A Performance-based Rating System for Home Resilience: The ReScU Concept

Abstract

Purpose - Citizens who live in disaster prone areas need to protect their properties – particularly their homes – against the destructive effects of natural disasters to avoid large-scale economic losses. This paper presents the basic concepts and methodology for an improved system for rating the resilience of homes against natural disaster perils. This system is referred to as the Resilient Scoring Utility (ReScU) framework.

Design\methodology\approach – A two-pronged approach was undertaken in developing the ReScU framework. Existing sustainable ("green") certification systems for homes were studied as potential models for a system to rate the natural disaster resilience of homes. Simultaneously, a diverse 25-member stakeholder (focus) group was assembled and questioned in order to better understand the issues surrounding homes, incentives and natural disasters.

Findings – Using the results from the above approach, the ReScU framework was designed with four key operational features: 1). an output that can be tied to incentives, 2). the use of performance-based evaluation criteria, 3). utilization of "threshold" adjustments for the location of homes, and 4). adaptability to new technologies, perils, and non-perils.

Originality/value - There are a few existing programs that offer assistance to homeowners by providing them with guidance on how to protect/reinforce their homes against natural disasters. Unlike these other programs, the ReScU system proposed in this paper is location specific, performance-driven, and readily can be tied to incentives. These features will assist homeowners, homebuilders, and others in designing, building, and maintaining more natural disaster resilient homes.

Key Words: natural disaster, housing, rating system, performance-based

Introduction

"Our goal is to ensure a more resilient Nation - one in which individuals, communities, and our economy can adapt to changing conditions as well as withstand and rapidly recover from disruption due to emergencies."
President Barack Obama (The White House, 2009)

People and communities in the southeastern United States (U.S.) are being affected by coastal disasters with increasing frequency. This increase is a result of the higher migration from in-land areas to coastal regions as well as a lack of preparedness for natural disasters (Gaddis *et al.*, 2007). Regardless of the reason, natural disasters are having a greater impact on, and leading to more serious consequences for, local and national communities and economies.

Based on data from the U.S. Census Bureau (2010), the number of residential housing units on coastlines (Atlantic, Gulf of Mexico and Pacific) increased from 16.1 million to 36.3 million between 1960 and 2008. Similarly, the coastal population rose in numbers from 47 million to 87 million from 1960 to 2009. Thus, more than 30% of the U.S population lives in coastal counties, where hurricanes and tropical storms are a growing concern (Crowell *et al.*, 2007).

In the Americas, the most damaging natural disasters are storms and floods, and between 1990 and 2009, these events were responsible for approximately 80% of the total losses from natural disasters (International Disaster Database, 2009). The insured portion of the economic loss totaled $420.6 billion in 2006-2007 due to the very active 2004 and 2005 hurricane seasons at the Atlantic coast (Kunreuther and Michel-Kerjan, 2009). Furthermore, a review of the distribution in insurance coverage (storms and flood) reveals that approximately 80% of insured residential and commercial properties are at high risk areas in the coastal region of Florida. This amount represents around $ 2.5 billion insured residential and commercial value.

The damage caused by various natural disasters to residential housing is still a concern. For example, Hurricane Hugo (1989) caused major damage to approximately 36,000 housing units, the Oakland Hills firestorm (1991) diminished more than 3,000 housing units, Hurricane Andrew (1992) damaged about 80,000 homes, the Northridge earthquake (1994) caused serious structural damage to about 60,000 houses, and Hurricane Katrina (2005) destroyed approximately 90% of the residential and commercial buildings in the Biloxi-Gulfport area (Edwards and Iskowitz, 2010, Comerio, 1997).

Although the economic loss from natural disasters is high, the mortality rate associated with them is decreasing, due to the rapid development of weather forecast technologies, increased awareness, improved communication channels, and better transportation that leads to faster evacuation (Goklany, 2007, Fronstin and Holtmann, 1994). The mortality rate could be lowered even more, and the resilience of homes could be significantly improved, with effective implementation of building codes and improved wind/hurricane resistant residential and commercial construction in hurricane prone or hazardous areas (Kunreuther and Michel-Kerjan, 2009, Mehta *et al.*, 1992) . Field studies conducted after Hurricane Ike and Hurricane Ivan, reveal that improved building technologies could significantly increase the survivability of a home and decrease the amount of damage (Reinhold *et al.*, 2005, Reinhold, 2008). The type of materials used and other building features, such as roof shape, roof age, protection of openings, wall construction, and enforcement of garage doors affect the wind resistance of homes significantly (Reinhold et al., 2005). These findings are supported by insurance data that shows that homes built according to newer building codes (with improved design and construction) were subjected to fewer claims and disbursements than those built to older codes (Reinhold, 2008, Edwards and Iskowitz, 2010).

