VOLUME 3: **FIRE**

DESIGNING FOR NATURAL HAZARDS

A RESILIENCE GUIDE FOR BUILDERS & DEVELOPERS

FIRE

ACKNOWLEDGMENTS

HUD's Office of Policy Development and Research:

Government Technical Representative: Michael D. Blanford

Technical Advisory Group:

Thanks to the following subject matter experts for their contributions to this guide.

USERS

Chair: Randy Noel, MIRM
Anne Anderson, SE
Heather Anesta, PE, SE
Illya Azaroff, FAIA
Dr. Henry Burton, SE
Matthew Cooper, PE
Andrew Kollar, AIA
Darlene Rini, PE
James Williams, AIA, PE, SE

PRODUCERS

Francis Babineau, PE
Daniel Buckley
Michael Chandler
Julia Donoho, AIA, Esq.
Michael Funk
Maria Hernandez
Elizabeth Miller
William Sanderson
Lisa Stephens
Frank Thompson
Dr. Theresa Weston

PUBLIC INTEREST

Dana Bres, PE
Nicholas Crossley
Melissa Deas
Greg Grew, AIA, CBO
Dr. Therese P. McAllister, PE
Amanda Siok
Dana Sjostrom, CFM
Nancy Springer, CBO
Kristopher Stenger, AIA
Russell Strickland
Meghan Walsh, AIA

Additional Fire Task Group Members

Co-Leader: Julia Donoho, AIA Esq.
Co-Leader: Dr. Anne Cope, PE
Carl Chretien, Sr.
Helen DiFate, AIA
Matt Dobson
Kenneth Filarski, FAIA, LEED Fellow
Melissa Howard
Alejandra Nieto
Michael Weber

Illustrations by VIZ Graphics

Authored by Home Innovation Research Labs

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

TABLE OF CONTENTS

INTRODUCTION TO VOLUME 3: FIRE

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 3: Fire,** which highlights the damage caused by wildfires and identifies resilient construction practices that can eliminate or minimize fire 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 very 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 prescriptive programs or lists 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 with which 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.

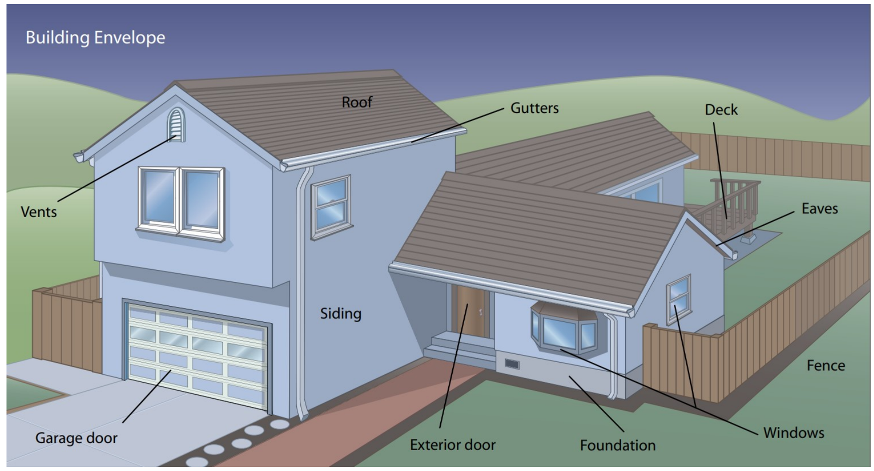


Figure 1. Building Envelope
Source: FEMA. Home Builder's Guide to Construction in Wildfire Zones.

Defining Wildfire Damage and Resilient Construction

A wildfire is defined by the Federal Emergency Management Agency (FEMA) as "an unplanned, unwanted fire burning in a natural area, such as a forest, grassland, or prairie. Wildfires can start from natural causes, such as lightning, but most are caused by humans, either accidentally or intentionally. Wildfires can damage natural resources, destroy homes, and threaten human lives and safety." For this ***Designing for Natural Hazards*** guide, the Fire Task Group focused on wildfires that occur as a natural hazard, not accidental fires (from cooking, equipment, smoking, etc.) or arson that occurs inside residential buildings.

The first undertaking for the Fire Task Group was to identify typical damage that happens when a wildfire occurs. To that end, the group reviewed case studies of wildfires published by the National Institute of Standards and Technology (NIST) and the California Department of Forestry and Fire Protection (CAL FIRE). The Task Group gathered and discussed the fire damage described in the reports, then reviewed a wide range of technical resources—for example, resources from FEMA, CAL FIRE, the National Wildfire Coordinating Group, the U.S. Department of Agriculture (USDA) Forest Service, and Wildland-Urban Interface (WUI) code—to identify the most relevant resilient construction content to be included in the Fire one-pagers.

For those building in an area that is already designated as a WUI Zone, nearly all of the resilient construction practices in this guide will apply, so simply using the WUI code in the local jurisdiction would be most prudent. However, if building a more fire-resilient residential building outside a WUI zone, this guide can help builders implement the practices incrementally by adding one or more fire-resilient features to the building.

