities, including those that might occur as a result of climate and natural disaster risk – though these were not the underlying motivation for this form of risk transfer. This existing protection (notwithstanding recent implications on future CRT related to the capital framework) could form an element of the regulated entities' strategy to manage climate change and natural disaster risk.

Investors and reinsurers have raised concerns on the topic of natural disaster risk in CRT. Following hurricanes Harvey and Irma in 2017, yield spreads on CRT bonds viewed as potentially exposed to loss widened significantly. The Association of Mortgage Investors sent a letter to the regulated entities, asking them to remove natural disaster risk from CRT. Reinsurers participating in the Agency Credit Insurance Structure (ACIS) and Credit Insurance Risk Transfer (CIRT) programs have frequently raised this topic, which is particularly germane given that specific natural disaster risk is the reinsurance industry's largest potential exposure and is the focus of significant analysis, measurement, and capital. However, the CRT market has remained robust in its current form – in both capital and reinsurance markets – including natural disaster risks.

The FHFA and the regulated entities should consider the CRT implications of climate and natural disaster risk on multiple fronts within this overall review.

Data disclosure. To analyze the potential natural disaster exposure in a CRT transaction, investors and reinsurers should require more-detailed data than are currently provided. Risk modeling tools depend on detailed property information at (or as close as possible to) specific locations in order to analyze a portfolio. The existing data on location are generally limited to a three-digit zip code. But natural disaster perils are sensitive to small variations in location, so a greater level of detail is needed to assess the risks. Consideration should be given to more detailed data disclosure that would enable risk analysis, while maintaining the required confidentiality of personally identifiable information.

Analytics and modeling. Specific risk-transfer transactions for natural disaster perils in (re)insurance and capital markets typically are accompanied by a third-party analytical assessment of the underlying risk. This assessment is a valuable tool for the protection of sellers and enhances the execution of transactions. Similarly, the FHFA and the regulated entities could consider enhancing the execution of the CRT transaction by providing natural disaster risk analytics to investors and reinsurers. There are a number of firms willing and capable of providing such analysis, including vendors of catastrophe models and (re)insurance broking firms.

Cost-benefit of coverage. While the existing CRT structures currently provide coverage for natural disaster risks, the FHFA and regulated entities should consider the existing and future costs and benefits of including such coverage. To the extent that the structures carve out credit losses resulting from physical damage (notwithstanding the practical implications of specific identification), there will be positive implications in terms of market expansion and pricing. With the greater understanding and quantitative analysis that is now possible, such analyses of costs and benefits should be considered in the context of an overall evaluation of climate and natural disaster risks and while working with market participants.

Catastrophe (re)insurance protection

The FHFA can consider a number of potential approaches to climate and natural disaster risk transfer as a supplement to or replacement for the coverage provided under the CRT programs. There is a significant existing market for assuming natural disaster risk from a variety of entities, including public entities, insurers, reinsurers, and corporates. The entities involved in this market (reinsurance companies, investment funds, vendor model firms, and brokers, including Marsh and Guy Carpenter) have invested considerable resources in understanding and quantifying the risks from the various natural perils. These entities could provide a substantial resource for the FHFA.

Fundamentally, climate and natural disaster risk manifests itself as credit risk for the regulated entities and other holders of mortgage credit risk. This poses a unique challenge in considering specific approaches to risk transfer, as it can be very difficult to ascertain whether a credit loss is the direct result of natural disaster-related causes or other causes. There are various approaches to designing potential protection products for the regulated entities. Some products include parametric protection. These pay out under pre-determined conditions (or parameters), which are selected to strongly correlate with potential losses of the protection buyer. After a natural disaster, parametric protection products could quickly and transparently provide funds to help the regulated entities manage the impact of related credit losses. Effective design of the parameters that trigger protection is vital and closely related to the earlier discussion of the science, data, and analytics that can be used in climate and natural disaster risk.

There are several examples where both public sector and mortgage credit entities have utilized risk transfer to mitigate climate and natural disaster risk. Bayview Asset Management has issued two parametric earthquake catastrophe bonds (Sierra Ltd. Series 2019-1 and 2021-1) to hedge the embedded risk on its mortgage asset holdings. Bayview has structured these bonds so that the protection is based on the occurrence of an earthquake exceeding specific parameters related to ground motion and shaking intensity, as measured by the United States Geological Survey (USGS) across several Western states. The two Bayview catastrophe bonds have provided fully collateralized protection totaling $425 million.