Although many homes are now following more stringent building codes and using improved materials and construction features, there is not a universal rating system that may be used to rate the strength or resilience of them against common natural disasters. A rating system can provide a common resilience framework, an easier comparison between homes in different locations, and clear documentation of the applied reinforcement techniques on homes. Moreover, incentives attached to the rating program could encourage future and existing homeowners to both design their homes more appropriately and/or apply the necessary reinforcement techniques to increase the survivability of their homes during various natural disasters.

In this paper, we discuss the concept of a performance-based rating system for home resilience that incorporates the homes location into its framework. Referred to as the Resilience Scoring Utility, or ReScU, our system uses a performance-based approach to rate the home with respect to its natural disaster resilience for common disaster perils. It can also be expanded to include non-hazards such as energy performance, water conservation, etc. ReScU is a flexible system in that it has been designed to encourage the addition of innovative technologies, materials, and design features through the adoption of performance-based evaluation criteria. It has also been designed to be applicable to different natural hazards and adjustable if these hazards or the surroundings of the home change. Finally, the ReScU rating system is designed to allow every home to receive a score based on its resilience, and this score can be used to provide incentives. Possible incentives for homeowners could include lower insurance rates and premium discounts. The homeowner may also be eligible for incentives such as tax breaks and low interest loans that may be offered by state or government organizations. And of course, this rating system could also be an effective tool for the insurance industry to allow them to better evaluate the risk associated with insuring properties in high risk regions.

It should be noted that the ReScU concept was developed with continuous collaboration and feedback from key stakeholders associated with housing and natural disaster events. Throughout the ReScU development process, meetings were held with the representatives of key stakeholder groups, including those from the insurance industry, state and government agencies, non-profit organizations, home building associations, nongovernmental organizations, and academia. A total of 25 stakeholders participated in these meetings.

Sustainable Building Programs and ReScU

Although we realized that there would be substantial differences between a "green" certification program for homes and a resilient one, the initial development of ReScU began by reviewing these existing green programs (local, regional and national) in order to provide a perspective about their advantages and disadvantages. These green programs included Leadership in Energy and Environmental Design for Homes (LEED-H), National Association of Home Builders (NAHB) Green Home, Earthcraft by Greater Atlanta Home Builders Association & Southface, and North Carolina Healthy Built Home.

As a major advantage, most green building certification programs have very good incentives associated with them that encourage their adoption. For example, upgrading to energy efficient heating and/or cooling system can result in a 30% tax break for the homeowner, and builders are eligible for a $2,000 federal tax credit if the home uses 50% less energy than a home built according to the code (North Carolina Solar Center, 2010).

However, a major disadvantage of these sustainable programs is that each of them use a different method to rate homes (Kaufmann and Melia-Teevan, 2008). Some of them rate the entire home while others just rate specific features of the home, such as indoor air quality.

Unfortunately, such variability in rating systems leads to confusion among homebuyers and homeowners since “green” homes cannot be compared to each other unless the homes are rated by the same program (Kaufmann and Melia-Teevan, 2008).

One inconsistency with green building programs is that some of them take into account the location of the home and some of them do not. For example, Earthcraft had developed different checklists for homes based on climate zones (Earthcraft, 2010). On the other hand, NAHB Green Home is not specific about location; it only has requirements for site selection and design (NAHB, 2006).

Finally, most of the green programs use prescriptive-based criteria in their implementation (Bohnhoff, 2010). Utilization of prescriptive-based criteria leave out “non-favored” alternatives, even if their result would have been the same as the ones currently favored by the prescriptive criteria (Bowyer, 2007). “ The creation of rating systems based on prescriptive criteria has resulted in designers chasing building points”, other than focusing on the real environmental impact of the home (Bohnhoff, 2010).

