VOLUME 5: **AUXILIARY**

DESIGNING FOR NATURAL HAZARDS

A RESILIENCE GUIDE FOR BUILDERS & DEVELOPERS

AUX

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Located in Upper Marlboro, Maryland, Home Innovation Research Labs (Home Innovation) was founded in 1964 as a wholly-owned, independent subsidiary of the National Association of Home Builders (NAHB). Originating as a small product testing laboratory, Home Innovation has since grown to become a full-service market research, building science research, consultant, product testing laboratory, and accredited third-party certification agency dedicated to issues related to the homebuilding industry.

DISCLAIMER

Visit the Disaster Recovery Tool Kit on the U.S. Department of Housing and Urban Development (HUD), Office of Policy Development and Research (PD&R) website—huduser.gov/portal/disaster-recovery.html—to find this report and other relevant resources, reports, guides, and ordinances sponsored by PD&R to aid homeowners and property owners in the disaster recovery process. Many of the reports in the kit are available in print by calling the HUD User Clearinghouse at 1–800–245–2691, option 1. As always, all reports are available as free downloads from HUD User.

FOREWORD

According to the National Oceanic and Atmospheric Administration, the United States spent $145 billion in 2021 recovering from natural disasters, which included wildfires, tropical cyclones, floods, tornados, drought conditions, and extreme winter storm events. To mitigate the impact of natural disasters, the U.S. Department of Housing and Urban Development (HUD) continues to develop technical guidance to improve the resilience of housing.

Resilience is characterized by a community's ability to minimize damage and recover quickly from extreme events and changing conditions.

The *Designing for Natural Hazards: A Resilience Guide for Builders & Developers* series was developed with a technical advisory group that included subject matter experts from a wide range of industry stakeholders. The experts were tasked with identifying above-code construction techniques to improve the resilience of residential buildings. A consensus process was used with the goal of creating a set of practical, actionable guidelines for builders and developers. The guidelines are intended for new construction, improvements before a natural disaster, and major reconstruction efforts after natural disasters, especially where entire communities need to be rebuilt.

The technical advisory group recognized that when natural disasters occur, certain damage is more likely than other types of damage. To address this challenge, the technical advisory group recommended a mitigation strategy that prioritizes high-frequency damage over damage that rarely occurs—based on post-disaster damage assessment reports. This novel approach encourages improving those parts of the building that typically get damaged first. It can also maximize the impact of disaster mitigation grants by preventing future damage to homes.

The resilience guides are an excellent addition to HUD's PD&R Disaster Recovery Took Kit. These guides should be updated periodically based on post-disaster damage assessment data—from future natural disasters. The resilience guides will be valuable resources to builders and developers seeking to incorporate resilience in housing.

Solomon Greene
Principal Deputy Assistant Secretary for Policy Development and Research
U.S. Department of Housing and Urban Development

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INTRODUCTION TO VOLUME 5: AUXILIARY

Designing for Natural Hazards is a set of resiliency guides for builders and developers. It is segmented into five short volumes, each focusing on a specific natural hazard type, as illustrated below:

This guide is **Volume 5: Auxiliary,** which highlights auxiliary hazards and damage caused by volcanoes, hail, extreme heat, and extreme cold; it also identifies resilient construction practices that can eliminate or minimize such damage in a meaningful way.

BACKGROUND

HUD tasked Home Innovation Research Labs (Home Innovation) to develop a set of practical, actionable guidelines for builders and developers to design and construct residential buildings, neighborhoods, and accessory structures in a manner that could improve residential resilience and integrate resiliency throughout the entire community. The ***Designing for Natural Hazards*** guides accomplish this task by providing technical content in a straightforward manner that is easy for a layperson to understand while also providing references for design professionals, builders, developers, and public officials to dive deeper into the necessary details. These resilience guides are not intended to substitute for engineering or architectural project design work; instead, the technical guidance identifies the components that can be enhanced or improved to achieve above-code performance that should make residential buildings and other community assets more resilient.

The ***Designing for Natural Hazards*** guides focus on new construction and major reconstruction after natural disasters, especially reconstruction in areas where entire communities need to be rebuilt after catastrophic events. The guides do not focus on minor repairs or renovations that are common after typical natural disaster events and do not address commercial buildings, although many of the construction practices identified are also applicable to multifamily mixed-use buildings with wood framing.

To make the guides as practical and have as much input and buy-in as possible, Home Innovation employed many of the same approaches used to assemble the Technical Advisory Group (TAG) when helping develop the American National Standards Institute (ANSI) standards. Specifically, Home Innovation recruited a balanced number of stakeholders to reach consensus on the approach to developing content. In addition, all Task Group meetings were open to the public, and input was solicited beyond the members of the TAG and its Task Groups. Although these guides were not developed in accordance with the requirements of an ANSI standard, the approach to these guides mirrored that spirit and intent of creating a voluntary, consensus document.

HOW TO USE THE GUIDES

The ***Designing for Natural Hazards*** guides are intended to be used by a wide range of stakeholders, including design professionals, builders, developers, and even prospective homebuyers. The guides differ from other resiliency programs and resources because they are not a prescriptive program or list of improvements. Instead, the resilience guides are designed to be flexible and allow users to focus on either a single resilient construction practice or multiple resilient construction practices, depending on the user's specific needs.

The technical content is provided on a single, double-sided page for each resilient construction practice. These "one-pagers" are intended to be printed and used as stand-alone documents for a builder or developer to specify an above-code construction practice. The one-pagers can also be given to a prospective homebuyer or building owner as a supplemental marketing document to highlight the resilient construction features that have been included in a new building.

Each one-pager includes key information about the specific natural hazard and resilient construction practice that will minimize or eliminate potential damage. The front of each document identifies (1) the damage expected by the hazard (as shown in the photo); (2) the frequency that a specific type of damage occurs; (3) a description of the resilient construction practice that can minimize damage; (4) a description of the mitigation strategy; and (5) a summary of the cost and benefit of implementing the resilient construction practice. The back of the document provides additional design guidance details, including (1) multiple design variations and supplemental resilient construction practices; (2) the corresponding level of difficulty associated with implementing alternative resilient construction practices; (3) the relative cost of implementing the various options; and (4) technical references that provide more information for each design option.

Because the resilient construction practices summarized in these guides are intended to be implemented in areas where the building code does not specify resilient construction practices, builders cannot rely on a building code official to verify that the practices have been followed. Therefore, builders who undertake these resilient construction practices will need to either incorporate the practices into their internal quality assurance process or hire a third-party organization to confirm that the resilient construction practice(s) was appropriately included in the design and constructed per their specification, which will require some additional detail beyond the one-pagers.

Defining Auxiliary Hazards and Resilient Construction

Auxiliary hazards are those that do not fit within the wind-, water-, fire-, or earth-related categories. The major auxiliary hazard for this guide is volcano-related damage, but hail, extreme cold, and extreme heat are also included (because they were not addressed in the other guides). The United States Geological Survey (USGS) states, "[Volcanic] eruptions often force people living near volcanoes to abandon their land and homes, sometimes forever. Those living farther away are likely to avoid complete destruction, but their cities and towns, crops, industrial plants, transportation systems, and electrical grids can still be damaged by tephra, ash, lahars, and flooding." The Federal Emergency Management Agency (FEMA) has provided mitigation and prevention guidance for damage due to hail (that is, roof and siding), cold waves (that is, freezing pipes and other snow loads), and heat waves (that is, pressure on the power grid and loss of power). For this ***Designing for Natural Hazards*** guide, the Auxiliary Task Group focused primarily on damage due to volcanoes but also provided guidance for cold and heat waves. The hail one-pager was added because it was not addressed specifically in the Water or Wind guides, and it is often regarded as a secondary damage category due to a major wind hazard event (tornado, severe thunderstorm, etc.).

The first undertaking for the Auxiliary Task Group was to identify typical damage that happens when volcanoes, cold waves, and heat waves occur. To that end, the group reviewed case studies of volcano hazard events, such as the recent eruption in Hawaii—Kilauea Volcanic Eruption on May 3, 2018, published by FEMA. The Task Group discussed the damage contained within the report, then reviewed a wide range of technical resources—for example, resources from FEMA, USGS, and the International Code Council (ICC)—to identify the most relevant resilient construction content to be included in the Auxiliary one-pagers.

