The Pearl Resilience Pillar:
Measuring and Motivating Climate Adaptation in U.S. Housing

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ABSTRACT

Climate-related disasters increasingly threaten the stability of the U.S. housing finance system. As wind, water, and fire events intensify, residential insurers have experienced record losses and responded with unprecedented levels of non-renewals and market withdrawals. Once largely limited to a small number of "high-risk" states like California, Florida, and Louisiana, these dynamics now threaten many other regions of the U.S. The National Association of Insurance Commissioners recently identified a widening "protection gap," as premiums rise and home insurance coverage becomes inaccessible, a dynamic that threatens the stability of mortgage and housing markets.

Resilience measures—such as impact-resistant roofing, elevated foundations, and ember-resistant vents—can substantially reduce losses and improve insurability, especially when incorporated at construction or through targeted retrofits. While these measures do not eliminate risk, they significantly improve recovery outcomes and financial security. Yet homeowners have limited access to clear, actionable information about a home's resilience. Publicly available tools like the First Street climate score reveal hazard exposure, but do not address the specific home's resilience, or provide guidance on how to mitigate a home's climate risk.

This paper presents the Resilience Pillar of Pearl's national home performance SCORE™ as a mechanism to close this information gap and motivate homeowners to implement resilience upgrades. The Resilience Pillar scores features that harden homes against floods, storms, wildfires, earthquakes, and extreme temperatures, using a 200-point scale integrated into the 1,000-point Pearl SCORE framework. This paper examines the conceptual and technical design of the pillar, its role in promoting market transparency, and its potential to support a more sustainable and insurable housing stock.

Introduction

The U.S. housing stock is facing unprecedented risk. Between 1980 and 2024, major weather-related natural disasters – convective storms, hurricanes, wildfires, floods, and other hazards –caused \$2.9 trillion in inflation-adjusted losses (NOAA 2024). The scale of these losses has been increasing rapidly: damages from the fifteen-year period between 2010–2024 totaled roughly \$1.7 trillion: 60% of the total amount over the 45 years studied.

Disaster-related losses are already affecting residential insurance markets: the availability of home insurance is decreasing, and home insurance prices are increasing. A recent analysis by the U.S. Department of the Treasury's Federal Insurance Office found that homeowners insurance premiums have increased significantly in many regions in recent years and that policy non-renewal rates are higher in areas with elevated climate risk (FIO 2025). If natural disasters continue to be as severe as they have been in the past decade, insurance losses will almost certainly rise sharply in both frequency and severity. Escalating claims are already forcing insurers to raise premiums, restrict coverage, or withdraw from high-risk markets altogether.

As insurance becomes less available, housing and mortgage markets will experience collateral effects. Because mortgage lenders typically require homeowners insurance as a condition of financing, disruptions in insurance markets have the potential to affect mortgage availability. Large-scale reductions in homeowners' ability to access mortgage finance could in turn affect property values and affordability in vulnerable areas. Research from the Federal Reserve Bank of Dallas found that rising homeowners' insurance premiums had increased the probability of mortgage delinquency and borrower financial stress in affected regions (Gallagher et al. 2025). Other research has revealed similar findings, as well as identifying reductions of property values in exposed regions. (See CBO 2024, Senate Committee 2024, and First Street Foundation 2023a and 2023b.)

The U.S. Financial Stability Oversight Council has highlighted how disruption of insurance markets and broad reductions in real estate values threaten the stability of the U.S. financial system (FSOC 2021). Federal Reserve researchers expressed similar concern that climate-related hazards could affect insurance markets, increase lending exposures, and reduce asset values across the financial system that supports U.S. housing and mortgage markets (Brunetti, et al. 2021).

The scale of exposure amplifies these concerns: the U.S. housing market is valued at roughly $55 trillion, and an estimated $12.7 trillion in residential property value is located in areas vulnerable to severe climate hazards (see Xu 2025, Manhertz 2025).

In this context, strategies to mitigate the damage that climate-related disasters cause to the U.S. housing stock are important for insurance and mortgage markets, for the larger financial system – and, most importantly, to the owners and occupants of U.S. homes.