Wildfires generally burn the exterior of buildings due to (1) direct contact with flames; (2) windblown embers landing on the building; or (3) extreme radiant heat that causes flammable chemicals or materials to combust. With that in mind, it is important to note that minimizing damage from wildfires is primarily focused on (1) minimizing the fuel around the building through fire-resistant landscape design and (2) using fire-resistant building materials for both the building envelope and outdoor living features, such as decks, fencing, and other building features, as illustrated in Figure 1.

Frequency of Damage Type

The guidance in this document is limited to low-density developments. Areas that have medium- and high-density developments—which typically add fuel once a wildfire spreads—are not considered. This guidance does not consider how the act of firefighting can mitigate the spread of wildfire; instead, the guidance is strictly focused on methods of improving the fire resistance of the homes.

After familiarizing themselves with specific damage types from the wildfire case study reports, the Fire Task Group was asked to determine the type of damage most likely to occur when considering all possible damage from wildfires. That information is difficult to pinpoint because, unlike other natural hazards, when fire damage occurs due to wildfires, generally the structure is a total loss. The dynamics of wildfires are complex because they depend on multiple factors, including the wind, terrain, fuel ignition potential, density of vegetation, building structures, size and intensity of the fire, and firefighting.

Historically, insurance companies have modeled risk for many natural hazards, including wildfires. Over the past two decades, however, they have found that many historical models no longer capture the current risk of wildfires and the resulting damage or losses. This realization has led to the development of new predictive wildfire modeling tools by risk management companies, such as Risk Management Solutions, Inc. (RMS; a Moody's Analytics Company); Verisk Analytics, Inc.; and Zesty.ai. In some cases, insurance companies are partnering with those analytics companies to develop improved models.

As part of the research for the development of this guide, the Insurance Institute for Business & Home Safety (IBHS) introduced Home Innovation staff and the Fire Task Group to Zesty.ai, a company specializing in data analytics for natural hazards that has developed new predictive fire modeling tools for the insurance industry, including its Z-FIRE™ modeling and scoring tool (https://www.zesty.ai/wildfire-risk). Zesty.ai collects satellite data that can be used to determine the defensible space, vegetation, and roofing type for buildings within an area that may be at risk for wildfires. Those metrics can help insurers build better predictive fire models and assess the risk of houses being damaged or lost during a wildfire. One should note that modeling based on post-event fire data may not fully capture actual structural-fire behavior because the models lack the influence of defensive firefighting activities. The propagation of fire is further confounded by the fact that the buildings themselves add to the fuel, and the models do not capture that consideration.

With those limitations in mind, the Fire Task Group reviewed the data provided by Zesty.ai and used it along with other guidance from FEMA, CAL FIRE, and the USDA Forest Service to determine that "defensive space and fuel management" were well correlated with better outcomes for low-density developments. From the data available, the Fire Task Group could not determine which elements of the building envelope (roofs, gutters, decking, etc.) were more vulnerable to embers. However, IBHS research (https://ibhs.org/wildfire/ember-entry-vents/) has shown that vented roofs and soffits can be improved with ember-resistant features. Those data were used in the one-pagers to identify the frequency (defined in qualitative terms as High, Medium, or Low) of each specific type of damage from wildfires on the basis of a review of available post-wildfire damage data and the judgment of the Fire Task Group. More detailed wildfire forensics could allow for better metrics to identify which house components are more likely to contribute to the building structure being lost.

Prioritizing High-Frequency Damage for Resilience

Because these resilient construction practices are intended for areas outside WUI Zones, several participants in 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 and 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 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. Again, the guidance is limited to low-density developments.

For example, on the basis of case studies and data analytics, defensible space and vegetation management are known to be critical factors during wildfires. Those two factors can often be the difference between one building and an entire neighborhood being lost. The one-pagers provide guidance for basic and supplemental construction practices to address the entire landscape from the building envelope to the property line. The cost metric is defined qualitatively, illustrating a range of incremental costs based on the implementation of additional practices.

Grouping Resilience Practices

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

Table 1. Example of “Good, Better, and Best” Approach to Resilient Construction Practices for Wildfire			
	USING MULTIPLE 1-PAGERS		
	GOOD	BETTER	BEST
Defensible Space	High Frequency	High Frequency	High Frequency
Roof Assembly	High Frequency	High Frequency	High Frequency
Foundation Components	High Frequency	High Frequency	High Frequency
Ducts, Vents, & Openings	High Frequency	High Frequency	High Frequency
Exterior Walls	X	Moderate Frequency	Moderate Frequency
Windows, Doors, & Skylights	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 Fire 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,” 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 Fire 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 in this guide should be updated to reflect improvements or modifications. To improve the damage frequency metric, builders need additional fire damage data to generally characterize how wildfires spread to a specific part of a typical building.