The Auxiliary Task Group also wanted to address the COVID-19 pandemic, but because the building infrastructure was not damaged due to this biological hazard, it is out of scope for this project. For hazards such as cold and heat waves, the Auxiliary Task Group considered redundant or backup systems to ensure that critical power and water services were not interrupted or damaged for an extended period.

Frequency of Damage Type

After familiarizing themselves with specific damage caused by volcano events from various disaster reports and disaster preparedness documents, the Auxiliary Task Group was asked to determine the type of damage that is most likely to occur when considering all possible damage from volcanoes. The damage is included on the one-pagers; to determine the frequency, the Auxiliary Task Group had to infer from technical reports, FEMA's Disaster Preparedness documents, and other mitigation programs.

The United States has five observatories that monitor volcanic activities: in Alaska, California, Cascades, Hawaii, and Yellowstone. USGS states that "scientists [at the observatories] also assess volcano hazards and work with communities to prepare for volcanic eruptions." In addition, USGS states that "assessments are also critical for planning long-term land-use, and effective emergency-response measures, especially when a volcano begins to show signs of unrest."

The areas in the United States with active volcanoes include California, Oregon, Washington, Alaska, Hawaii, American Samoa, and the Mariana Islands. Notable eruptions that have threatened the health and safety of residents and damaged property and infrastructure, according to USGS, include the following:

In 2018, more than 700 structures were destroyed when swift-flowing lava erupted from fissures in Kilauea Volcano's lower East Rift Zone. Lava covered 35.5 square kilometers (13.7 square miles), which included homes, farms, wild spaces, roads, highways and critical infrastructure. Kilauea is ranked as the U.S. volcano with the highest threat score in the very-high-threat category.

In 2009, more than 300 flights were canceled and Ted Stevens Anchorage International Airport was shut down when Redoubt Volcano erupted clouds of volcanic rock and ash. Redoubt ranks in the very-high-threat category.

In 1980, a powerful explosion at Mount St. Helens devastated huge tracts of forest and killed people tens of miles from the volcanic source, and debris avalanches and mudflows choked major rivers and destroyed bridges. Mount St. Helens is ranked a very-high-threat volcano.

Generally, the observatories can give the surrounding areas notice before a major volcanic eruption occurs. The damage will be catastrophic if buildings are in the immediate vicinity of a volcanic eruption, as shown in Figure 1.

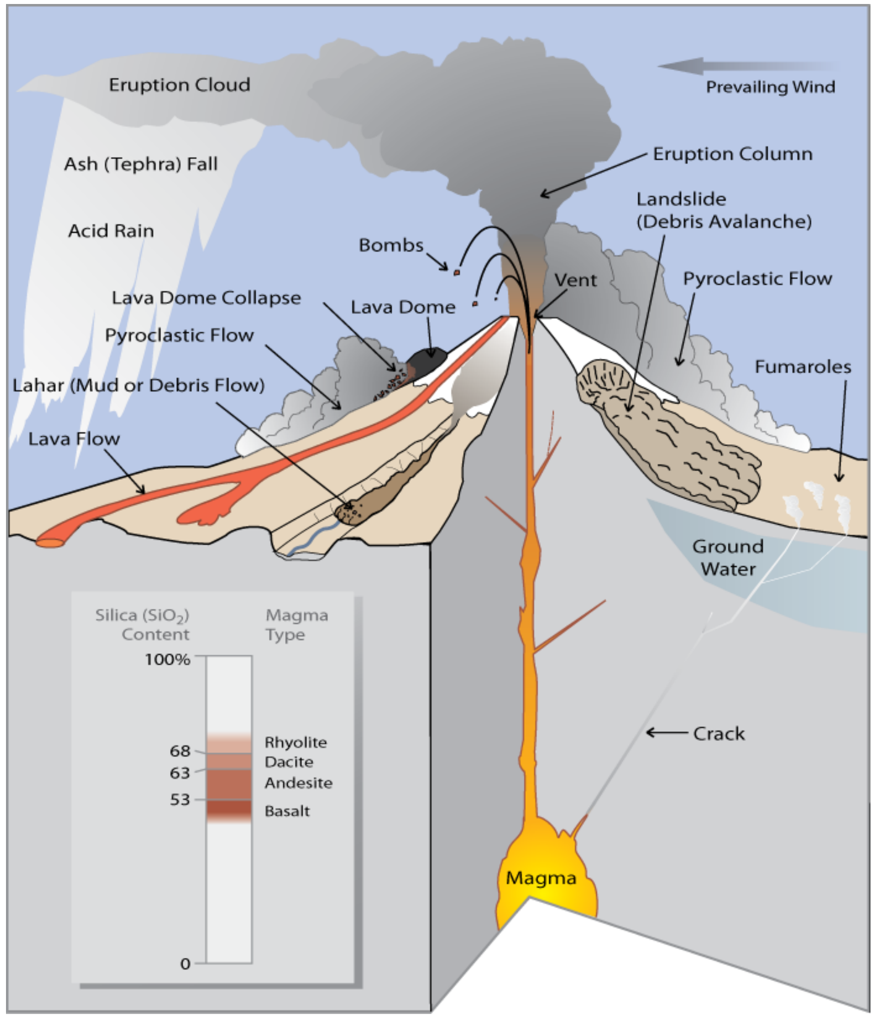


Figure 1. Illustration from U.S. Geological Survey Fact Sheet 002-97
Source: USGS

Prioritizing High-Frequency Damage for Resilience

Because these resilient construction practices are intended for low-risk areas that need additional resilience to various hazards, several participants on the Technical Advisory Group recommended prioritizing high-frequency damage areas of the building as the most practical mitigation strategy for resilience. Many were concerned that if funding for above-code practices/strategies were limited, or if a builder wanted to invest in a specific resilient construction practice above all others, knowing what was most important to do would be difficult if not for some level of prioritization. Data about the frequency of damage type are necessary for builders and developers to prioritize the resilient construction practices that will yield the greatest benefit—or the least amount of damage—to the building. The damage frequency metrics on the one-pagers are intended to provide builders and developers with a general idea of the frequency and severity of possible damage, so that cost alone is not driving the mitigation strategy.

The auxiliary guide is different from other volumes of the ***Designing for Natural Hazards*** series because the hazard types are vastly different. As a result, the user must consider each hazard type (that is, volcano, hail, heat wave, and cold wave) as a stand-alone area of concern.

The Auxiliary Task Group used disaster preparedness content because formal damage assessment reports are limited for volcanoes (due to their rare occurrences compared with other hazards) and the frequent occurrence of hail, heat waves, and cold waves. To some extent, the collective judgment and expertise of the Auxiliary Task Group members were used when determining high-, moderate-, and low-frequency damage. For areas that commonly have hail, heat waves, or cold waves, the built environment is well adapted to minimize the effects, but for those areas where those hazards are rare, the consequences may be significant.

Grouping Resilience Practices

The Auxiliary Task Group believed that licensed design professionals and subject matter experts would be able to prioritize the resilient construction practices without much guidance. However, given the multiple options and design alternatives on the one-pagers, the Auxiliary Task Group thought that recommending some bundling of multiple one-pagers for volcano hazards would still be valuable so that a builder or developer could offer a prepackaged system of resilient construction practices, similar to other resiliency programs.

Table 1. Example of "Good, Better, and Best" Approach to Resilient Construction Practices for Auxiliary Hazards			
	USING MULTIPLE 1-PAGERS		
	GOOD	BETTER	BEST
Volcano: Site Design and Utilities	High Frequency	High Frequency	High Frequency
Volcano: Ash	High Frequency	High Frequency	High Frequency
Volcano: Building Materials and Envelope	X	Moderate Frequency	Moderate Frequency
Volcano: Structure	X	X	Low Frequency

The most basic prepackaged system of resilient construction practices could be as simple as selecting the basic practice for each of the one-pagers in the Auxiliary Guide to encourage some baseline level of resilience. The Task Group also explored a "Good, Better, and Best" approach to grouping the one-pagers, in which the basic levels of resilience would be branded as "Good," while the more advanced practices could be combined with those basics to offer a "Better" option, and the most comprehensively resilient practices could be considered a "Best" level of resilience. Table 1 provides an example of this type of approach for Volcano Resilience, in which the one-pagers are grouped on the basis of the frequency of occurrences.

Certain resilient construction practices may be alternatives, whereas others may be additional practices to be implemented. This method allows for even further customization of a "Good, Better, and Best" approach for a builder or developer looking for this type of guidance.