Residential Resilience

Mitigation opportunities are real, significant, and scalable across the existing housing stock. Research on improving the resilience of homes to natural disasters has expanded rapidly over the past decade. A wide range of measures – wind- and impact-resistant roofing, adequate drainage and backflow prevention systems, properly located and designed HVAC equipment, and dozens of other measures – have been shown to materially reduce disaster-related damage.

The ideal time to incorporate resilience measures is during new construction, but many retrofit improvements can significantly strengthen the resilience of existing homes. Examples include strengthening roof decking and installing hurricane straps to reduce wind damage, adding flood vents and elevating mechanical equipment to limit flood losses, and creating defensible space and installing ember-resistant vents to reduce wildfire ignition risk.

Empirical evidence demonstrates that these measures can substantially reduce disaster damage and associated losses for homeowners, insurers, and the broader economy. A 2020

FEMA analysis found that buildings constructed to modern International Code (I-Code) standards avoided approximately $27 billion in hurricane, flood, and earthquake losses between 2000 and 2016. The study further projected that if all new buildings nationwide were constructed to modern I-codes codes, cumulative savings from reduced disaster losses could reach approximately $600 billion by 2060.

Because this analysis focused primarily on new construction, it captures only a small portion of the potential resilience benefit. New homes represent only a small share of the total U.S. housing stock each year. More than 140 million existing housing units are exposed to natural hazards. If even a portion of the existing housing stock were upgraded through resilience retrofits to approach modern code performance, the resulting reduction in disaster losses could be far larger than the savings associated with new construction alone.

Evidence from retrofit-focused studies supports this conclusion. A University of Alabama analysis of insurance claims from Hurricane Sally in 2020 found that insurers paid $149.3 million in storm-related losses among homes in its sample. The researchers estimated that if all conventional homes in the sample had been built or retrofitted to the Fortified Roof standard, insured losses would have been reduced by approximately $99.9 million (67%). If homes had met the more stringent Fortified Gold standard, losses would have been reduced by about $111.8 million (75%) (Alabama Department of Insurance and Center for Risk and Insurance Research 2025).[1]

Evidence from other hazards shows similar benefits. Studies of wildfire risk have found that homes with defensible space and ember-resistant construction features are significantly less likely to ignite during wildfires. Analyses of wildfire damage in California have found that vegetation management and ember-resistant construction features are strongly associated with home survival (Syphard and Keeley 2019). Flood mitigation measures such as elevating mechanical equipment, installing flood vents, and sealing foundations have likewise been shown to substantially reduce building damage and repair costs following flood events (Aerts et al. 2018).

More generally, the National Institute of Building Sciences' *Natural Hazard Mitigation Saves* study found that every dollar invested in hazard mitigation through federal mitigation grant programs saves an average of six dollars in future disaster costs. Together, these findings demonstrate that resilience measures—particularly when applied through retrofit improvements to the existing housing stock—can significantly reduce disaster losses at scale (NIBS 2019).

This research suggests that the U.S. housing stock is characterized by a substantial "resilience gap"—the difference between how homes currently perform when exposed to natural hazards and how they could perform if widely available resilience measures were implemented. The scale of the opportunity is enormous. The U.S. contains more than 140 million housing units, the vast majority of which were built before modern disaster-resilience standards were widely adopted. Because new construction typically adds only about one percent to the housing

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[1] The Fortified Roof standard is a voluntary, beyond-code re-roofing program developed by the Insurance Institute for Business & Home Safety (IBHS).

stock each year, improving the resilience of existing homes through retrofit measures will be essential to reducing disaster losses. Even incremental improvements in resilience across the existing housing stock could produce very large reductions in aggregate losses over time.

The concept of a "resilience gap" has a close parallel in the energy efficiency literature. For decades, energy researchers have described an "efficiency gap"—the difference between the energy buildings actually consume and the level of consumption achievable if widely available cost-effective energy efficient measures and technologies such as insulation, air sealing, and installation of high-efficiency HVAC systems were implemented. National modeling by the National Renewable Energy Laboratory suggests that residential energy use could be reduced by roughly one-quarter using currently available efficiency measures, producing on the order of $50 billion per year in avoided household energy costs across the U.S. housing stock (Wilson et al. 2017).

