Builder's Guide to Construction in Wildfire Zones

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1. Introduction

While the number of reported wildfires has remained relatively consistent across the last 35 years, the severity of these events has grown significantly. Casualties, property damage, and post-fire impacts such as landslides, flash floods, and mudslides have increased due to wildfires.

The expansion of the wildland-urban interface (WUI), defined as areas where development meets undeveloped vegetation, has increased fire risks. Human development in the WUI introduces ignition sources (e.g., power lines, campfires) and exposes more people and infrastructure to dangerous conditions. Effective wildfire mitigation, including exposure reduction and structure hardening, is necessary to reduce risk and increase community resilience.

There are many terms that carry specific meaning in the context of wildfire which are important to understanding the contents of this report. Most of these definitions are based on the National Wildfire Coordinating Group's (NWCG's) online glossary[1], other nationally recognized fire organizations and existing FEMA terminology.

Defensible Space – The area or space around homes and buildings where vegetation and other features (e.g., trash, firewood piles, vehicles, propane tanks and other combustibles) are managed to reduce the structure's risk of ignition due to radiation (heat), direct flame impingement, or exposure to embers from a wildfire.

Embers – Smoldering or flaming particles of vegetation from tree branches, leaves, shrubs, grass, chaparral, or other urban combustibles (such as building components, fences, sheds) that ignite and burn during a wildfire and are carried by winds in front of the wildfire at varying distances.

Fire-Resistance Rating – The period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by fire tests or methods based on fire tests.

Ladder Fuel – Fuels which provide vertical continuity between fuel sources, thereby allowing fire to carry from surface fuels (i.e., grass) into the leaves and branches of trees or shrubs with relative ease.

Noncombustible (Building Material) – Material of which no part will ignite and burn when subjected to fire; any material conforming to American Society for Testing and Materials (ASTM) E136 meets this requirement.

Wildfire – An unplanned, unwanted fire burning in a natural area.

Wildland Urban Interface (WUI) – The line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetation fuels.

[1] https://www.nwcg.gov/publications/pms205

1.1. Understanding Risk in the Wildland-Urban Interface

Not all communities in the WUI have the same level of fire risk. Topography, vegetation, weather, and built environment conditions (e.g., rural, semi-rural, urban, building typologies) impact whether wildfire poses a significant threat. Wildfire losses can extend beyond structures (e.g., homes and commercial buildings). Other valuable community assets at risk include infrastructure, natural resources, watershed, and cultural or historical sites.

Structure survivability relies, in part, on the combination of the building construction, building material composition, and wildfire intensity and duration. Both need to be addressed to adequately harden a community. Wildfire mitigation should meet two objectives, as outlined in the National Institute for Standards and Technology (NIST) WUI Hazard Mitigation Methodology (HMM)[2]:

1. Reduce the structural losses in WUI fires by hardening structures and parcels; and
2. Prioritize mitigation efforts to reduce overall mitigation costs.

IMPORTANT NOTE: The most effective wildfire mitigation provides a balance between exposure reduction and structure hardening.

Figure 1. According to NIST's WUI Hazard Mitigation Methodology, WUI fire hazard mitigation is a balance between two input dials--reducing exposure and increasing structure hardening. (Source: NIST HMM)

The following factors affect the probability that a building will survive a wildfire:

- Topography
- Weather
- Defensible space
- Building envelope
- Structure building materials
- Structure contents
- Structural Spacing and Density
- Community infrastructure
- Community design
- Design of the structure

[2] https://www.nist.gov/el/fire-research-division-73300/resources/hazard-mitigation-methodology-hmm

This document outlines best practices to reduce the vulnerability of buildings during a wildfire. While the focus is primarily on new construction, best practices for existing construction are also noted.

1.2. Ignition and Fire Spread

Ignition of a building and its components occurs through radiant heat transfer, direct flame impingement, or direct ember exposure, as illustrated in Figure 2. This document provides guidelines for minimizing each of these mechanisms to inform the construction of fire-resistant structures.