With the aforementioned points in mind, we set-out to design a resilience scoring utility for rating homes that could be:

1. Easily connected to incentives
2. Flexible and “universal” with respect to house type, peril, and location
3. Performance-based

Hazard Perils in the ReScU Framework

As mentioned previously, the ReScU rating system includes various hazards that a home may have to withstand based on its location. Simply, homes in different geographical locations may be vulnerable to different types of hazards. For example, homes may be subjected to more hurricanes in the coastal regions vs. in the west where they are more vulnerable to earthquakes. ReScU uses the location of a home to determine the possible natural disasters for which the home must be reinforced. The knowledge of possible disasters that might affect a home at a particular location is advantageous because it could allow for better and more efficient reinforcement technologies to be targeted towards that natural hazard. Existing information, such as insurance and weather models, FEMA floodplain maps, etc., could be used to determine the vulnerability of homes to different natural hazards at various locations.

Hazards currently targeted by the ReScU system include:

- Wind (including hurricane-related wind),
- Flood,
- Earthquake,
- Fire,
- Wildfire,
- Hail, and
- Mudslide.

Performance Guides and the "Building Score"

Unlike existing green rating systems, ReScU uses performance requirements to rate homes for their resilience towards each of the natural disasters. In other words, ReScU will require certain functional goals be met for the performance of homes against natural hazards. A performance based guide has been developed for each of the hazards and the guide will be used to give points/scores to the homes. Performance-based rating systems do not require specific prescriptive tools, and will accept any proven prescriptive method as long as the applied tools contribute to achieving the required performance level.

The performance guides will include requirements for each of the major elements of a house, defined as the foundation, wall, roof, openings, whole house, and miscellaneous "others."

The guides will also contain best practice (prescriptive) recommendations that may be used to achieve the particular performance requirement. An example of a performance-based criterion within the wind peril guide for the roof element could be reinforcement techniques utilized to enable the roof to withstand up to 150 mph wind speeds – and best practice recommendations include the use of hurricane straps. Points or scores will be earned by a home for each of the performance criteria.

The total number of points a home receives by following recommendations outlined in the performance guides is referred to as its *Building Score*, and a home will receive a perfect Building Score (tentatively 100 pts) for a particular hazard risk if it meets all the required performance based criteria. An example shown in Figure 1 demonstrating the Building Scores obtained for each of the hazard perils.

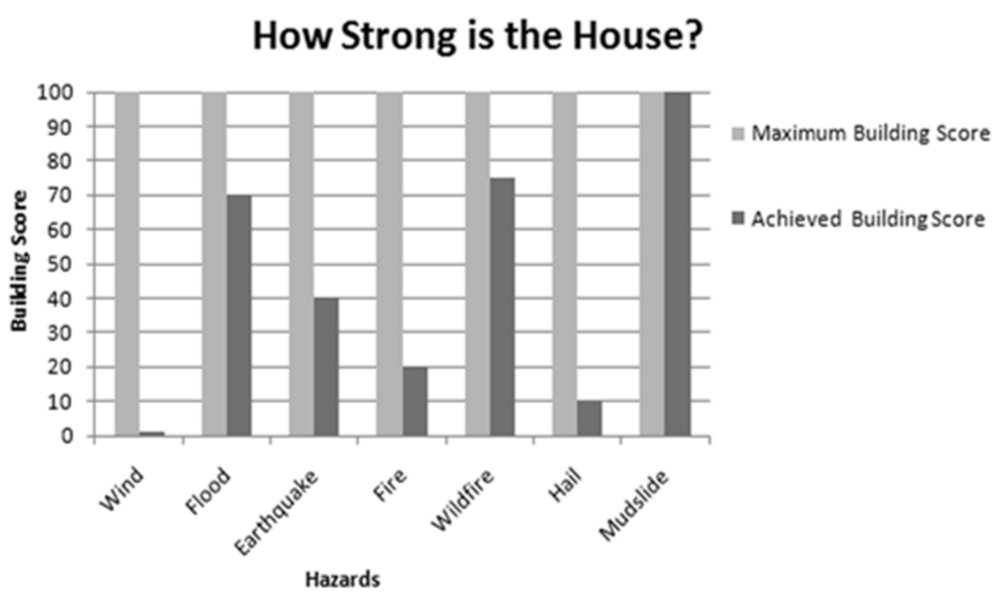

Figure 1. An Example Building Score

The light gray bar for each hazard represents the maximum obtainable Building Score – irrespective of its geographic location – assuming that the home is constructed using all best practices as specified in the performance guide. The black bars represent the actual rating for that home for each hazards based on the manner in which the home is actually constructed.