The efficiency gap is relevant to the resilience gap as a precursor and example: many of the challenges that energy professionals have experienced closing the efficiency gap will be relevant to the resilience field. More significantly, however, the efficiency gap and resilience gap are closely related. The measures necessary to address resilience to extreme heat and cold overlap closely with efficiency measures. For other hazards, efficiency measures often enhance passive survivability, and some directly mitigate climate risk.

Closing the residential improvement gap is not out of reach financially. Studies of residential mitigation programs suggest that meaningful resilience improvements typically cost about 1–3% of construction cost for new homes (roughly $3,000–$13,000) and $5,000–$25,000 for retrofits designed to mitigate the damage caused by common hazards such as storms, floods, and wildfires (NIBS 2019; IBHS 2020; FEMA 2020). That said, new home prices are beyond the average buyers' budgets, and most homeowners don't have $5,000–$25,000 lying around to be used for retrofits.

Driving Resilience Improvements Through Visibility

The opportunity to improve the resilience of U.S. homes is immense and promising. However, the evidence overwhelmingly suggests that resilience improvements are not being made at the speed or scale necessary to mitigate the damage caused by future climate-related disasters and the consequent risks to insurance and mortgage markets.

Resilience improvements to the residential housing stock will be made almost entirely by home builders and owners. Builders who construct to emergent resilience standards, or homeowners who install disaster mitigation measures such as impact-resistant roofing, improved roof attachments, wildfire-resistant vents, or elevated mechanical equipment, often receive little or no financial benefit from these investments unless disaster strikes and the home suffers less than nearby less resilient properties.

Market mechanisms that could reward builders and homeowners for resilience improvements include:

- Higher home sale prices relative to comparable homes without resilience features;

- Lower insurance premiums reflecting reduced expected losses;
- Preferential mortgage terms or lower interest rates due to reduced default risk;
- Public-sector incentives tied to verified mitigation measures.

To supply these benefits, however, the respective markets all require information. At present, resilience features are largely invisible in housing markets. Hazard exposure is increasingly well documented through flood maps, wildfire risk tools, and other datasets, but the presence of mitigation features such as those discussed earlier – impact-resistant roofing, improved drainage, wildfire-resistant construction, or other home-hardening measures – is rarely captured in real estate transactions or widely available property data. As a result, there is no way to identify and differentiate between homes that have implemented resilience measures and those that have not.

The insurance market illustrates this problem. Insurers today rely on highly sophisticated catastrophe models to estimate hazard exposure at the level of individual properties. These models incorporate detailed information about flood risk, wildfire hazard, hurricane wind fields, and other climate-related threats. However, the datasets insurers use for underwriting typically contain only limited information about the mitigation features that reduce losses. While some jurisdictions offer discounts for documented mitigation measures, these programs remain limited and typically require inspections or certifications that are not widely available. As a result, insurers can often estimate the hazard risk facing a property with considerable precision, but typically have far less visibility into the resilience measures that reduce that risk. This makes programs that incentivize resilient homes through reduced insurance rates difficult to implement.

Addressing this resilience gap therefore requires more than identifying effective mitigation measures. It also requires mechanisms that provide the information necessary for housing markets, insurers, and lenders to recognize and reward resilience investments. Without reliable information about resilience features, the financial incentives necessary to support increased resilience investments at scale will never be provided.

Creating Market Visibility

Pearl has created a potential solution to this crucial problem of visibility. Pearl (formerly Pearl Certification) is a firm dedicated to driving improvements in the performance of U.S. homes by making home performance visible, in particular at time of sale. In 2024, Pearl decided to focus on creating a national performance rating to achieve this mission.

Professionals use the term “home performance” to denote multiple performance dimensions of a home – health, safety, comfort, energy and water efficiency, and resilience – because they recognize that these performance dimensions are deeply interconnected. The building shell and mechanicals, for example, have profound effects on health, safety, comfort, energy efficiency, and resilience. However, home performance is not a term used by most consumers, and, to the extent that they think about any of the dimensions of home performance, do not see them as being connected.