The January 2021 Case Study of the Camp Fire (https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2135.pdf) identified three key pathways for wildfire spread, as follows:

1. Post-fire field data collection and first responder observations identified structure ignition vulnerabilities, including structure-to-structure ignition pathways.
2. Fire spread through Paradise, and subsequently, Magalia was fueled by vegetative fuels, including ornamental shrubs, bushes, and trees; structural fuels, including homes, garages, detached auxiliary buildings, and commercial occupancies; and cars, trucks, and campers.
3. Separation distances between fuel packages within a parcel and between parcels did not prevent rapid fire spread.

Although these pathways highlight the importance of clearing vegetation and defensible space, the dryness of the surrounding forest area, terrain, and high winds were key drivers for the size and intensity of the Camp Fire.

NIST further states in the Camp Fire case study, “[D]ocumenting structure ignition vulnerabilities and structure ignition pathways is critical to developing technical guidance for improving building codes, standards, and best practices to reduce future losses. During the data analysis, several structure ignitions were identified to have been directly observed by first responders, providing firsthand information about structure ignition pathways. Their observations indicated that fuels on residential parcels can act as wicks to bring fire to the residential structures.”

The Fire Task Group discussed methods of preventing smoke damage and improving indoor air quality during a wildfire (with a special clean room designated within the building), but those methods were not included in the guide because they require further research or field validation. Although the techniques discussed seemed technically sound, the group was reluctant to recommend one-pagers on resilient construction practices that were not yet proven effective. However, most buildings that survived the Camp Fire with little fire damage suffered major smoke damage.

The Camp Fire Public Report issued by the Butte County District Attorney states the cause as follows: “A fire started underneath a PG&E transmission tower near Camp Creek Road.” The Fire Task Group did not address the benefits of underground power lines or other ember-resistant methods for major transmission lines or power poles. However, hazard mitigation for major power grid infrastructure is another area for future research.

Wildfire damage to a housing development.

Damage Frequency

HIGH

Construction Practice

Establishing defensible space by reducing fire-ready fuels near the home can be part of the initial build or a remodeling project.

Mitigation Strategy

Remove combustibles from around the building. Use hardscapes and succulents in the first 5 ft. Plan landscaping to decrease the density of trees and shrubs near structures.

Cost & Benefit

Cost range to implement: $–$$$

Benefit: Defensible space reduces fire-ready fuels close to the building and can prevent ignition. Newer research shows that the first 5 ft. around the perimeter is critical.

DEFENSIBLE SPACE

The proximity of fire-ready fuels—including landscaping, fencing, and other combustible materials—close to the home creates a vulnerability to ignition during wildfire events. A defensible space is an area around a building in which vegetation, debris, and other types of combustible fuels have been treated, cleared, or reduced to slow or stop the spread of wildfire and help protect the home from catching fire (either from embers, direct flame contact, or radiant heat). Embers can travel long distances from burning forested areas into developments. If those embers ignite fuels close to the home, the danger of total loss is high, and the danger of wildfire for the neighborhood is also high. Creating a defensible space is one of the most cost-effective ways to protect a building from wildfire and often can be created. Good defensible space also provides firefighters a safe area in which to work to defend homes.

GUIDANCE	DIFFICULTY	COST
Use hardscapes and succulents for the landscaping within the first 5 ft. of the building. [1,2]	Easy	$
For forested areas, when developing a community: thin trees and shrubbery within the community to provide 30 ft. of defensible space for each structure. [1,2]	Moderate	$$
Establish a means of annual landscaping maintenance within the neighborhood association to refresh defensible space. [1,2]	Complex	$$$
Use noncombustible fencing within the first 30 ft. of the building, and include provisions in the neighborhood association covenants stating this requirement for future fencing installations. [3,4]	Easy	$
Ensure that accessory buildings are more than 30 ft. away from the main structure, and incorporate separation distance provisions in the neighborhood association covenants. [5,6]	Easy	$
Zoning can be used to cluster development into defensible areas and keep development away from fire hazards, such as steep slopes, where fires are difficult to contain. Develop green zones, parks, water retention, or roadway infrastructure as fire breaks. Incorporate multiple ingress and egress planning as part of evacuation planning. [7]	Complex	$$$

RESOURCES

1. Chapter 7A, 701A.5 Materials and Construction Methods for Exterior Wildfire Exposure. *2019 California Building Code*.
2. Section 603, Defensible Space. *2021 International Wildland-Urban Interface Code* (IWUIC).
3. *Preparing Homes for Wildfire* (NFPA.org). National Fire Protection Association.
4. *How to Prepare Your Home for Wildfires*. National Fire Protection Association.
5. *Wildfire Ready* (Disaster.org).
6. *Wildfire Ready: Home Preparedness Guide* (Disaster.org).
7. *Protect Your Home & Property from Wildfire* (csfs.colostate.edu). Colorado State Forest Service.