Hazard Thresholds

One of the main goals of developing ReScU was to formulate a home rating system that could be easily adapted for natural hazards regardless of the geographic location of the home. As such, the home is scored separately for its resilience against each hazard. . By setting up different threshold values for the hazards for particular locations, the necessary resilience can be accomplished more efficiently. For example, homes do not have to be reinforced against the same natural disasters if they are located in the coastal regions or when they are located in the mountains and the ReScU score reflects this fact. The calculation of the threshold value will be shown in the later section of this paper.

Recognizing that homes in different geographical areas will be subjected to different hazard perils, the ReScU system uses *Hazard Thresholds* to account for the variabilities of specific hazards. These thresholds are minimum performance scores that the home must attain for its particular geographic location. In general, the Hazard Thresholds for the various perils are based on the frequency of those particular hazards for a particular location. Simply, frequent hazards have higher thresholds and less frequent hazards have lower thresholds. For example, if a home is located in the Midwestern United States (US), then the probability of that home being impacted by a hurricane will be lower relative to that same home located along the east coast. Thus, the overall wind hazard threshold will be lower for that home. These thresholds are determined from historical data, pilot studies, and existing weather/hazard models.

As mentioned above, the Hazard Threshold values will account for the severity of the perils in the houses particular geographic location. Thus, the numerical range for the Hazard Threshold values will be similar to the Building Score (but will obviously be independent of it, being based on location only). In our example, the Hazard Threshold values range from 20 to 100. The lower value in the range is currently and arbitrarily at this point in the development of ReScU, set at 20 in recognition of the fact that a peril with a low probability of occurrence will not garner incentives. How the Hazard Threshold value is used to generate the ReScU score and account for location is discussed in the next section.

The ReScU Score

A graphical representation of the ReScU rating system is shown in Figure 2.

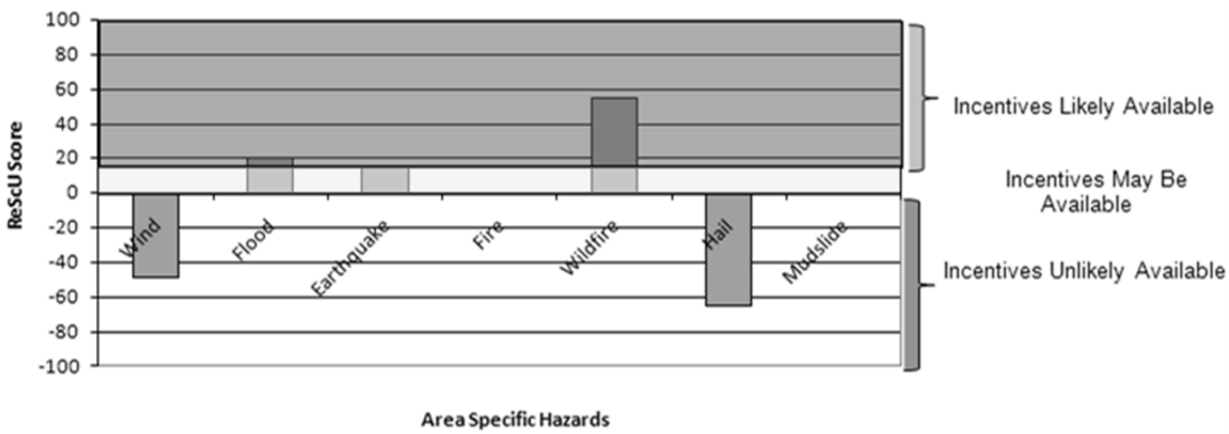

Figure 2. An Example ReScU System Chart

The horizontal axis on the ReScU chart (Figure 2) shows the common natural disaster hazards and the vertical axis shows the ReScU Score. The bars represent the ***differences*** between the Building Scores and the Hazard Threshold values. If the difference is positive, then the home is built to higher standards of resilience as compared to a home that has not. Thus, the homeowner may be able to obtain incentives (depending on the magnitude of the difference). If the difference between the Building Score and the Hazard Threshold value is negative, then the home (based on its current construction) does not meet the minimum requirements and incentives are unlikely to be available. In this case, in order achieve a higher Building Score and obtain a positive difference, additional measures are needed to improve the performance of the home.