Consumers consistently indicate in national studies that they value aspects of home performance, such as health and energy efficiency. Surveys carried out by a range of reputable firms, from Consumer Reports to the National Association of Realtors (NAR 2023) to the National Association of Home Builders (NAHB 2021), for example, consistently show that a large proportion of homeowners value energy efficient homes and energy efficient home features. A smaller proportion of respondents say that they would pay more for efficient homes. In practice, however, these stated preferences have not translated into robust consumer demand for high performance homes and high performing features.

The problem is that most consumers don't recognize home performance as a concept and don't think of their homes as "performing." The survey responses indicate that they value the benefits of a high-performing home: health, safety, comfort, low utility costs, and the ability to generate and/or store energy, for example. But most consumers have only a very vague idea of how specific home features translate into performance benefits.

The Pearl SCORE

To help communicate what home performance is and how it consists of multiple dimensions of a home, Pearl created the Pearl SCORE: a performance rating for every single-family home, duplex, and manufactured home in the U.S.. The letters of the name spell out five key dimensions of home performance:

- **S**afety and health
- **C**omfort
- **O**perational efficiency
- **R**esilience
- **E**nergy generation and storage

The SCORE is a number on a thousand-point scale that indicates a home's performance on these five dimensions relative to all other homes in the U.S. It gives consumers a single simple number that introduces them to the idea that their home performs, and suggests how their home's performance measures up to their neighbors' homes, or the homes they're interested in buying. Homeowners or home buyers can investigate the factors that drive a specific home's score in the online Pearl registry and app, and can learn about home performance in the process.

Pearl's system assigns each home a SCORE according to the quantity and quality of its performance features. The SCORE takes into account over 300 home features and characteristics. The more performance features a home has, and the more efficient or effective they are, the more points a home will earn. The 500-point threshold is generally equivalent to a home built to IECC 2012 standards. Homes that score over 500 points, and are reviewed to ensure that they have addressed key health and safety issues, may be eligible for Pearl's Silver, Gold, and Platinum medallions.

Pearl has generated a SCORE and an energy model for 92 million U.S. single-family homes, duplexes, and manufactured homes based on data available through public permit and assessor records, MLS data, and proprietary data sources. Comparison of the energy models indicates that they are almost as accurate at predicting actual energy bills as models based on extensive site-observed data.[2]

Four of the five Pillars in Pearl SCORE are constructed as solutions to a set of related home performance problems. The Safety Pillar, for example, addresses:

- Health problems from poor indoor air quality (including particulate matter, carbon monoxide and other combustion byproducts, and radon);
- Health problems from moisture-induced mold growth;
- Health problems from exposure to hazardous materials;
- Health problems from unsafe potable water;
- Safety problems from an inaccessible environment.

The fifth Energy Pillar is constructed around opportunities to generate, store, and manage energy. This framing reflects the fact that most U.S. residents do not currently see the fact that a home cannot generate and store energy as a "problem."

The holistic design of the SCORE is intended to interest and provide relevant information for a wide range of U.S. residents. Different people will focus on and derive value from different aspects of the SCORE: a family with children who have asthma may focus on the Safety pillar, while cost conscious homeowners may be interested in the energy and water efficient features in the Operations pillar.

The SCORE's holistic design also serves to communicate the multiple benefits that many performance features provide. Insulation, for example, provides comfort, operational efficiency and resilience benefits. This richness of benefits can be lost if only one dimension of home performance is considered.

The Resilience SCORE

Pearl made resilience one of the five pillars in recognition of the rapidly increasing threat that climate-related disasters pose to U.S. homes, and potential for resilience measures to mitigate the damage these disasters cause. The Resilience Pillar, like the other components of the Pearl SCORE, is designed to translate the complexities of building science into a standardized metric that enables resilience features to be incorporated into real estate transactions, insurance underwriting, and mortgage risk assessments.

The Resilience Pillar scores homes on the extent to which they are prepared to withstand natural disasters. The scoring system looks at vulnerability to five natural disaster types:

- Flooding

[2] A paper detailing these findings is forthcoming.