NEXT STEPS AND FUTURE RESEARCH

As resilient construction practices evolve, the one-pagers within this guide should be updated to reflect improvements or modifications. To improve the damage frequency metric, additional data are necessary beyond what is currently collected.

The Auxiliary Task Group recommended that the definition of resilience be expanded to include health and safety of the building occupant beyond the structure of the building. Because this research project occurred during the COVID-19 pandemic, the Auxiliary Task Group felt compelled to consider safety in terms of biohazards such as airborne viruses and how they can be circulated through the heating, ventilation, and air conditioning (HVAC) system. The scope of the project does not address this concern that the Auxiliary Task Group had, but it is a valid area for future research.

Infrastructure damaged by advancing lava flow.

VOLCANO: SITE DESIGN AND UTILITIES

The site design must include unobstructed emergency ingress. Hazard mitigation practices include firebreaks to minimize fire damage caused by volcanic eject and lava flows. Utilities should be buried underground, and backup power sources should be installed. Residents must be aware that volcanic eruptions can cause other natural hazards, such as earthquakes, subsidence, mudslides, erosion, tsunamis, and wildfires.

Damage Frequency

HIGH

Construction Practice

Provide protection for utilities and redundant power sources in case of power failure.

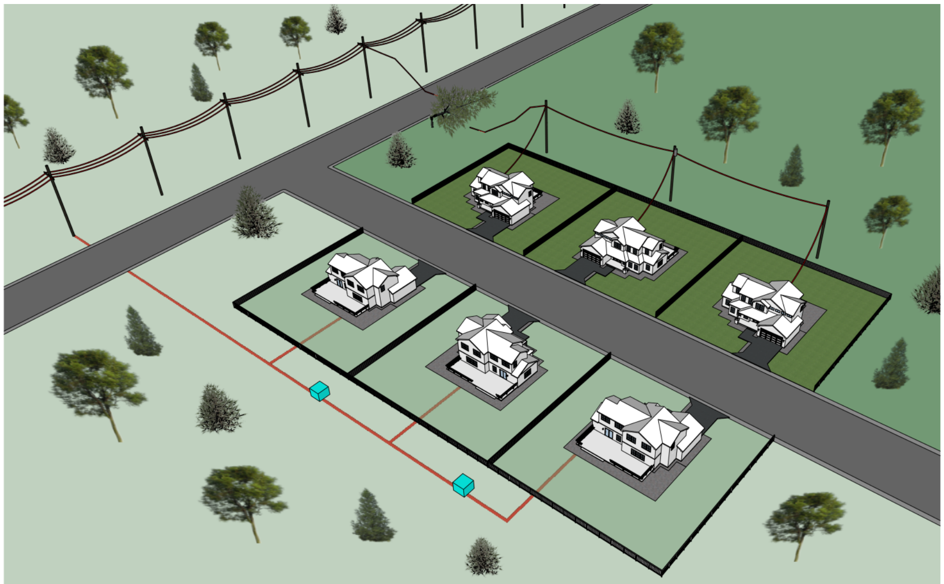
Mitigation Strategy

Ease recovery efforts and increase hospitality of the home through protection and backups.

Cost & Benefit

Cost range to implement: $–$$$$

Benefit: Design elements reduce the impact from a nearby volcanic eruption. Better infrastructure design can reduce damage to a building structure.



GUIDANCE	DIFFICULTY	COST
Electrical Service Protection		
Bury electric service and communications lines underground. [1]	Easy	$
Bury electric service and communications lines underground and in metal or PVC conduit. [1]	Moderate	$$$
Bury electric service and communications lines underground in conduit and harden by encasing in concrete. [1]	Complex	$$$$
Emergency Site Access		
Design development site to include alternate emergency ingress and egress for access by emergency crews and include provisions for wildfire, mudslide, and flooding as part of site design. [2,3] *Staff Note: Ensure that design is in accordance with local ordinances*.	Moderate	$$–$$$
Backup Power		
Backup generator powered by natural gas, diesel, or propane. [4]	Easy	$$$
Portable battery backup or generator interface system. [4]	Moderate	$$
Firebreak		
Use green zones, parks, water retention, or roadway infrastructure as fire breaks. Multiple ingress and egress planning as part of evacuation planning. [5]	Easy	$–$$$

RESOURCES

1. Section E3803.1 Minimum Cover Requirements. 2018 IRC.
2. *Best Practices: Emergency Access in Healthy Streets*. County of Los Angeles Public Health. March 23, 2013.
3. *Community Resilience Toolkit*. U.S. Department of Housing and Urban Development. February 2020.
4. *Emergency Power Systems for Critical Facilities: A Best Practices Approach to Improving Reliability.* FEMA P-1019. 2014.
5. *CAL FIRE Fuel Breaks and Use During Fire Suppression.* California Department of Forestry & Fire Protection. March 21, 2019.

Homes covered in volcanic ash.

Damage Frequency

HIGH

Construction Practice

Use design techniques and protective devices to reduce the impact of the ash created during a volcanic eruption.

Mitigation Strategy

Ease recovery efforts and minimize damage to structure and home through material selection and design.

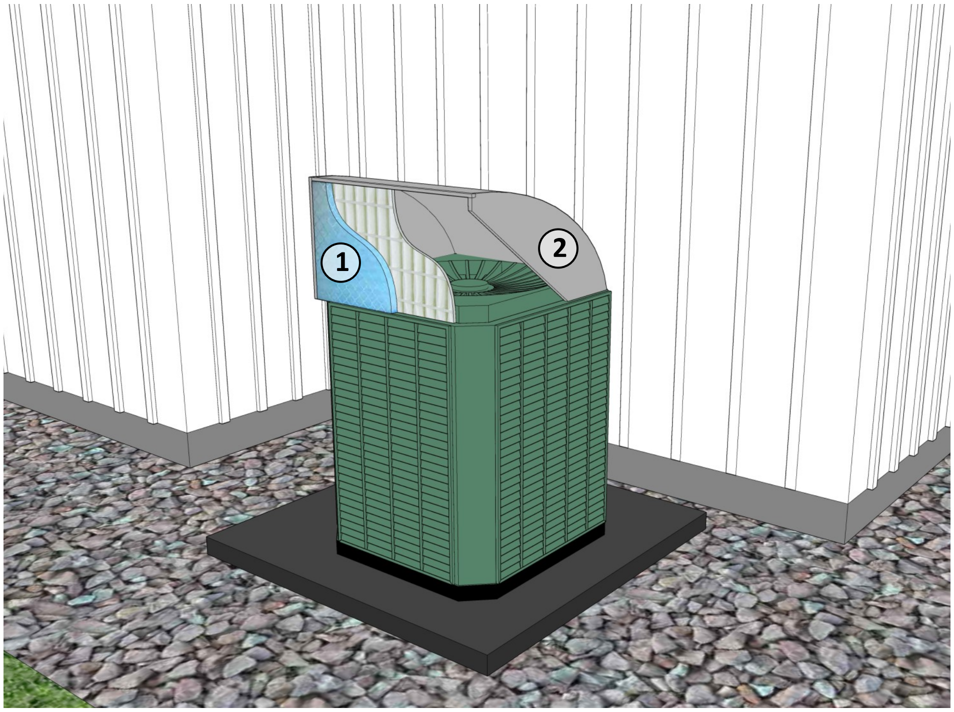
Cost & Benefit

Cost range to implement: $–$$$$

Benefit: Design elements reduce the impact on structure from a nearby volcanic eruption. Can greatly reduce damage to a structure and its mechanical equipment and avoid indoor air quality issues.

VOLCANO: ASH

Avoid roof designs with a long span and low pitch. They are typically the most vulnerable to ash loading and damage to roofing materials. Backup power sources must be protected from ash, which can damage outdoor equipment. Covers and filters on equipment air intakes are important to hazard mitigation. Install protection on all exterior gutter and drainage systems to prevent ash accumulation. Use gutters, downspouts, and roof drains that are designed for easy removal, cleaning, and repair. Gutters will accumulate ash from the roof, reducing the drainage capacity and further increasing loading. Ash may block gutters and downspouts, leading to localized flooding and water damage, especially on roofs, on drainage networks, and in ceiling spaces. Residents must be aware that volcanic eruptions can cause other natural hazards, such as earthquakes, subsidence, mudslides, erosion, tsunamis, and wildfires.