The results from the ReScU rating system may be interpreted differently by different users, i.e., insurance industry, communities, builders, etc. Moreover, the ReScU rating system allows communities to apply the ratings according to their specific location, requirements, and needs.

An example of a ReScU rating spreadsheet used to generate the bar graph in Figure 1 is shown in Table 1. In the ***first column*** the potential hazards are listed that a home is exposed to, based on the location of the home. In the ***second column*** the actual points (Building Scores) are shown that the home has received for each of the hazard perils. These points are awarded based on its performance as specified in the performance guides. The ***third column*** shows the threshold value for each of the hazards. These Hazard Thresholds are governed by the location of the home as explained earlier. For example, if the house is located in a wind zone or in a hurricane prone area, these values (i.e., numbers) are higher than if it is not located in those areas. The ***fourth column*** shows the ReScU score. The ReScU Score is obtained by subtracting the Building Score from the Hazard Threshold value. For example if the Building Score for wind is 75 points and the Hazard Threshold is 40 points, then

ReScU Score = Building Score - Hazard Threshold

ReScU Score = 75 pts – 40 pts = **35 pts**

Table 1. The ReScU Spreadsheet

Hazards	Building Score	Hazard Threshold	ReScU Score
	(0-100)	(20-100)	
Wind	75	40	35
Flood	15	20	-5
Earthquake	40	25	15
Fire	20	20	0
Wildfire	25	20	5
Hail	50	30	20
Mudslide	10	20	-10

Applying the ReScU System: Varying Locations

In this section, the methodology of the ReScU will be illustrated by placing an example home in three different geographical locations and evaluating their ReScU scores. For these examples, a typical American Home is chosen. It is 2000 sq^2 in size, and has three bedrooms; two baths and a one or two car garage. We assume that this house was built according to the Miami-Dade building code that requires a higher level of performance in some areas than prevailing building codes in others. An elevated foundation is used for the house, and the roof is designed and constructed to resist higher wind speeds. Moreover, a secondary water barrier is placed beneath the siding, and impact and water resistant windows and doors are installed. Reinforced concrete is used for the continuous footing and foundation walls. For landscaping, ponds and stone walls are used. Trees, bushes and other foliage are planted a safe distance from the home. Table 2 shows a partially completed ReScU spreadsheet with entries for the example house. This home is placed in several locations and the ReScU scores calculated.

Table 2. General ReScU Spreadsheet for the Example House

Hazards	Building Score	Hazard Threshold	ReScU Score
	(0-100)	(20-100)	
Wind	60		
Flood	70		
Earthquake	45		
Fire	40		
Wildfire	85		
Hail	70		
Mudslide	20		

The Building Score column in Table 2 shows that, of the maximum of 100 points for each hazard, the home achieved 60 pts on wind, 70 pts on flood, 70 pts on hail, 85 pts on wildfire, 45 pts on earthquake, 40 pts on fire and 20 pts on mudslide (based on the performance guide for that natural hazard). For hurricanes (wind and flood), the model home gets points for its elevated foundation, reinforced roof, installation of a secondary water barrier and its impact and water resistant windows and doors. The model home also earns points in the wildfire hazard for safe landscaping and the utilization of a fire barrier material. In the earthquake hazard, points are given for the reinforced foundation and wall. Please note that the mudslide hazard was not targeted, per se, in this example; however, there are still a couple of points awarded for that hazard.

The house will now be placed in three different locations throughout the United States to examine the change in the ReScU scores. Note that for this example, the assigned points for each of the different hazards in the ReScU system are tentative. The exact procedure of assigning the points has not yet been determined.

Location 1. State of Florida: Hurricane and Flood Prone

The completed ReScU spreadsheet for the house located in Florida, a state that is prone to hurricanes and flooding is shown in Table 3. Due to its location, **wind, flood** and **hail hazards** are more **emphasized** in the ReScU system. As a result, the Hazard **Thresholds** for these hazards are **higher** than the other hazards'.

Table 3. ReScU Spreadsheet for the Example House Located in a *Hurricane Prone* and *Flood Zone* Area

Hazards	Building Score	Hazard Threshold	ReScU Score
	(0-100)	(20-100)	
Wind	60	45	15
Flood	70	40	30
Earthquake	45	20	25
Fire	40	20	20
Wildfire	85	20	65
Hail	70	40	30
Mudslide	20	20	0

The ReScU score for flood hazard is shown below:

ReScU Score for Flood Hazard = Building Score - Hazard Threshold
ReScU Score for Flood Hazard = 70 - 40 = 30 pts

Figure 3 shows the ReScU scores for this house in this location as well as its relationship to possible incentives.