- Storms (including hailstorms, hurricanes, tornadoes)
- Wildfires
- Earthquakes
- Extreme temperatures

Scoring for the Resilience Pillar is based on the extent to which the home is resilient to these potential natural disasters. Homes are scored according to the natural disasters to which they are vulnerable, as indicated by climate risks zones. A home that is located within a 500-year floodplain, for example, is scored according to the extent to which it incorporates flood-resilience features, such an elevated foundation made from water-resistant materials, pumps, and/or drainage systems. Conversely, a home located above the 500-year floodplain is not penalized for a lack of flood resistant features because the flood risk is low.

A perfect resilience SCORE indicates that the home has taken all reasonable mitigation measures to protect itself (home hardening) against the disaster(s) to which it is vulnerable, and should thus withstand those disasters much better than an average home.

One of the characteristics of the Pearl SCORE is that a performance feature can contribute points to multiple pillars. Insulation, as discussed above, generates comfort, operational efficiency and resilience benefits, and as a result it contributes points to the Comfort and Operations Pillars, and some of the disaster types in the Resilience Pillar. The higher the R-value of the insulation and the better the installation quality (as measured by RESNET grades), the more points earned.

Disasters Categorization

Natural disasters can be divided into many categories. FEMA's National Risk Index (NRI) identifies 18 separate natural hazards affecting U.S. communities. Some systems identify dozens of unique hazards.

Pearl chose to focus on five categories of disaster that map to the four commonly identified damage mechanisms:

Table 1. Damage Mechanisms and Pearl SCORE Pillar Disaster Categories

Damage Mechanism	**Pearl Pillar**
Wind	Storms
Water	Flooding
Fire	Wildfires
Ground motion	Earthquakes

The fifth natural disaster type, extreme heat and cold, was incorporated into the Pearl system because it is associated with high levels of mortality. Of the five disasters, extreme temperatures cause the most deaths on average per year: roughly twice as many as all other disasters combined. Extreme heat is typically the biggest killer, causing between approximately 150 and 300 deaths a year (NOAA 2022).

Table 2. Typical U.S. Deaths per Year by Hazard Category

Hazard category	Typical U.S. deaths per year attributed to hazard	Notes
Extreme heat	~150–300+	The single largest cause of weather-related deaths in the U.S.
Extreme cold	~100–200	Hypothermia and exposure; can exceed heat in some datasets depending on definitions (CDC)
Water (floods, storm surge, rip currents)	~80–120	Flooding is the leading sudden-event killer among storms
Wind (tornadoes, hurricanes, severe storms)	~50–100	Highly variable because rare large hurricanes dominate totals
Wildfires	<10 direct deaths most years	Indirect smoke mortality can be much higher but is usually counted separately and occurs over a longer time period
Earthquakes	≈0 most years	Very rare but catastrophic when they occur (e.g., 1906, 1989)

By contrast, extreme heat and cold typically cause much less physical damage and thus have a much less significant economic impact than the other types of natural disasters.

Table 3. Relative Mortality and Housing Damage by Hazard Type

Hazard type	Relative mortality	Relative housing damage	Key reason
Extreme heat / cold	**Very high**	Very low	Health exposure rather than structural damage
Water (floods, storm surge)	Moderate	**Very high**	Flooding damages large numbers of homes simultaneously
Wind (hurricanes, tornadoes, severe storms)	Moderate	**Very high**	Roof loss, debris impact, structural failure
Wildfire	Low direct deaths	**High but localized**	Entire neighborhoods can burn
Earthquakes	Very low in most years	Potentially catastrophic but rare	Concentrated in limited regions

Passive Survivability

One feature of all of the natural disaster scoring systems is a set of points allocated for passive survivability. During many natural disasters, injury and loss of life often occur in the hours or days following the disaster. In the case of flooding or severe storms, survivors may experience injury or loss of life while stranded in their homes during the period when floodwaters abate and before help arrives. A home with features that support survivability will keep the occupant buffered from temperature extremes, even if the heating and cooling systems are not working, and may provide power through independent solar or storage systems.[3]

[3] Use of the term "shelter in place," previously used in place of "passive survivability," has been discouraged by the public sector to prevent inadvertent endorsement of the practice of staying in place during disasters, rather than relocating to relative safety.