1. Temporary filter
2. Temporary hood

GUIDANCE	DIFFICULTY	COST
Volcanic Ash and Ejecta: HVAC		
Locate and screen air intakes to limit exposure to falling ash. [1]	Easy	$
Provide easily accessible filters and screens that can be cleaned and replaced during event.	Easy	$
Avoid conditions that will result in negative pressure in building to prevent introduction of pollutants into circulation systems.	Moderate	$$
Install mechanical equipment with pre-stage filters and in a way that limits the introduction of ash and pollutants into the system and allows them to be circulated within the indoor environment.	Complex	$$$$
Volcanic Ash: Roof Design		
Roof structure is designed to accommodate thick ash load (+/- 4 in./>100 mm) comparable with snow load. [1]	Easy	$$–$$$
Do not use flat roof design with roof or parapet drains that can clog due to ash accumulation, causing interior flooding.	Easy	$
Use simple roof shape configurations to minimize ash buildup and drift. Avoid the following: • Long joist spans subject to failure from unbalanced load. • Low pitched roof. • Complex roof geometries that lead to "drifting." • Parapet walls, chimneys, dormers, and projections through the roof.	Easy	$
Locate roof penetrations near the peak to minimize exposure to ash buildup and drift.	Easy	$
Volcanic Ash: Gutters		
Install gutter protection to prevent ash accumulations. [1]	Easy	$
Use round or box-shaped gutters for greater flow and easy cleaning.	Easy	$
Install gutters so that they can be removed, cleaned, and reinstalled.	Moderate	$$
Avoid roof drains, scuppers, and design features (including flat roof design) that require drainage through the building or openings that can be clogged by ash accumulation.	Easy	$
Install gutters and downspouts with a minimum gauge of 0.032.	Easy	$$–$$$
Volcanic Ash and Ejecta: Roof Materials		
Use simple roof geometry and standing corrugated style metal roofing. Limit penetrations through roof. [1]	Easy	$$
Install standing seam metal roofing with a minimum thickness of 0.030 in., and design with few or no valleys or other seams or obstructions perpendicular to the eaves (maintain flow line). Apply polyvinylidene fluoride coating (for example, Kynar), or equivalent to enhance chemical and corrosion resistance.	Easy	$$$
Use impact-resistant, Class A synthetic slate or similar materials. [2]	Easy	$$$$
Use barrel- or shingle-formed roof tiles. Consideration must be given to quake-resistant design of the structure to avoid roof collapse due to additional weight.	Moderate	$$$$

RESOURCES

1. *Volcanic Ash Impacts and Mitigation*. Volcanic Ashfall Impacts Working Group. April 2021.
2. ASTM E84-21a *Standard Test Method for Surface Burning Characteristics of Building Materials*.

Homes destroyed by advancing lava flow.

Damage Frequency

MODERATE

Construction Practice

Use heat-resistant materials. Plan to avoid damage and shorten recovery time from nearby volcanic eruption.

Mitigation Strategy

Ease recovery efforts and minimize damage to structure and home through material selection and design.

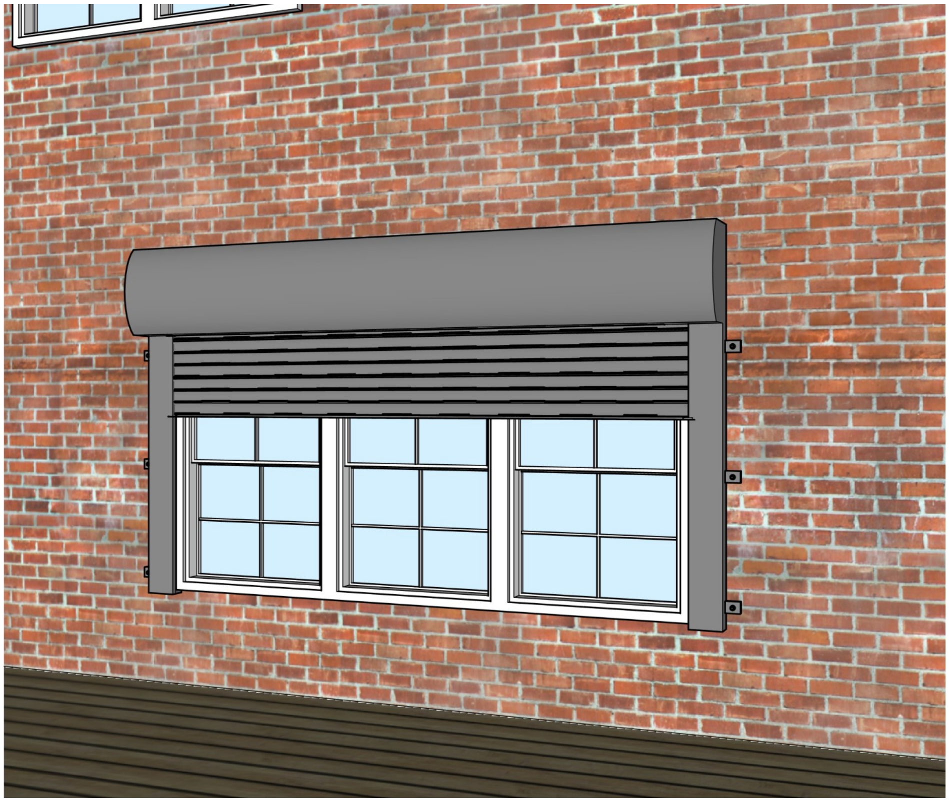
Cost & Benefit

Cost range to implement: $–$$$$

Benefit: Design elements reduce the impact on structure from a nearby volcanic eruption. Material specification can greatly reduce damage to a structure and avoid major damage.

VOLCANO: BUILDING MATERIALS AND ENVELOPE

Use materials that are abrasion resistant and either fireproof or fire resistant, which drastically improve the structure's resilience to damage caused by a nearby eruption, including secondary damage from mud- or landslides, earthquakes, and flooding. Increase the strength and durability of building materials to minimize damage from ejecta and related hazards. Use interior finishes that will be resistant to damages related to lack of ventilation, elevated levels of volcano smog (VOG), and elevated levels of sulfur dioxide (SO2) during active eruptions and that will also be conducive to ash cleanup. Use protective covers and devices on roof tank water collection systems and cisterns to minimize damage and contamination due to ash or gas. Be aware that volcano zones can be subject to related secondary natural hazards, such as earthquakes, subsidence, mudslides, erosion, floods, tsunamis, and wildfires.



GUIDANCE	DIFFICULTY	COST
Window Protection		
Include nonflammable, operable shutters in design to prevent damage from sifting ash and ejecta to protect windows and doors.	Easy	$
Include hurricane glass in door and window openings in accordance with ASTM E1886. [1]	Easy	$$$
Include ballistic glass in door and window openings in accordance with E1996 or ASCE 7. [2,3]	Easy	$$$
Include tambour-style roll-down shutters on all building openings.	Moderate	$$
Include automated tambour-style roll-down shutters that can create a seal to prevent infiltration of airborne ash and VOG.	Complex	$$$$
Roof & Exterior Envelope		
Avoid roof ventilation systems or placing HVAC systems on roof or on the facing side of anticipated flow.	Easy	$
Incorporate Class A or equivalent heat-resistant/fire-resistant/fireproof roofing materials and rated assemblies. [4]	Moderate	$$$
Incorporate Class A or equivalent heat-resistant/fire-resistant/fireproof cladding materials, windows, and doors and incorporate UL fire-rated exterior wall design and rated assemblies. [4]	Moderate	$$$
Maintain 14-in. vertical clearance from grade to cladding, and keep landscaping a minimum 3 ft. from structure to provide natural firebreak.	Moderate	$$$
Use heat-resistant/fire-resistant/fireproof (reinforced masonry, reinforced poured-in-place concrete, etc.) for structural system and envelope.	Complex	$$$$
Interior Finishes		
Use abrasion-resistant flooring with a minimum rating: [5] • Porcelain tile—Porcelain Enamel Institute (PEI) rating of Group 3 or equivalent. • Laminate or vinyl plank—AC4 or equivalent.	Easy	$$$
Use wall finishes and details that are SO2, water, and cleanser resistant and easily cleaned.	Easy	$$$
Use concrete construction for floors and walls to provide maximum resistance to abrasive ash and VOG pollutants.	Moderate	$$$$
Water Collection Systems		
Use easily deployed and durable (fireproof) covers in preparation for a predicted event. [5]	Easy	$$
Provide mechanical covers that are easily and quickly deployed.	Moderate	$$$

RESOURCES

1. ASTM E1886-19 *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*.
2. ASTM E1996-20 *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*.
3. ASCE/SEI 7-22 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*.
4. ASTM E84-21a—*Standard Test Method for Surface Burning Characteristics of Building Materials*.
5. *Volcanic Ash Impacts & Mitigation.* Volcanic Ashfall Impacts Working Group. April 2021.