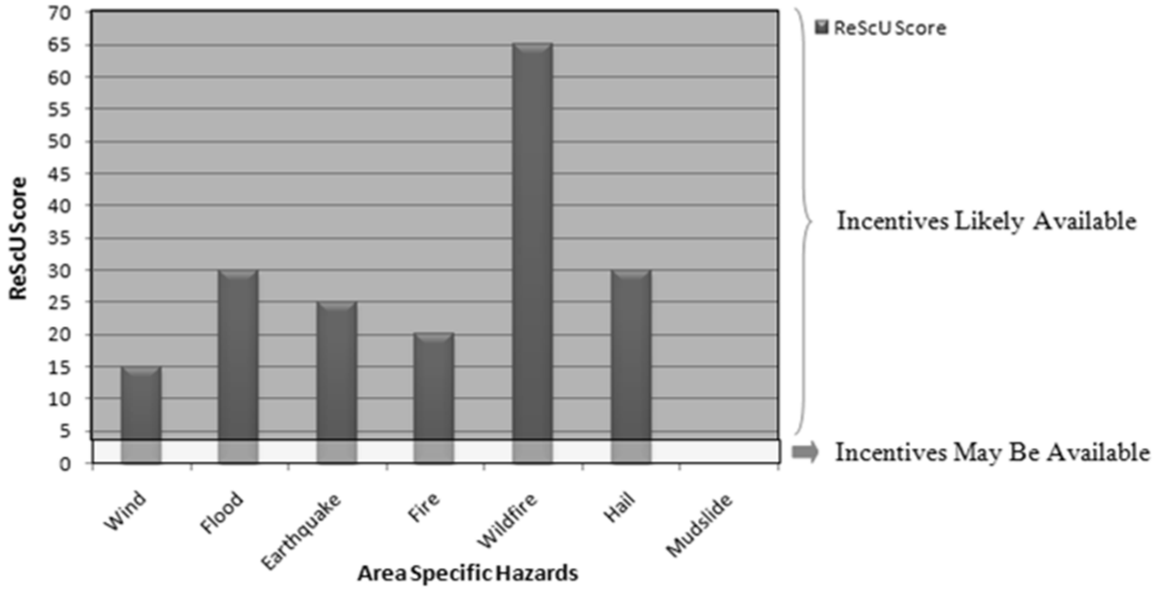

Figure 3. ReScU Score for a Hurricane Prone and Flood Zone Area

Location 2. State of California: Wildfire Prone Area

When the house described above is moved to a location in California, known for its wildfire hazards, the Hazard Thresholds in the ReScU system for each of the perils are adjusted. Table 4 shows the ReScU spreadsheet with the new threshold values. The area is more prone to wildfires; hence the wildfire Hazard Threshold value is 70, higher as compared to that in Table 3 (for the state of Florida). In contrast, earthquake hazards are not as common, and its Hazard Threshold value is 30.

For the model home, those reinforcement techniques that were useful for the hurricane prone area do not result in the same number of points towards the ReScU score because the hazards are not common in this wildfire area. Therefore, the threshold values are lower for wind, flood and hail hazards.

Table 4. ReScU Spreadsheet for the Example House Located in a *Wildfire Prone* Area

Hazards	Building Score	Hazard Threshold	ReScU Score
	(0-100)	(20-100)	
Wind	60	20	40
Flood	70	20	50
Earthquake	45	30	15
Fire	40	20	20
Wildfire	85	70	15
Hail	70	20	50
Mudslide	20	40	-20

To obtain the ReScU score in this example, the wildfire hazard ratings are:

ReScU Score for Wildfire Hazard = Building Score - Hazard Threshold

ReScU Score for Wildfire Hazard = 85 - 70 = 15 pts

The ReScU scores are represented in Figure 4 with their relationship to possible incentives.