Resilience and Energy Efficiency

Although energy efficiency and energy generation and storage are represented by two other Pillars in the Pearl SCORE (Operations and Energy, respectively) it is significant to note that a number of performance features, particularly shell measures, commonly thought of as "energy efficient" also contribute to the Resilience pillar, see Table 4 below. Their contribution is most important to the resilience to extreme heat and cold "problem," and to the survivability component of each of the other disaster types. High-quality windows also protect against storms, however, and air sealing and ventilation protect against smoke from wildfires.

Table 4. Efficiency and Resilience Benefits by Home Performance Measure

Home Performance Measure	Efficiency Benefit	Resilience Benefit
Air sealing	Increased efficiency	Reduces impact of extreme temperatures
Insulation	Increased efficiency	Reduces impact of extreme temperatures
High-performance windows	Increased efficiency	Improved storm resistance and reduces impact of extreme temperatures
Duct sealing	Increased efficiency	Reduces smoke infiltration
Mechanical ventilation	Adequate indoor air quality	Post-disaster habitability / mitigates smoke infiltration
Solar + storage	Load reduction	Backup power
Heat pumps	Increased efficiency (if not costs)	Reduces combustion risks during disasters and can provide heat if home is equipped with solar and storage

Contractors

Contractors are the primary actor making performance improvements in the existing housing stock. The energy efficiency sector is perennially concerned about the quality of contractors working on energy efficiency-related home features. However, in the case of efficiency, a body of best practices and technologies has accumulated over the course of several decades. There are many resources for a contractor to learn how to incorporate best energy efficiency practices into their work. Further, energy efficiency improvements are generally structured by systems: HVAC and insulation contractors.

This type of contractor expertise is less common for many resilience measures. Resilience measures are often individual components, such as ember resistant vents, sump pumps, or hurricane ties, rather than systems. The fact that different hazards require different strategies further complicates the issue. There are very few institutional frameworks – such as the utility programs in the efficiency sector – that are working to coordinate trades in ways that systematically coordinate contractors or develop broad specializations in ways that could create a relatively simple delivery system for home hardening.

One of the potential benefits of the SCORE's Pillar system is that it provides a framework for coordinating contractor activities and encouraging a broad systemic look at resilience, and its connections to other performance dimensions.

Conclusion

The energy efficiency sector has spent decades developing strategies to make U.S. homes more efficient and to reduce energy consumption. The speed at which climate change is occurring, and the magnitude of the threat that climate-related disasters pose to the U.S. housing stock, and to the associated insurance and mortgage industries, suggests that we will not have the luxury of decades to make U.S. homes more resilient. The issue requires urgent attention, at scale.

This paper argues that a crucial part of the overall strategy to drive large scale residential resilience improvements is market transparency. Transparency will enable the creation of market-based and public sector incentives that will motivate homeowners to make resilience improvements.

The Pearl SCORE's resilience pillar proposes a way to provide this transparency. The SCORE approach provides a simple way for consumers to start to think about home performance as a thing, and a simple metric, with appropriate underlying complexity that can be revealed as necessary, that provides crucial signals for market actors, from home buyers to insurers to mortgage lenders.

Appendix

The Resilience Pillar scoring is based on third-party standards and guidance. The following lists some of the resources used as the basis for the scoring methodology:

- Insurance Institute for Business & Home Safety (IBHS):
  - Wildfire Prepared Home designation
  - Home Disaster Guides
- National Fire Protection Agency:
  - 2022 Standard for Wildland Fire Protection (NFPA 1140)
  - Firewise USA
- International Code Council. 2021 International Wildland-Urban Interface Code (IWUIC)
- American Society of Civil Engineers: ASCE 24
- American Society of Civil Engineers: ASCE 7-22
- Federal Emergency Management Agency (FEMA)
  - Community Rating System
  - Flood maps
  - National Flood Insurance Technical Bulletins
  - FEMA P-361: Safe Rooms for Tornadoes and Hurricanes
  - FEMA P-1100: Seismic Retrofit Guidelines for Existing Residential Buildings
- Building America Solutions Center: Disaster Resistance
- Federal Alliance for Safe Homes (FLASH): Buyers Guide to Resilient Homes
- International Residential Code (IRC)

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