*Burning roof due to lack of **Class A** roofing material.*

ROOF ASSEMBLY

The roof is regarded as the most vulnerable component of a building. One of the main purposes of the roof is to protect the building from the weather elements. Some roofs are designed only for that purpose and not for natural disasters, such as wildfires. Embers are pieces of burning wood or vegetation that can travel more than a mile when airborne. If those embers land on a home, the risk of ignition is high. For that reason, the use of Class A roofing material is recommended if the home is in a wildfire-prone area. Asphalt shingles, clay or concrete tiles, metal, and slate are all fire-resistant materials rated to withstand severe fire exposure. Accumulated debris presents an increased risk to roof systems due to the chance of ember ignition. Homeowners should be made aware of the key role of roof and gutter debris removal in maintaining the fire-resistant performance of the roof system.

Damage Frequency

HIGH

Construction Practice

Designing and installing a roof with fire-resistant features can substantially mitigate wildfire risks in wildfire-prone areas.

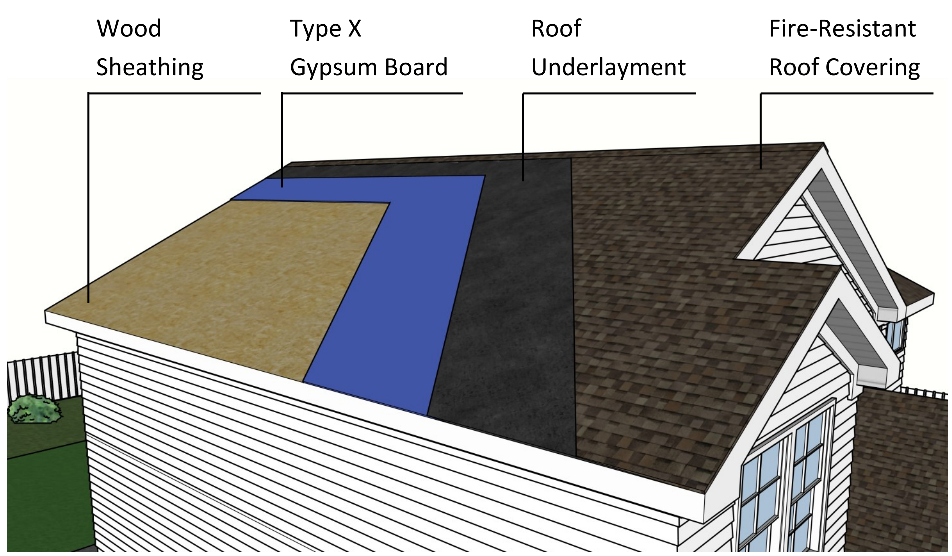
Mitigation Strategy

Strengthening the roof system to protect the structure and resist wind-blown embers and other wildfire exposure.

Cost & Benefit

Cost range to implement: $–$$$

Benefit: Excellent mitigation measures that are effective in all Fire Severity Zones.



GUIDANCE	DIFFICULTY	COST
Install Class A fiberglass-reinforced asphalt and shingles with a 5/8-in. gypsum roof board that complies with ASTM C 1177 over the wood decking. [1]	Easy	\$–\$\$
Install noncombustible roof claddings (clay/concrete tile, slate, & metal). Bird stops at all tile eaves. [2]	Moderate	\$\$–\$\$\$
Cover attic vents with noncombustible mesh. [3]	Easy	\$
Clad eaves/soffits with noncombustible materials. [3]	Easy	\$\$

RESOURCES

1. Fact Sheet #5—Roofs, *Home Builder's Guide to Construction in Wildfire Zones.* FEMA P-737.
2. *Fire in California* (ucanr.edu). University of California (UCCE).
3. Section 504, Ignition-Resistant Construction. *2021 International Wildland-Urban Interface Code* (IWUIC).

Embers igniting foundation area. Source: IBHS

Damage Frequency

HIGH

Construction Practice

Floors over open foundations to be protected by Type X gypsum board and noncombustible cladding.

Mitigation Strategy

Preventing the spread of fire into the building through the floors of an open foundation by protecting open foundations with noncombustible protective mesh and Type X gypsum board.