The New York Metropolitan Transportation Authority (MTA), meanwhile, accessed the reinsurance markets in 2013, 2017, and 2020 via the MetroCat Re cat bond. After witnessing the significant impact of Hurricane Sandy in 2012 on New York’s subway system, the MTA chose a parametric mechanism that triggers payments when the storm surge causes water to rise to a pre-agreed level at selected measurement stations around New York Bay. The stations are highly correlated with expected flooding at MTA’s vulnerable infrastructure locations. Under the latest, 2020, issuance, the system is designed to provide a cash influx to the MTA of $100 million if those conditions materialize, allowing the MTA to deploy funds to repair infrastructure or respond to the emergency.

The US Federal Emergency Management Agency’s (FEMA) National Flood Insurance Program (NFIP) has utilized risk transfer programs since 2017 to better manage losses incurred in major flood events. FEMA has secured more than $6.5 billion in total risk transfer protection through both traditional reinsurance and risk transfer executions from catastrophe bonds since the inception of these programs. The inaugural reinsurance placement for FEMA in 2017 provided a demonstration of the utility and responsiveness of this risk transfer when the entire $1.042 billion limit was recovered as a result of Hurricane Harvey.

These examples provide valuable perspective on the potential structures and sources for climate and natural disaster risk transfer. The FHFA and the regulated entities should consider transferring natural disaster risk that exceeds their risk appetite and available financial resources. To the extent that these solutions are pursued, it should be viewed as a process. It will build from risk analysis to structuring, discussions with market participants, and an initial transaction. Ultimately, it will lead to a series of regular placements that access the global spectrum of risk takers in the reinsurance and capital markets.

Incentivizing resilience

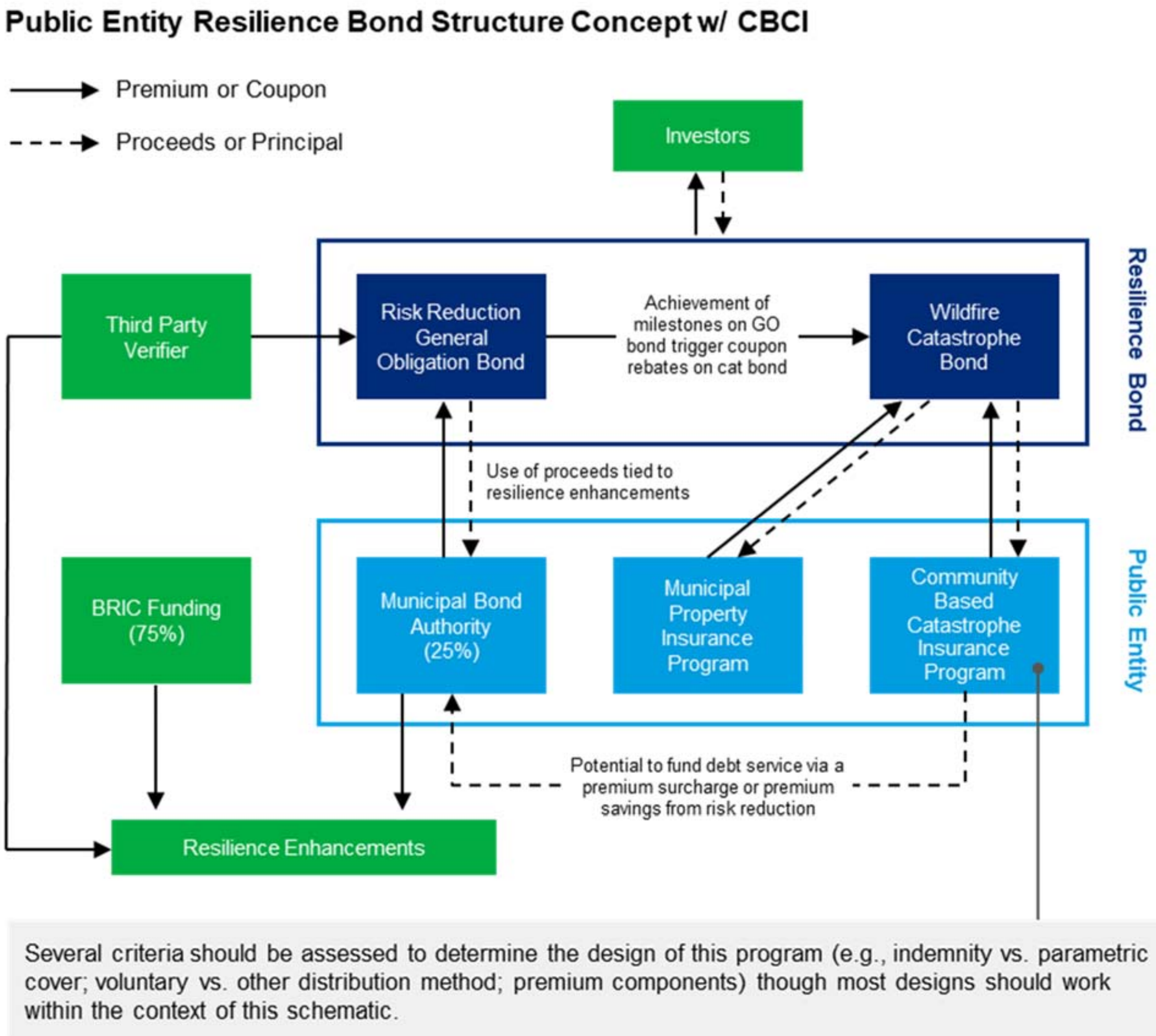
The FHFA and the regulated entities should also consider their role in enhancing the resilience of communities exposed to climate and natural disaster risk. This is challenging for many reasons. The main challenge relates to the difficulty of paying for risk reduction investments due to a lack of supporting cash flow. The avoidance of future costs resulting from investments in risk reduction are difficult to monetize. Therefore, most such investments rely on the capacity to issue general obligation bonds of local municipalities, utilities, or special districts. In many cases, this capacity is already stretched.