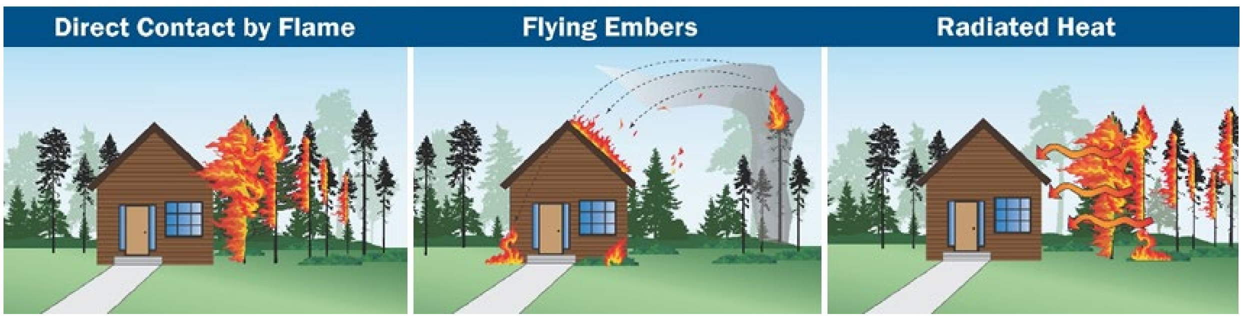

Figure 2. Key Mechanisms for Wildfires Leading to Property Damage and Loss.

1.3. Multi-Hazard Considerations

While this document focuses primarily on wildfire, multi-hazard and/or secondary hazard events are common. Communities should use a multi-disciplinary approach to wildfire mitigation to reduce additional losses from flooding and debris flows. The following should be considered:

- Natural hazard events such as high winds can exacerbate fire hazard conditions (i.e., topography, fuel, and weather) (Figure 3).
- Wildfires can increase the likelihood and severity of post-fire flooding and debris flows. Additional details regarding post fire debris flows can be found on the USGS Postfire debris-flow hazards website.[3]
- Development practices in the WUI may not adequately address wildfire mitigation or may inadvertently exacerbate the effects of multi-hazard events.
- Wildfire mitigation requires a multi-disciplinary approach to address the impact of natural hazards on wildfire risk through effective land management and building techniques.

Additional details on multi-hazard considerations can be found in the Maui Wildfire Mitigation Assessment Team *Recovery Advisory #5: Multi-Hazard Considerations and Mitigation Strategies for*

[3] https://www.usgs.gov/programs/landslide-hazards/science/postfire-debris-flow-hazards

Residential Construction[4] and *FEMA DR-4634: Marshall Fire Mitigation Assessment Team: Mitigation Strategies to Address Multi-Hazard Events.*[5]