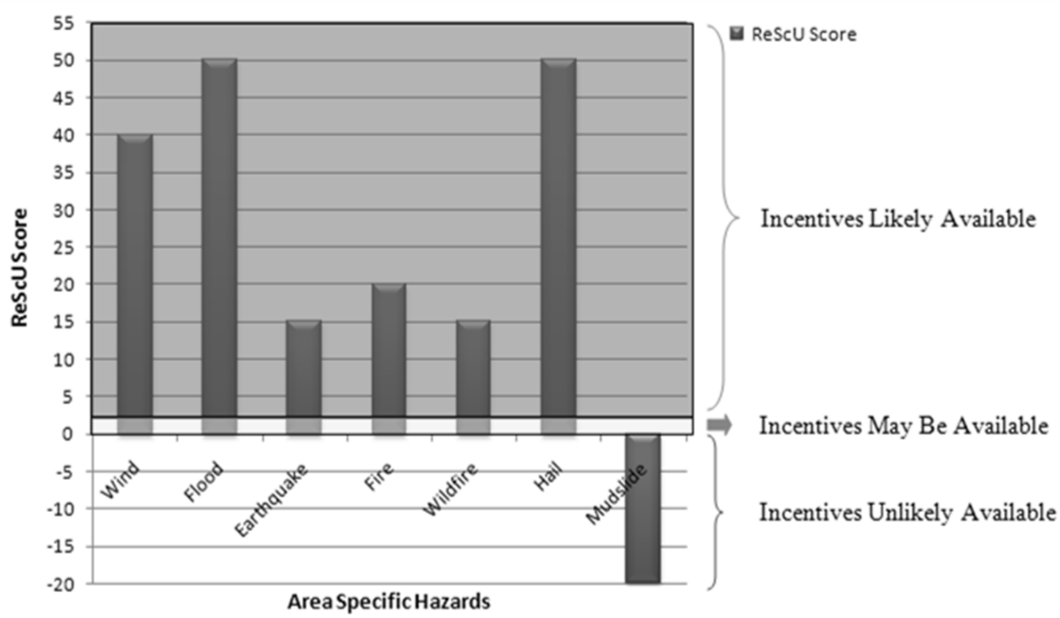

Figure 4. ReScU Score for a Wildfire Prone Area

Location 3. State of Iowa: FEMA Flood Zone A

Now, if the house is located in a Flood Zone A area, such as in Des Moines, IA, then the hazard threshold values in the ReScU system will reflect that as a significant peril. Table 5 shows the ReScU spreadsheet and Hazard Threshold values for our example house located in Iowa.

Table 5. ReScU Spreadsheet for the Example House Located in a *Flood Prone* Area

Hazards	Building Score	Hazard Threshold	ReScU Score
	(0-100)	(20-100)	
Wind	60	30	30
Flood	70	80	-10
Earthquake	45	20	25
Fire	40	20	20
Wildfire	85	20	65
Hail	70	20	50
Mudslide	20	20	0

The model home in this scenario does not earn the same points for the ReScU Score for the wildfire hazard as it did in the previous examples. In other words, the features the home possessed that were useful for wildfire resilience, such as landscaping materials, result in a different ReScU score due to the change in its hazard threshold value. The ReScU scores for the house located in a flood hazard area are shown in Figure 5.