DESIGNING FOR NATURAL HAZARDS

A RESILIENCE GUIDE FOR BUILDERS & DEVELOPERS

Homes destroyed by advancing lava flow.

Damage Frequency

MODERATE

Construction Practice

Use earthquake-resistant materials. Plan to avoid damage and shorten recovery time from nearby volcanic eruption.

Mitigation Strategy

Ease recovery efforts and minimize damage to structure and home through material selection and design.

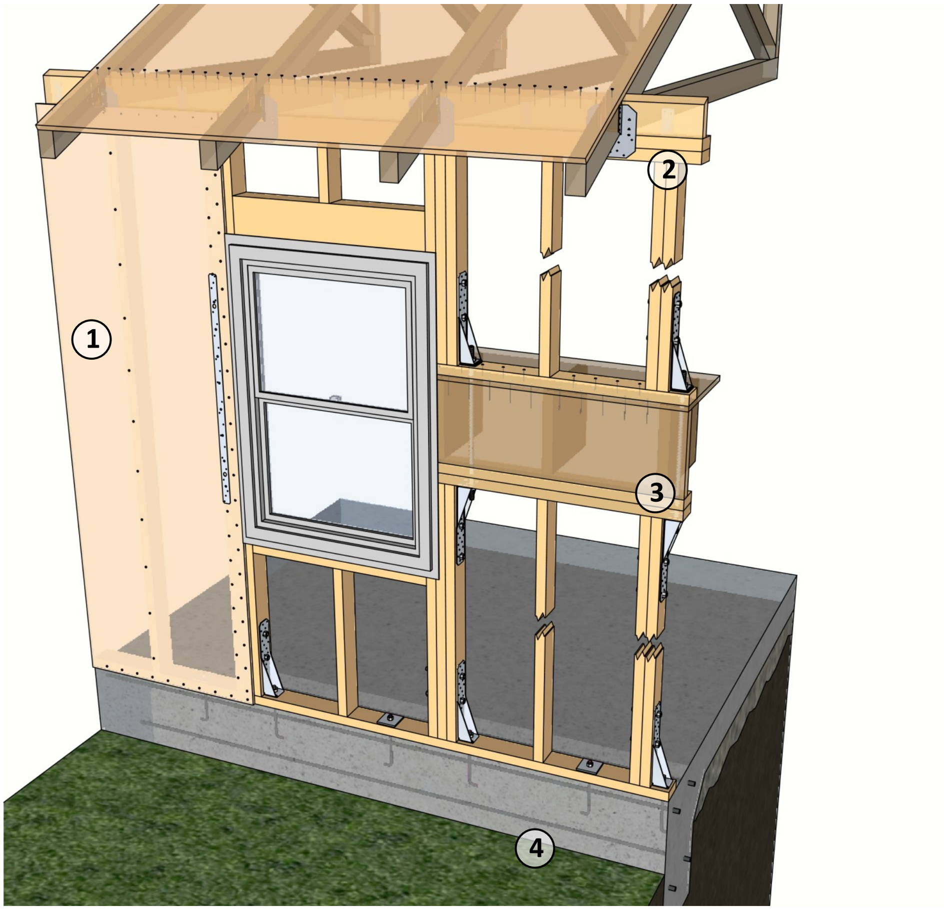
Cost & Benefit

Cost range to implement: $–$$$$

Benefit: Design elements reduce the impact on structure from a nearby volcanic eruption. Consider load path for seismic performance to reduce damage to a structure and its mechanical equipment and avoid major structural damage.

VOLCANO: STRUCTURE

Use design techniques that improve the load path of the structure to resist earthquake damage, which is a potential hazard when volcanic eruptions occur. Use specific materials that improve the structure's resilience to damage caused by mud- or landslides and flooding. Residents must be aware that volcanic eruptions can cause other natural hazards, such as earthquakes, subsidence, mudslides, erosion, tsunamis, and wildfires.



1. Sheathing reinforcement
2. Roof-to-wall connection
3. Wall-to-floor connection
4. Wall-to-foundation connection

FOR WIND AND SEISMIC LOADS

GUIDANCE	DIFFICULTY	COST
Wall-to-Foundation Connection		
Connect the shear wall to the sill plate with the required nailing pattern of the shear walls using shear wall edge nailing into the sill plate. Nailing into the treated sill plate requires fasteners that will not corrode over time.	Easy	$
Use anchor bolts to fasten the sill plate to the foundation wall to prevent sliding, and use plate washers to prevent splitting.	Easy	$
Install hold-down anchors or straps next to openings and at the end of walls to resist potential uplift.	Easy	$
Alternate 1: Provide anchor bolts and hold-down anchors with the size and spacing to satisfy the IRC. Follow requirements for Seismic Design Category D. Minimum anchor bolts are typically ½-in. bolts at 4–6 ft. on center (o.c.). Hold downs generally are only required at narrow braced walls less than 4 ft. wide and at corners, as determined by prescriptive braced wall design. [1,2,3]	Easy	$
Alternate 2: Provide continuous sheathing with wood structural panels and anchor bolts with 3x3 plate washers as required at braced wall panels around the entire perimeter of the building. [1,2,3]	Easy	$
Alternate 3: Anchor bolt spacing, sheathing attachment. Using minimum anchor bolt spacing of 32 in. o.c., use 10d nails and nails spaced to 4 in. o.c. at panel edges and 8 in. in the field. [4]	Easy	$
Alternate 4: Double hold downs, bigger anchor bolts. Increase the number of hold downs to braced wall panels that are less than 6 ft. wide; increase anchor bolt size from ½-in. diameter to 5/8-in. diameter. [5]	Easy	$$
Alternate 5: Increase the number of hold-downs and anchor bolts for 50 percent higher load, or next size up. Provide engineered design using the IRC, and select an importance factor of 1.5 or a fraction thereof. [4]	Easy	$$$
Foundation		
Use pier/piling foundation systems anchored to solid rock or driven helical pier foundation systems to resist lateral load from mudslides. [6]	Moderate	$$$
Establish first floor/living area elevations above potential mud flood height.	Moderate	$$$
Use “flow through” design, which may incorporate breakaway walls and other techniques to allow flood and mud to flow through unoccupied spaces without damaging structural integrity of building.	Moderate	$$$
Structural bracing is parallel with anticipated direction of flow of flood and mud.	Complex	$$$$

RESOURCES

1. Section R403.1.6 Foundation Anchorage. 2018 IRC.
2. Section R602.1 Wall Bracing. 2018 IRC.
3. Section 602.10.6 Construction Methods. 2018 IRC.
4. Figure 2-7 Overturning load path connections and deformations. *Homebuilders' Guide to Earthquake Resistant Design and Construction*. FEMA 232. June 2006.
5. Figure R602.10.6.1 Alternate Method. 2018 IRC.
6. Volcanic Landslides. *Landslides are Common on Tall, Steep, and Weak Volcanic Cones*. USGS.

Siding damage from hailstorm.

Damage Frequency

HIGH

Construction Practice

Follow manufacturer's instructions for best installation practice.

Mitigation Strategy

Proper installation and attachment of siding to the walls and roofing products.