To get past this bottleneck, some have proposed resilience bonds that link risk reduction financing to risk transfer financing. In a resilience bond structure (See Exhibit 15.), a risk reduction activity is paid for in part by a reduction in insurance premium resulting from the reduction in risk – after this enhancement has been completed and verified by a third party. Municipalities have attempted to initiate resilience bond structures, and other bonds without an insurance rebate component. However, to date no such issuances have been consummated.

The challenge is that the reduction in risk to service the principal and interest payments of the bond are insufficient to support communities' municipal insurance purchases. One way to potentially address this issue is through CBCI, a mechanism through which a community can offer catastrophe insurance to residences or small businesses in their jurisdiction. The insurance is offered as an alternative or a supplement to private insurance or state-backed FAIR plans.

In a CBCI structure, insurance coverage is aggregated at a community level. The CBCI program can warrant a premium reduction for community members upon satisfactory completion of a risk reduction activity. These savings would not be possible in an open market system due to the size and diversity of the private market and its manifold effects on pricing. The savings in premiums can either be passed on to community members or be banked to service the debt on the bond financing the risk reduction activity.

Exhibit 15: Public entity resilience bond structure concept with community-based catastrophe insurance



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About Marsh McLennan and Our Commitment to the FHFA

Extreme precipitation, fires, earthquakes and other hazards could damage or destroy infrastructure and the physical real estate assets that back single family and multifamily housing finance markets of the regulated entities. Drought, extreme temperatures and ground water depletion may have non-linear socioeconomic impacts which could trigger massive migration shifts with potentially severe consequences to regional economies and the ability of borrowers and renters to fulfill their financial obligations. Low-income borrowers and renters may be especially vulnerable to such disruptions.

In strengthening the financial system's stability and resilience, we encourage the FHFA to continue to promote and emphasize the critical importance of strong risk identification practices and robust climate scenario analysis. As no one can predict the future, instilling the discipline of scenario analysis, informed by climate science, across the FHFA's regulated entities will serve to inform critical risk management decisions – including customer solutions, product design, risk-based pricing and capital management.

Like other public institutions with concentrated risks, the FHFA and the regulated entities need to recognize that they may not be the most efficient holders of climate change risk and that it may make most sense for them to participate in a global risk transfer market with other institutions that are more efficient managers and holders of risk. New risks will emerge and the risk transfer market and management science of climate change will evolve. Marsh McLennan is uniquely positioned to help the FHFA and other agencies to measure, manage, and potentially transfer these risks to the most efficient holders of these risks. We look forward to participating with the FHFA to address these challenges.

Marsh McLennan is the world's leading professional services firm in the areas of risk, strategy and people. The company's 76,000 colleagues advise clients in over 130 countries. With annual revenue of $17 billion, Marsh McLennan helps clients navigate an increasingly dynamic and complex environment through four market-leading businesses:

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