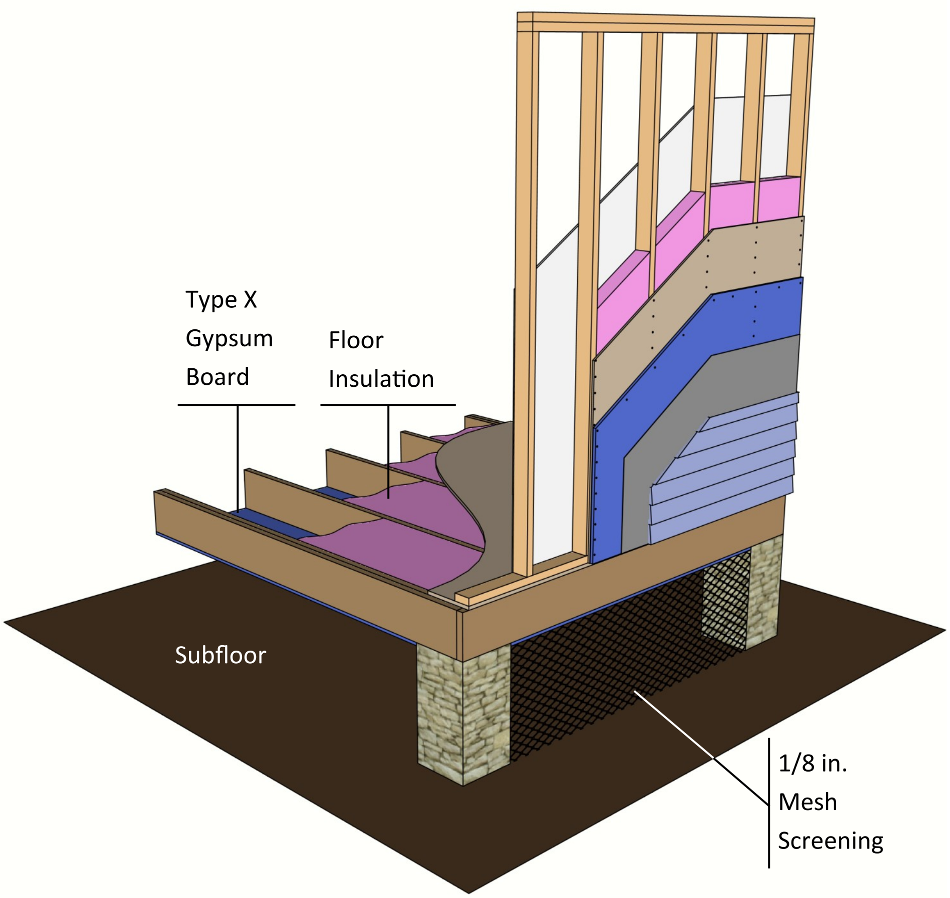
Cost & Benefit

Cost range to implement: $–$$$

Benefit: Ensures a well-protected house by avoiding the ignition of foundations by wind-borne embers and convective and radiant heat.

FOUNDATION COMPONENTS

The ceiling of open crawlspaces or vented closed foundations can be vulnerable to fire and embers if left exposed. Foundation vents in a crawlspace present a risk of ember entry during wildfire exposure, similar to a vented attic. Elevated foundations present risks due to embers or ignition due to radiant heat or direct flame exposure, depending on the surrounding site and geography. Mitigation measures vary widely depending on the type of foundation specified. Ideally, foundations designed to mitigate wildfire risk will be closed (unvented) systems made from noncombustible materials. Examples would be slab-on-grade, full-depth concrete basements, or unvented crawlspaces. For open foundations, installing 1/8-in. mesh screening is suggested in wildfire-prone areas, as it effectively minimizes the entry of embers. Embers or hot gases can ignite the underside of the first floor. Attaching a 5/8-in.-thick exterior Type X gypsum board to the underside of the joists would reduce the likelihood of that occurrence.



GUIDANCE	DIFFICULTY	COST
Protect floor over open foundation with Type X gypsum board and noncombustible cladding. [1]	Moderate	$$$
Cover foundation vents with noncombustible mesh, less than 1/8-in. openings. [2]	Easy	$

RESOURCES

1. Fact Sheet #12—Foundations, *Home Builder's Guide to Construction in Wildfire Zones.* FEMA P-737.
2. *Protect Your Property from Wildfire—Pacific Northwest Edition*, Institute for Business and Home Safety.

Embers igniting vent and gutter. Source: IBHS

Damage Frequency

HIGH

Construction Practice

Installation of vents designed to prevent and resist the intrusion of embers and flames would be beneficial to a building.

Mitigation Strategy

Mechanical intake, exhaust openings, and exterior wall penetrations should be made less vulnerable to minimize the entry of heat, hot gases, and embers.