Cost & Benefit

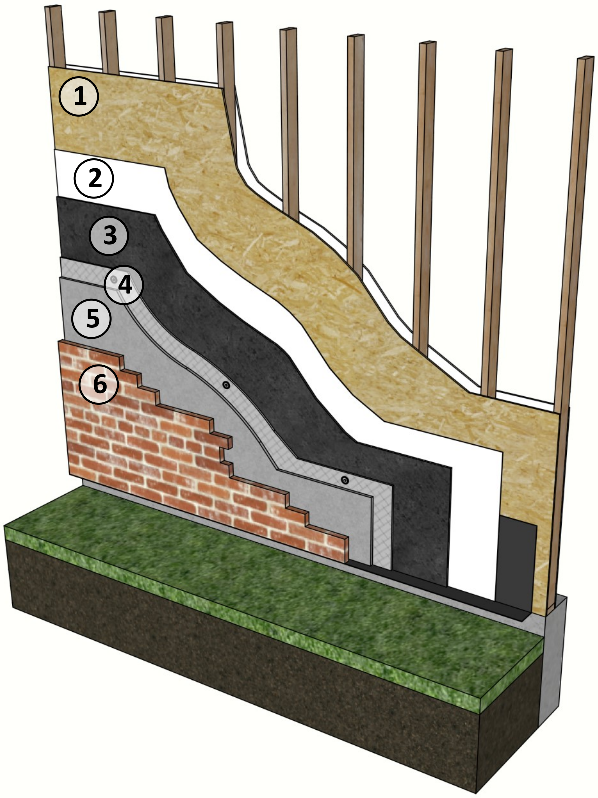
Cost range to implement: $–$$$

Benefit: Good installation of roofing and siding products designed for impact can prevent costly damage during hailstorms.

HAIL: IMPACT-RESISTANT SIDING & ROOFING PRODUCTS

Siding and roofing products can suffer damage and require costly repairs due to hailstorms, thunderstorms, tornadoes, or other wind and water hazards. Hailstorms frequently accompany thunderstorms, such that their occurrence is common. Hail can cause substantial damage to vehicles, other components of the building envelope, and landscape.

The general solution to hail damage is to install a roof product that is rated to resist impact from hail. Install siding products that are hail resistant. Consider including measures such as structural bracing, shutters, laminated or impact-resistant glass in windowpanes, and other hail-resistant building components to minimize damage.



1. Wood sheathing
2. Weather-resistive barrier
3. Drainage mat
4. Metal lath
5. Backing material for thin brick
6. Adhered thin brick veneer

GUIDANCE	DIFFICULTY	COST
Masonry Wall Cladding		
Exterior wall coverings: Follow IRC R703 construction/installation guideline. [1]	Moderate	$$–$$$
Material selection: Choose masonry exterior wall covering for hail resistance. The manufacturers of brick, stone, and other masonry materials often publish data on the impact-resilient claims about their products. Third-party test labs specialize in impact testing. [2]	Moderate	$$–$$$
Polymeric Siding		
Exterior wall coverings: Follow IRC R703 construction/installation guideline. [1]	Easy	$–$$
Material selection: Choose polymeric siding that is rated for impact. These products typically have enhanced formulation, thicker walls, and/or foam integrated into the design to better absorb the impact of hail. Manufacturers often publish data if they are making an impact-resilient claim about the product. Third-party test labs specialize in impact testing. [2]	Moderate	$–$$$
Wood and Fiber Cement Siding		
Exterior wall coverings: Follow IRC R703 construction/installation guideline. [1]	Easy	$–$$
Material selection: Choose wood or fiber cement siding that is rated for impact. These products may have stated warranties against the impact of hail. The manufacturers often publish data if they are making an impact-resilient claim about the product. Third-party test labs specialize in impact testing. [2]	Moderate	$–$$$
Roof Covering		
Asphalt shingles coverings: Follow IRC Chapter 9, Roof Assembles guideline. [3]	Easy	$$–$$$
Material selection: Choose roof covering that is rated for hail impact. These products may have stated warranties against the impact of hail. Manufacturers often publish data if they are making an impact-resilient claim about the product. Third-party test labs specialize in roof covering tests for hail impact. Test Method UL 2218 establishes a class rating, with 4 being the highest. [4,5]	Moderate	$$–$$$

RESOURCES

1. Section R703 Exterior Covering. 2018 IRC.
2. Impact Cannon Test: ASTM E1886, ASTM E1996 & FEMA 361, Intertek.
3. Chapter 9, Roof Assemblies. 2018 IRC.
4. *Hail Impact Tests for Roof Covering*. IBHS.
5. UL 2218 – *Impact Resistance of Prepared Roof Covering Materials*.

Roof collapse due to heavy snowfall.

Damage Frequency

MODERATE

Construction Practice

Design for higher snow loads, and use durable materials to protect structure during an extreme cold event.

Mitigation Strategy

Use proper building materials and site and building design to increase resistance to damage from long-term exposure to extreme cold.

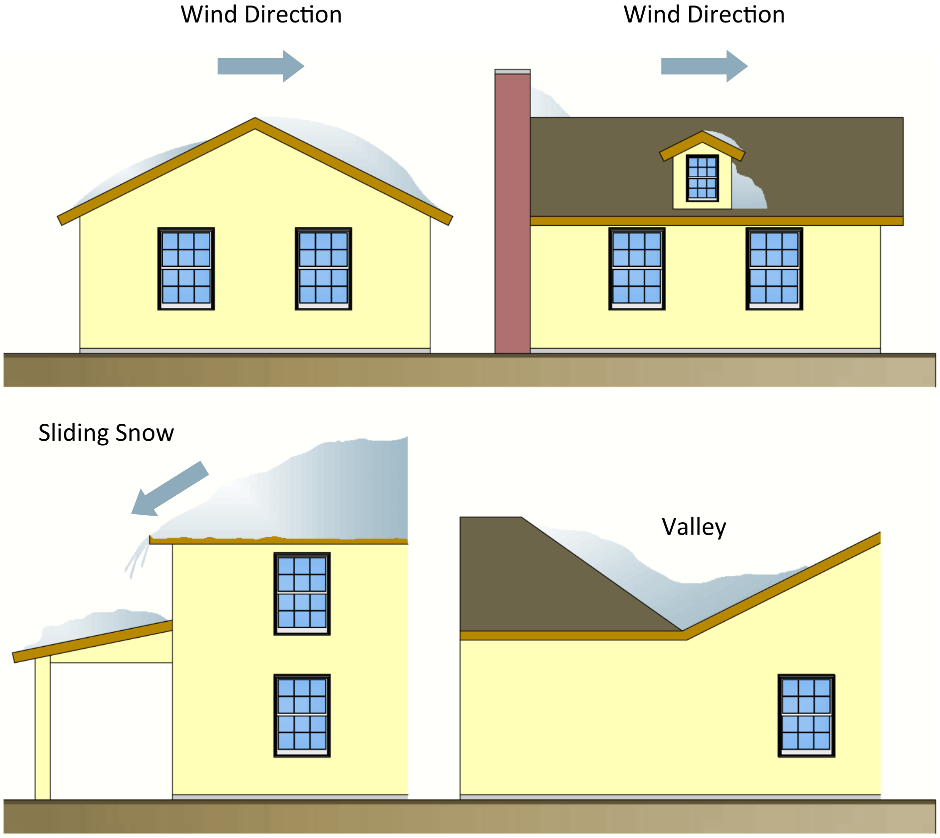
Cost & Benefit

Cost range to implement: $–$$$$

Benefit: Roof design elements reduce the impact on structure from an extreme cold event. Design can reduce damage to a structure and avoid major roof damage.

EXTREME COLD: ROOF STRUCTURE AND SNOW LOADS

Site and building designs are key to ensuring that the structure can withstand a heavy snowfall without sustaining damage. Proper construction techniques will increase the strength of the structure, minimizing damage caused by extended cold periods and heavy snowfall.



GUIDANCE	DIFFICULTY	COST
Roof Design		
Design for snow loads, and avoid parapets, chimneys, and other projections on the downslope section of roof where snow/ice shear is possible. Avoid using cricket and stranded saddles where snow and ice can accumulate. [1]	Easy	$$$
Ensure minimum 6 in. over 10 ft. positive slope away from foundation on all grading, walks, drives, and auxiliary structures.	Easy	$–$$
Install ice and water shield on the entire roof area and four ft. upside walls, with proper flashing at eaves and roof-wall intersections.	Easy	$–$$
Properly design and maintain gutters, soffit ventilation/temperature control, and eave interface to protect against ice accumulation damage to gutters and ice damming. [1]	Moderate	$$
Site Design		
Use products such as brick or stone applied to west- or southside exterior to enhance thermal mass, and use stone or tile adjacent to passive solar gain window areas on the interior to retain passive heat gain.	Easy to Moderate	$
Install electric distribution and connection lines underground to prevent storm damage.	Easy to Moderate	$
Install potable and wastewater lines at least 6 ft. deep—deeper if frost depth dictates. [2]	Easy	$
Site home to take advantage of passive solar gain and to avoid door and window exposure to prevailing windward direction.	Easy	$$$$
Foundations in Extreme Cold		
Install frost footers in basement to prevent basement walls from heaving with power failure and extreme cold.	Easy	$$$$
Increase depth of footers above code, and install frost insulation around foundation and under slab/crawlspace.	Moderate	$$$$
Additional steel reinforcements at all corners of the foundation wall.	Moderate	$$$
Install shallow insulated foundation on all slabs and flatwork, and consider installing on basement slabs if extended power outage is likely. [3]	Moderate	$$$$
Have access to main water shutoff outside foundation.	Easy	$$
Ensure that proper cold weather concrete installation guidelines are followed.	Easy	$

RESOURCES

1. *Risk Management Series: Snow Load Safety Guide.* FEMA P-957. January 2013.
2. *Winter Storm | Mitigation (Property).* FEMA.
3. *Design Guide for Frost-Protected Shallow Foundations.* HUD.