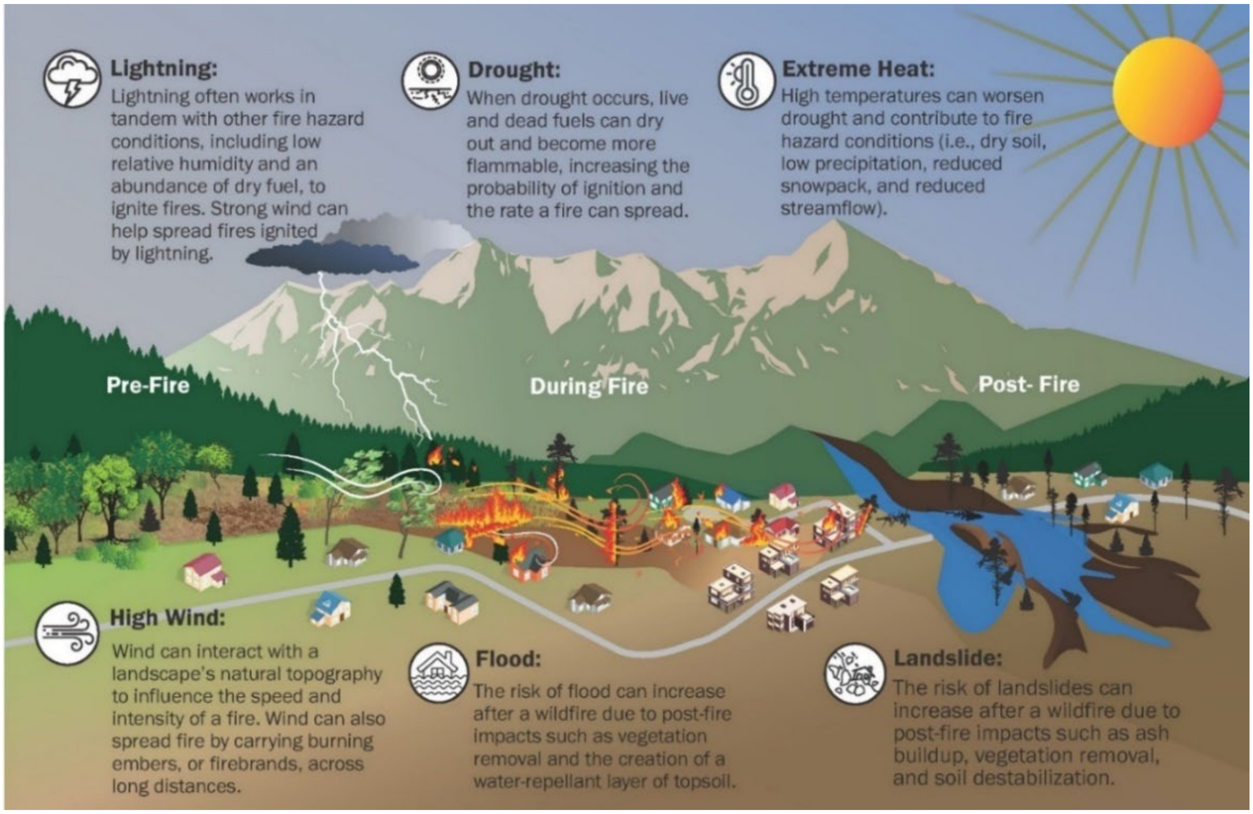

Figure 3. Multiple hazards can contribute to or result from wildfires (Marshall Fire Mitigation Assessment Team Report).

1.4. Hazard and Risk Assessments

A wildfire risk assessment is crucial to help communities and building owners understand specific wildfire vulnerabilities, prioritize risk reduction efforts, and develop effective mitigation strategies. A wildfire risk assessment identifies where wildfire is most likely to threaten something of community value, such as human life, property, natural/historic resources, or other features or resources of local value. By identifying and evaluating wildfire hazards and their potential impacts, risk assessments enable informed decision-making, resource allocation, and long-term resilience planning.

The foundation of an accurate hazard and risk assessment is evaluation of wildfire fuels, weather, topography, assets at risk, and the probability of wildfire occurrence. This information informs the Fire Hazard Severity Zone, typically rated from low to extreme. While some areas with frequent wildfire activity, such as parts of California, have defined Fire Hazard Severity Zones, not every

[4] https://www.fema.gov/sites/default/files/documents/fema_rsl_ra-5-maui-mat-multi-hazard-strategies_051325.pdf
[5] https://www.fema.gov/sites/default/files/documents/fema_rsl_marshall-mat-mitigation-strategies-to-address-multi-hazard-events_042025.pdf

community has formally delineated them. In cases where state or local designations are not available and per the direction of the authority having jurisdiction, the fire hazard severity of a specific building site can be assessed using the form in Section C101 of the *2024 International Wildland-Urban Interface Code* (IWUIC).[6] More broadly, the general wildfire risk of a community can be found in the community hazard mitigation plan.

Quantifying Wildfire Hazard Risks: To attempt to quantify the risk of wildfire, various groups have developed wildfire hazard and risk maps; however, a national consensus-based wildfire risk map for community planning and wildfire building safety does not currently exist. Where a local wildfire hazard map does not exist for every community, several options may be available to assist in determining risk. Even in communities with a wildfire hazard map and defined WUI area, hazardous conditions can extend beyond these areas defined as high risk. If the local community has a hazard mitigation plan and/or Community Wildfire Protection Plan, information regarding wildfire risk may be included.