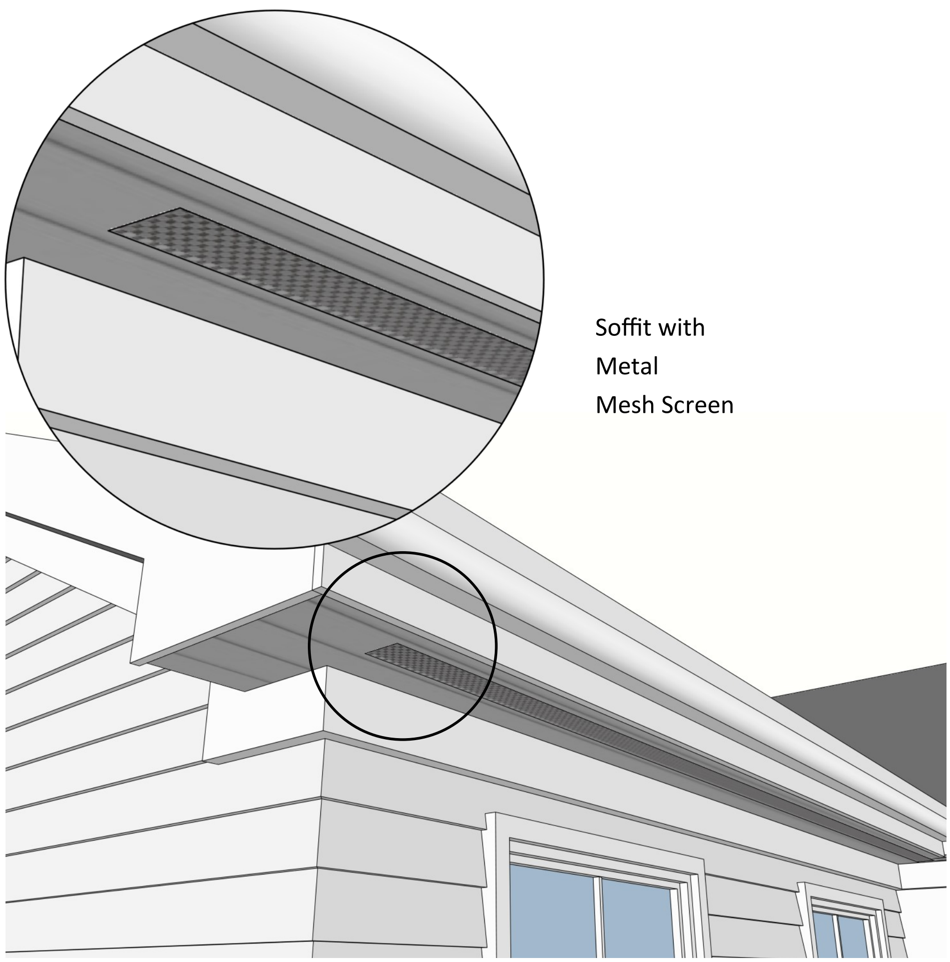
Cost & Benefit

Cost range to implement: $–$$$

Benefit: Prevents wind-borne embers, convective heat, and radiant heat from entering through exterior vent openings.

DUCTS, VENTS, AND SERVICE OPENINGS

Ducts, vents, and service openings serve important functions, including providing ventilation to remove unwanted moisture and supplying oxygen for gas appliances such as water heaters and furnaces. Providing ventilation while also keeping out embers can present a dilemma. Wind-blown embers are the principal cause of building ignition and can readily enter these spaces. Ember entry can ignite combustible materials in the interior of the home and attic, resulting in a building burning from the inside out. Embers ignite dry materials more easily, so limiting the entry of embers into attic spaces is critical. Embers can be kept out by installing noncombustible material for all vent components and corrosive-resistant, metal mesh screens with a maximum opening of 1/4 in. at all vent openings. For HVAC system vents, install metal wall louvers with adjustable, tight-fitting blades that can be closed if a wildfire threatens. For fixed louvers, install metal shutters or mesh over them.



GUIDANCE	DIFFICULTY	COST
Install specially designed metal shutters over wall louvers that are in a fixed position and cannot be closed. [1]	Moderate	$$
Install metal wall louvers with adjustable, tight-fitting blades with a fusible link that will close the blades when wildfire threatens. [1]	Moderate	$$
Limit ventilation openings to 144 sq. in., and install corrosive-resistant, metal mesh screens with a maximum opening of 1/4 in. at all vent openings. [2]	Easy	$

RESOURCES

1. Fact Sheet #8—Vents, *Home Builder's Guide to Construction in Wildfire Zones.* FEMA P-737.
2. Section 504.10, Vents. *2021 International Wildland-Urban Interface Code* (IWUIC).

Exterior wall engulfed in flames.

EXTERIOR WALLS

Exterior walls can be susceptible to flame contact and radiant heat. Flames and heat can ignite combustible wall coverings. When exterior walls ignite, the fire can penetrate the outer layer and ignite the sheathing or spread on the surface and ignite other building components, such as the roof, soffit, windows, and doors, resulting in substantial damage to, or total loss of, the building. Wood products, such as boards, panels, or shingles, are common siding materials. However, they are flammable and not good choices for fire-prone areas. For the best protection, ensure that exterior wall coverings are noncombustible or fire resistant and not susceptible to melting. Concrete, fiber-cement panels or siding, stucco, masonry, and metal are recommended materials. Those coverings should not ignite and fuel the fire.

Damage Frequency

MEDIUM

Construction Practice

Use noncombustible or fire-resistant materials such as exterior fire-retardant-treated wood or fiber-cement for trim boards around doors, windows, eaves, and corners.