Ruptured pipe.

EXTREME COLD: UTILITIES AND SYSTEMS

Increasing insulation is key to a home's ability to resist an extreme cold event without sustaining major damage. Increased insulation on water supply lines can prevent pipes from freezing and breaking if power is lost. Backup power is also essential to maintaining temperature inside the structure above freezing, which is important to protect vital systems and the structure from further damage. Controlling moisture inside the home to prevent mold growth is another important consideration for extreme cold environments. Site and building designs are key to ensuring that the structure can withstand a heavy snowfall without sustaining damage.

Damage Frequency

MODERATE

Construction Practice

Use materials with high thermal resistance and design techniques to lower heating loads.

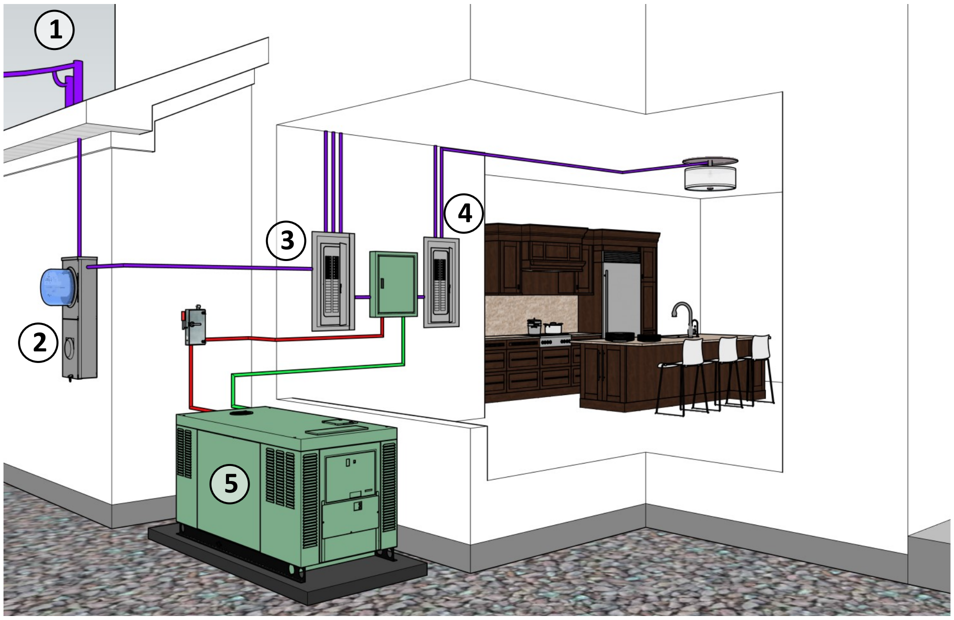
Mitigation Strategy

Control humidity and increase thermal resistance of building materials to increase resistance to damage from long-term exposure to extreme cold.

Cost & Benefit

Cost range to implement: $–$$$$

Benefit: Design elements reduce the impact on structure from an extreme cold event. Reduce damage to a structure and its mechanical equipment, and allow occupants to remain in the home.



1. Power from utilities
2. Electric meter
3. Main breaker panel
4. Household backup circuit panel
5. Generator

GUIDANCE	DIFFICULTY	COST
Power and Insulation		
Install backup power generation for extended power disruptions, considering alternative fuels to provide reliable redundancy during fuel supply chain disruptions. [1,2]	Easy	$$$$
Install secondary heating sources with alternative fuels to provide heat during disruptive events. [2,3]	Easy	$$$
Use 2x6 wall construction to allow for increased insulation R-value, and use “energy heels” on roof trusses with at least 13 in. of wall/roof truss intersection height for insulation. Use blown-in wall insulation to maximize insulation effectiveness.	Moderate	$$
Install air sealing and foam package to ensure no air leakage or penetration.	Easy to Moderate	$
Use breathable, vapor-permeable barrier under exterior cladding.	Easy	$
Airflow, Ventilation, and Moisture/Mold Control		
Control the formation of mold (especially related to quick changes in temperature) by proper/climate-appropriate envelope design, nonmechanical (that is, passive) ventilation, and indoor moisture management and control.	Easy	$$
Incorporate appliances that do not rely on propane or natural gas as combustion sources.	Easy	$
Properly vent moisture from all cooking and bathing. [2]	Moderate	$$
Identify and properly design for dew point and moisture migration through walls, and properly design attic ventilation and use the proper R-value batt insulation (versus blown) to maintain airflow through attic.	Easy to Moderate	$
Use site orientation to allow for passive heating and limited exposure to prevailing winds/weather. [2]	Moderate	$$$
Plumbing Systems		
Easy, single-turn ¼-turn shut-off valves.	Easy	$$$$
Insulate all water pipes, and do not locate water or waste pipes on exterior walls. [4]	Easy	$$$
With well, include storage and pressure tank.	Moderate	$$
With septic, include gray water or cistern backup water supply and emergency power or manual ejection mechanism.	Easy to Moderate	$
Use gravity-flow waste systems and natural-pressure water systems to allow waste and water to be distributed during a grid outage.	Easy	$

RESOURCES

1. *How to Prepare for a Winter Storm.* FEMA.
2. *Power Outages and Indoor Air Quality (IAQ).* EPA.
3. *Power Outages.* USDHS.
4. *Winter Storm | Mitigation (Property).* FEMA.

Heat wave.

EXTREME HEAT

Increasing insulation is key to a home's ability to resist an extreme heat event without sustaining major damage. Backup power is another essential item to maintaining temperature inside the structure and cooling system, which is important to protect vital systems from damage. Controlling moisture inside the home to prevent mold growth is also important for extremely hot and humid environments. Site and building designs are key to ensuring that the structure can remain safe to occupy.

Damage Frequency

MODERATE

Construction Practice

Use materials with high thermal resistance and design techniques to lower cooling loads.

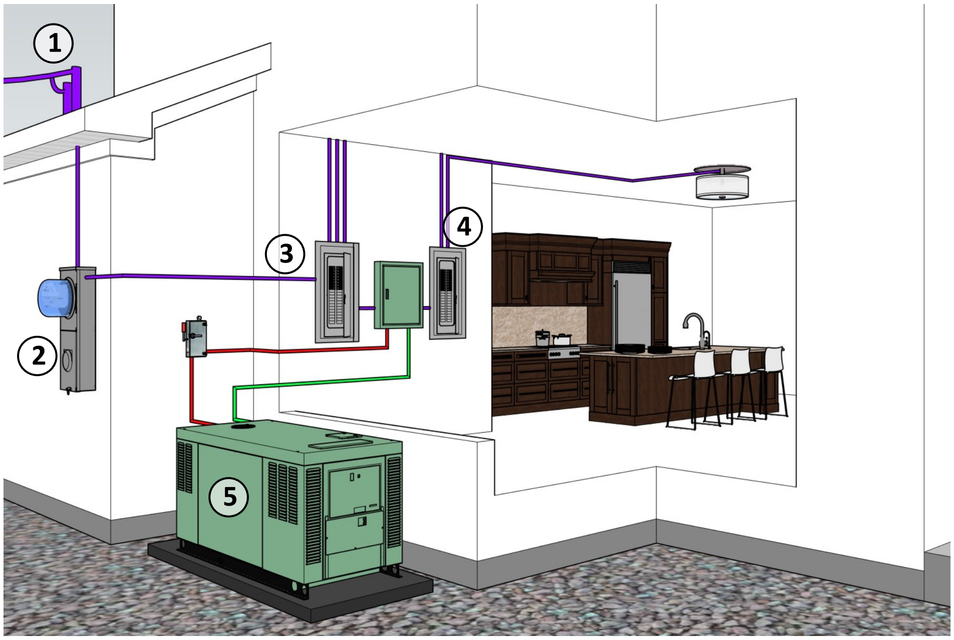
Mitigation Strategy

Increase thermal resistance of building materials, and use site and building design to boost the home's ability to remain livable during long-term exposure to extreme heat.