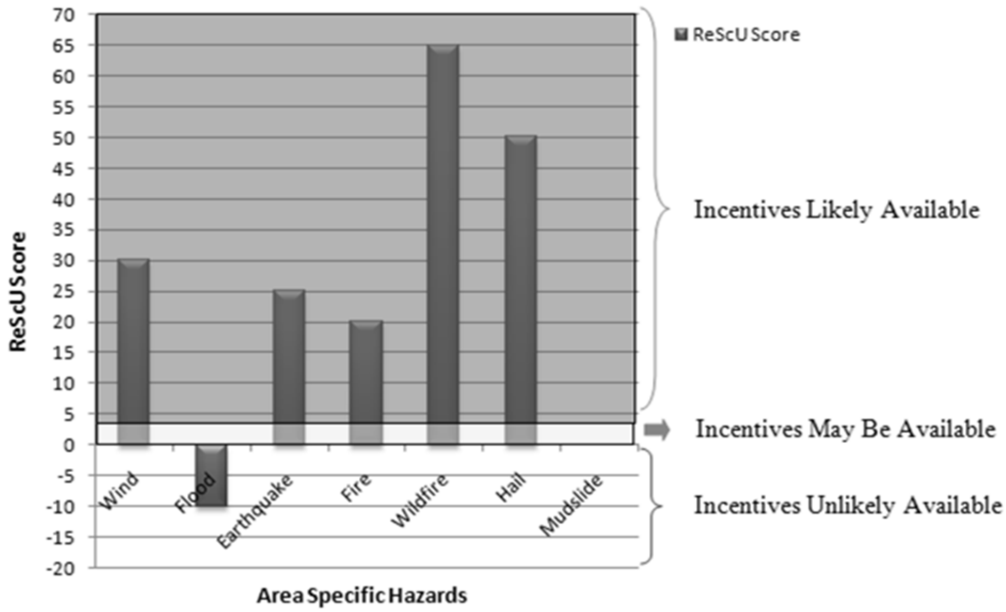

Figure 5. ReScU Scores for a Flood Prone Area

Applying the ReScU System: Varying Perils

A modification of the previous example (the home located in the flood zone) will illustrate how a change in the peril affects the ReScU score. Specifically, if a dyke (earthen levy) is built around the river in that example, the house will be less prone to flooding. Thus, the flood Hazard Threshold value will be lowered. Previously, the flood Hazard Threshold was 80 points, but because the home is now outside of the flood zone, the threshold value decreases to 20 pts (Table 6).

Table 6. ReScU Spreadsheet for the Example House Located in a *Non Flood Prone* Area

Hazards	Building Score	Hazard Threshold	ReScU Score
	(0-100)	(20-100)	
Wind	60	30	30
Flood	70	20	50
Earthquake	45	20	25
Fire	40	20	20
Wildfire	85	20	65
Hail	70	20	50
Mudslide	20	20	0

The ReScU graph for this same house, now located outside of the flood zone, is shown in Figure 6. Under this scenario, the bar for flood peril is no longer in the negative zone, since the threshold value for flood hazard has changed from 80 to 20.

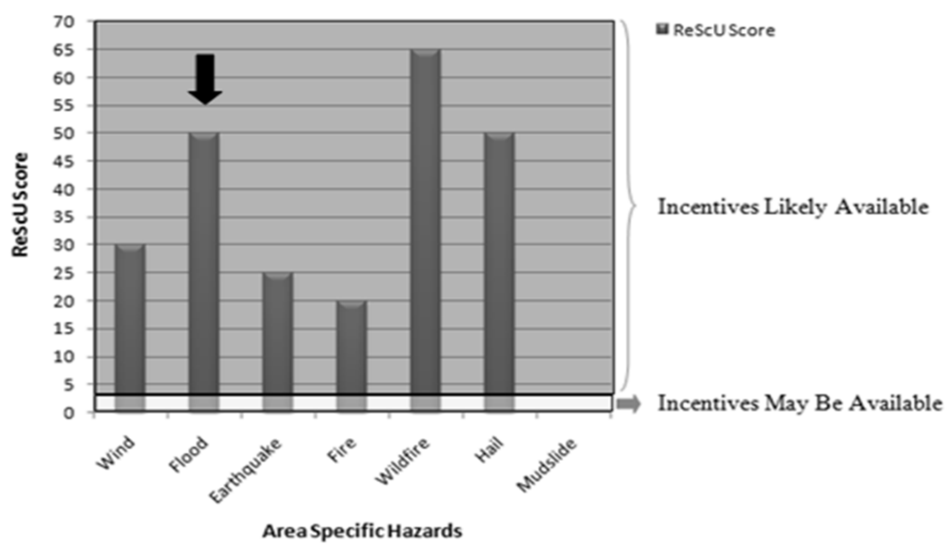

Figure 6. ReScU Score for a non Flood Prone Area

Conclusions

The Resilience Scoring Utility – ReScU – is being designed as a comprehensive rating system for measuring the performance of homes against various natural disaster perils. This system has three key elements: use of performance-based requirements, Threshold Values to account for location, and an incentive-based approach. Additional features of the ReScU system include:

- Ease of use
- Applicability to site-specific hazards
- Use of performance-based construction criteria with prescriptive solutions
- Alignment to existing code and other building programs
- Flexibility to allow communities to set rating thresholds
- A format which is simple to expand to include other hazard perils as well as non-peril criteria (e.g., water conservation)
- A format for measuring housing resilience in existing or newly planned communities

With effective application of the ReScU program, more resistant communities and neighborhoods could be created by lowering property damage, and accelerating the recovery time after a major natural disaster.

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