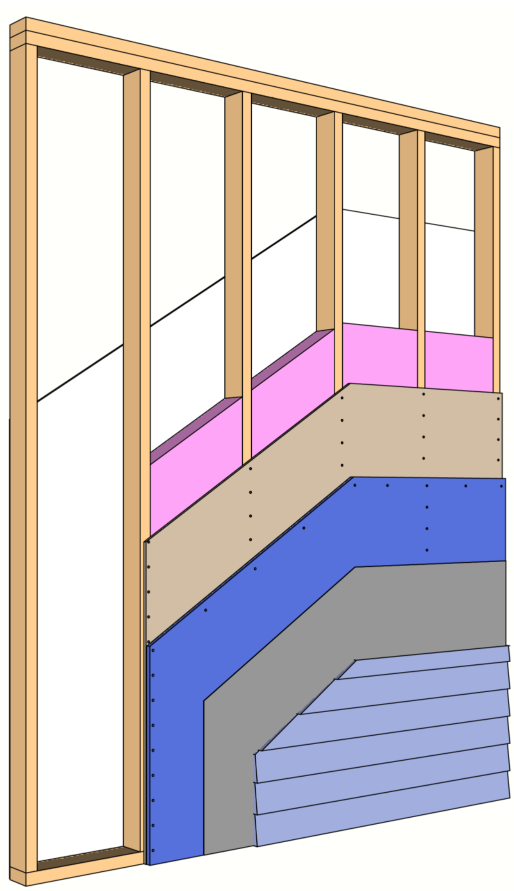
Mitigation Strategy

Noncombustible wall systems or fire-resistive construction products should be implemented at the planning and design stage, as retrofitting such systems can be difficult.

Cost & Benefit

Cost range to implement: $–$$$

Benefit: Strengthening the wall systems with noncombustible cladding or sheathing helps to provide an extra line of defense.



GUIDANCE	DIFFICULTY	COST
Use noncombustible or fire-resistant exterior wall coverings that are not susceptible to melting. [1]	Easy	$–$$
For vinyl siding (note that vinyl siding is not recommended), install one layer of 5/8-in. type X exterior gypsum board with taped joints underneath house wrap. [1]	Moderate	$$
Use noncombustible construction—for example, cement-based concrete building systems (concrete masonry unit (CMU)/block, removable form, precast, Insulated Concrete Forms (ICFs), shotcrete, autoclaved aerated concrete (AAC). [2]	Moderate–Complex	$–$$$

RESOURCES

1. Section 503, Ignition-Resistant Construction and Material, *2021 International Wildland-Urban Interface Code* (IWUIC).
2. Fact Sheet #7—Exterior Walls, *Home Builder's Guide to Construction in Wildfire Zones.* FEMA P-737.

DESIGNING FOR NATURAL HAZARDS

A RESILIENCE GUIDE FOR BUILDERS & DEVELOPERS

Radiant heat and smoke permeating through windows.

Damage Frequency

LOW

Construction Practice

Install multi-paned windows with one pane of tempered glass to reduce the chance of breakage in a wildfire.

Mitigation Strategy

Avoid the ignition of interior building components and contents due to the intrusion of wind-borne embers, hot gases, and radiant heat through fenestration.

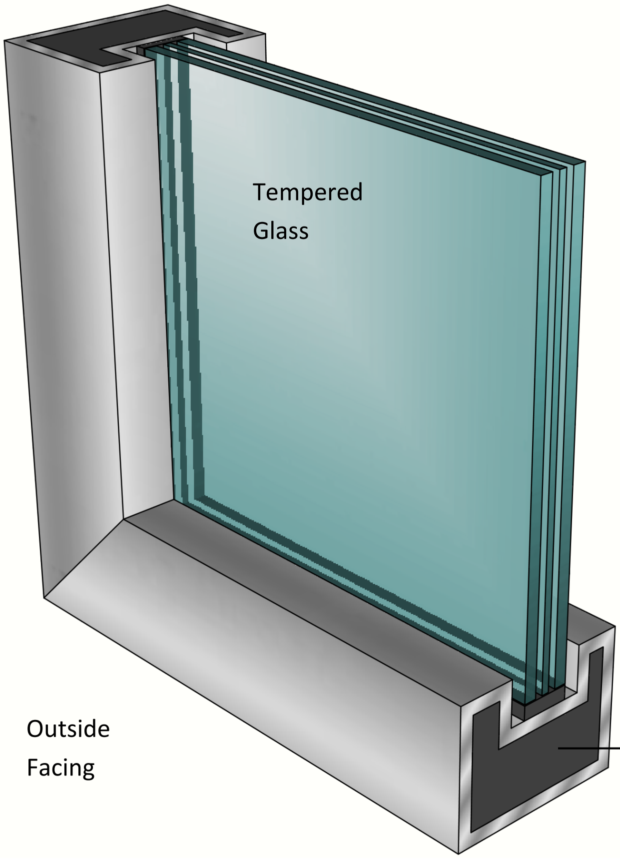
Cost & Benefit

Cost range to implement: $–$$$

Benefit: Windows, doors, and skylights are vulnerable to damaging radiant exposure and ember contact from wildfires. Strengthening those components provides additional protection to the structure.

WINDOWS, DOORS, AND SKYLIGHTS

Fenestration destruction can occur due to a temperature increase caused by radiant exposure, flame, and ember contact. Radiant heat from a wildfire can cause windows to break even before the home is on fire, allowing embers to enter and start fires inside. Normally, embers can travel up to a mile or more in front of the wildfire. Single-paned and large windows are particularly vulnerable. Installation of dual-paned windows with one pane of tempered glass will reduce the chance of breakage in a fire. With double-paned windows, the outer and inner layers are separated by a sealed air space, which serves as a thermal shield and protects the inner pane. The inner pane heats up more slowly and uniformly and may not fail even if the outer pane does. For additional protection, install insect screens and exterior metal window shutters. Solid metal shutters are unlikely to ignite or melt and are therefore recommended.