Cost & Benefit

Cost range to implement: \$–\$\$\$\$

Benefit: Design elements increase the likelihood of a home remaining livable during an extreme heat event.



1. Power from utilities
2. Electric meter
3. Main breaker panel
4. Household backup circuit panel
5. Generator

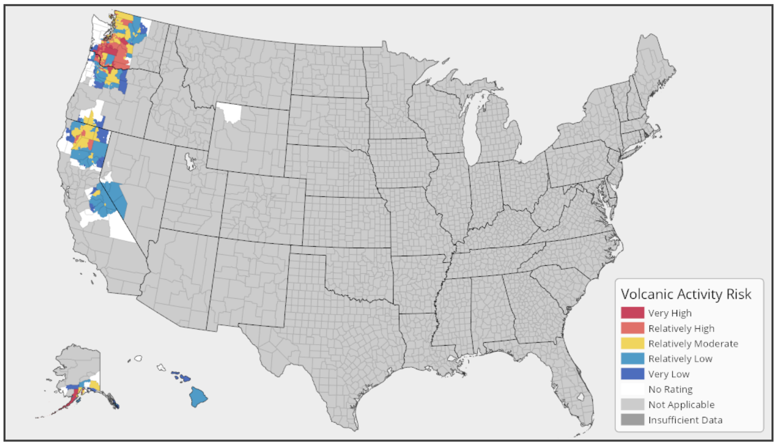
GUIDANCE	DIFFICULTY	COST
Backup Power		
Backup generator powered by natural gas, diesel, or propane. [1,2]	Easy	$$$
Solar with battery backup. [2]	Easy	$$$
Portable battery backup or generator interface system. [2,3]	Moderate	$$
Roof Design		
Properly designed attic ventilation using nonmechanical method as first option.	Easy	$
Humidistat-triggered mechanical ventilation of attic with solar or other backup power source.	Moderate	$$$
Install thermal barrier/blanket under roofing to control attic temp and prevent shingle damage.	Moderate	$$$
Use properly designed and drained green/vegetative roof system. [4]	Complex	$$$–$$$$
Site and Home Design		
Landscaping, tree planting, or preservation plan that ensures shading of entire structure. [4]	Easy	$$–$$$$
Site home on property to minimize broad roof and wall exposure to south and southwest.	Easy	$
Design home with exterior walls that allow for thermal mass, with deep overhangs and windows set back for shading.	Easy	$$
Water Security/Drought Mitigation		
Xeriscape/natural landscape (eliminate external use of water while preserving grading, drainage, and shading). [5]	Easy	$
Incorporate wildfire protection provisions. [5]	Easy	$–$$$$
Ensure that initial well installation is deep enough to preserve viability and quality to avoid necessity of drilling new well with water table decline during extended drought conditions. [5]	Easy	$$$

RESOURCES

1. *Be Prepared for Extreme Heat.* FEMA.
2. *Power Outages and Indoor Air Quality (IAQ).* EPA.
3. *Power Outages.* USDHS.
4. *Using Green Roofs to Reduce Heat Islands.* EPA.
5. *Planning for Drought Resilience.* Fact Sheet. FEMA. September 2021.

REFERENCES

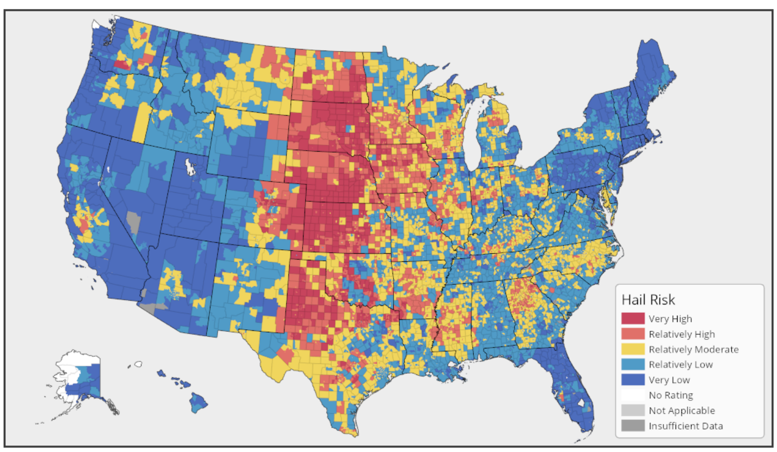
FEMA's Interactive Volcano Risk Map illustrates the risk by county: https://hazards.fema.gov/nri/volcanic-activity.



Federal Emergency Management Agency (FEMA)

Preliminary Damage Assessment Report: Hawaii—Kilauea Volcanic Eruption and Earthquakes. PR-4366-DR. FEMA. May 11, 2018. https://www.fema.gov/sites/default/files/2020-03/FEMA4466DRHI.pdf.

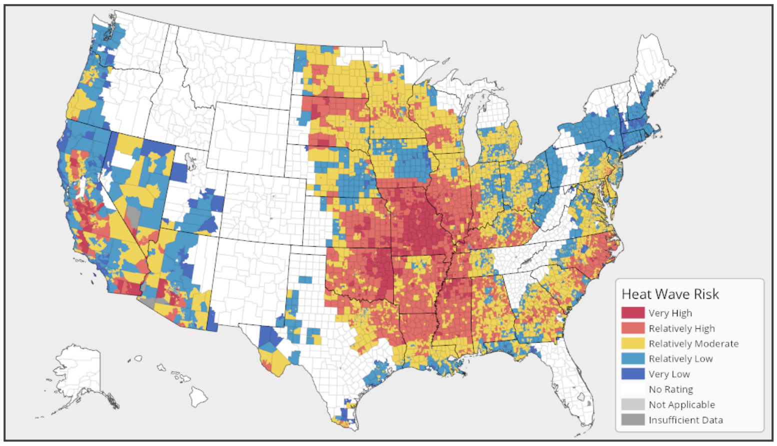
FEMA's Interactive Hail Risk Map illustrates the risk by county: https://hazards.fema.gov/nri/hail.



Insurance Institute for Business & Home Safety (IBHS)

How to Measure a Hailstone. https://ibhs.org/wp-content/uploads/How-to-measure-a-hailstone_06-28-2021-1.pdf.

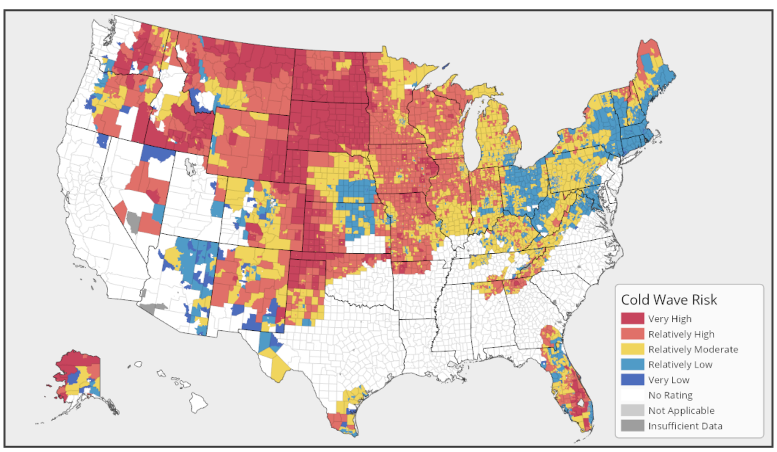
FEMA's Interactive Heat Wave Risk Map illustrates the risk by county: https://hazards.fema.gov/nri/heat-wave.



U.S. Department of Homeland Security (USDHS)

Prepare for Extreme Heat.
https://www.ready.gov/heat#prepare.

FEMA's Interactive Cold Wave Risk Map illustrates the risk by county: https://hazards.fema.gov/nri/cold-wave.



Federal Emergency Management Agency (FEMA)

Get Ready for Winter Weather.
https://www.fema.gov/blog/get-ready-winter-weather.

MAY 2023