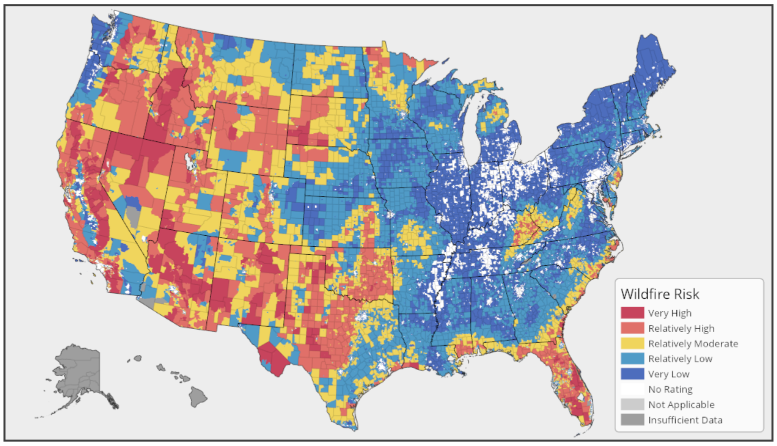
GUIDANCE	DIFFICULTY	COST
Install dual-paned windows with one pane of tempered glass to reduce the chance of breakage in a wildfire. [1,2]	Easy	$–$$
Install screens in all usable windows to increase ember resistance and decrease radiant heat exposure. [1,2]	Easy	$–$$
Install shutters to absorb some of the radiant energy and provide protection against the impact of windblown debris. [1,2]	Moderate	$$–$$

RESOURCES

1. *Fire-Resistant Windows* (firesafemarin.org). Fire Safe Marin.
2. Fact Sheet #11—Exterior Doors, *Home Builder's Guide to Construction in Wildfire Zones.* FEMA P-737.

REFERENCES

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



Federal Emergency Management Agency (FEMA)

Home Builder's Guide to Construction in Wildfire Zones. Technical Fact Sheet Series. FEMA P-737. September 2008. https://www.fema.gov/sites/default/files/2020-08/fema_p_737_0.pdf.

Prepare Your Organization for a Wildfire Playbook. https://www.fema.gov/sites/default/files/2020-03/fema_faith-communities_wildfire-playbook_0.pdf.

Defensible Space. Technical Fact Sheet No. 4. September 2008. https://www.ready.gov/sites/default/files/2020-03/home-builder-guide-construction-defensible-space.pdf.

Wildfire Safety Social Media Toolkit. https://www.ready.gov/wildfire-safety-social-media-toolkit.

Town of Paradise Wildfire Mitigation Projects. January 2022. https://www.fema.gov/sites/default/files/documents/fema_town-paradise-wildfire-mitigation-projects.pdf.

National Institute of Science and Technology (NIST) Reports

National Fire Research Laboratory. https://www.nist.gov/el/fire-research-division-73300/national-fire-research-laboratory-73306.

Camp Fire Preliminary Reconnaissance. NIST Technical Note 2105. August 2020. https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2105.pdf.

Preliminary Data Collected from the Camp Fire Reconnaissance. NIST Technical Note 2128. December 2020. https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2128.pdf.

A Case Study of the Camp Fire—Fire Progression Timeline. NIST Technical Note 2135. January 2021. https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2135.pdf.

A Case Study of a Community Affected by the Witch and Guejito Fires: Report #2—Evaluating the Effects of Hazard Mitigation Actions on Structure Ignitions. NIST Technical Note 1796. May 2013. https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1796.pdf.

Effects of Wind Speed and Angle on Fire Spread along Privacy Fences. NIST Technical Note 1894. July 2016. https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1894.pdf.

Wind-Driven Fire in a Ranch-Style House in Texas, 2009. https://www.nist.gov/el/fire-research-division-73300/firegov-fire-service/wind-driven-fires.

USDA Fire Services Resources

Fire in the Wildland-Urban Interface: Understanding Fire Behavior. n.d. https://www.srs.fs.usda.gov/factsheet/pdf/fire-understanding.pdf.

Hayman Fire Case Study. General Technical Report. 2003. https://www.fs.usda.gov/treesearch/pubs/5588.

Knowledge Management: An Application to Wildfire Prevention Planning. 1989. https://www.fs.usda.gov/treesearch/pubs/46297.

A Methodology for Determining Operational Priorities for Prevention and Suppression of Wildland Fires. 2014. https://www.fs.usda.gov/treesearch/pubs/46360.

Fuel Treatments: Are We Doing Enough? Science Update 25. 2018. https://www.fs.usda.gov/treesearch/pubs/57406.

Adapting to Wildfire: Rebuilding After Home Loss. 2015. https://www.fs.usda.gov/treesearch/pubs/49020.

MAY 2023