Incorporation of wildfire hazard information (e.g., wildfire hazard and risk maps, local wildfire/fire safety ordinances, zoning restrictions, wildfire safety elements in general plans) in early planning phases of new development, including subdivisions, is critical. Contractors, developers, design professionals and planners should undertake the following to understand wildfire hazards during the planning process:

1. Evaluate all relevant state and local wildfire hazard and risk maps. Wildfire hazard and risk maps at the state level are typically provided by the State Fire Marshal's office, State Forestry Department, State University, or equivalent state fire agency. At the local level, wildfire hazard and/or risk maps are typically provided by county or local fire agencies, office of emergency services, or other local government agencies.
2. Assess risk as a function of hazard, exposure, and vulnerability; a small, modest housing development or senior care facility may have a greater wildfire risk than a golf course community with managed green space. The contractor, designer, and/or planning professional should evaluate site-specific hazards and potential risks to the proposed development.
3. Determine if an environmental review is required as part of the planning phase. The objectives of environmental reviews may conflict with the objectives of wildfire hazard and risk reduction measures, so consultation with both a wildfire/fire safety specialist and an environmental protection specialist is recommended to appropriately address and balance public safety and environmental concerns.
4. Evaluate all relevant local level community planning documents, plans, and maps. This may include, but is not limited to, the following:
    - Community Comprehensive Plans
    - General plans, master plans, zoning requirements, and land-use planning

[6] https://codes.iccsafe.org/content/IWUIC2024V1.0

- Community Wildfire Protection Plans
- Hazard Mitigation Plans - Reference Marshall Fire Mitigation Assessment Team document *Mitigation Strategies to Address Multi-Hazard Events*[7] for additional best practices
- Emergency operation plans and procedures
- Unit Strategic plans or other fire department planning documents

5. The level of detail in these documents varies widely between jurisdictions. In best-case scenarios, these plans should provide hazard mapping for the area, indicate overlap between natural hazards and vulnerable community assets, detail structural vulnerabilities, and list concerns about post-wildfire impacts.
6. Consult state and locally adopted wildfire safety building and fire codes, ordinances, and other relevant regulatory documents. If the state or local jurisdiction has not adopted wildfire-specific safety regulations, refer to the 2024 International WUI Code (Table 502.1 and/or Appendix C: Fire Hazard Severity Form) for best practices for site-specific fire hazards.[8]
7. Consult with the local fire department to determine local requirements, additional best practices documents, wildfire planning processes and reviews and/or alternative mitigation initiatives appropriate to the area.

[7] https://www.fema.gov/sites/default/files/documents/fema_marshall-fire-mat-mitigation-strategies-address-multi-hazard-events.pdf
[8] https://codes.iccsafe.org/content/IBC2024V1.0

2. Planning and Site Selection

Proper selection of the construction site can reduce wildfire risk. This section helps property owners who plan to build homes, buildings or other structures understand the relationship between wildfire behavior and fuels, weather, and topography so they can select construction sites that minimize the potential for damage from wildfires.

A construction site's topographic features should be evaluated for wildfire risk. A building's configuration and location should be chosen with the intent to minimize the risk from topographic features. Wildfire severity and rate-of-spread of fire increase at specific topographic features such as saddles, ridge lines, drainages, canyons (Figure 6), and steep slopes. Some jurisdictions provide additional siting requirements (e.g., minimum setbacks, additional defensible space requirements, additional structural hardening measures, development of a fire protection plan) for buildings and developments located in high wildfire hazard areas. Most jurisdictions do not have neighborhood-, community- or regional-level planning, or wildfire zoning requirements for new developments in very high-risk landscapes.

A detailed discussion on different wind types and how topography impacts winds can be found at the National Wildfire Coordinating Group (NWCG) website.[9]

2.1. Topography

Topography is the configuration of the earth's surface and is the most stable of the elements in the wildfire environment. Topography significantly impacts wildfire behavior as it influences local winds by sheltering areas from prevailing winds or channeling winds through prominent canyons and drainages. Factors of topography that affect fire behavior include slope, aspect, terrain features, and elevation with the steepness of slope being the most influential. Consideration should be given to sloped terrain, saddles, ridgetops and hilltops, and canyons as described below.

- **Sloped terrain.** Wind-driven fires follow wind direction and are influenced by topography. In the absence of strong wind, wildfires typically follow topography, burning primarily upslope and up-canyon.
- **Saddles.** Where a valley crosses a ridge, a saddle is created between two peaks. Saddles act as wind funnels and are one of the most hazardous locations for structures.
- **Ridgetops and hilltops** Wind speeds tend to be higher at ridgetops and hilltops where wind flows over abrupt changes in topography. Buildings in these locations can have increased exposure to wildfire.
- **Canyons.** A wildfire at the bottom of a vegetated canyon can lead to extremely hazardous upslope conditions. A canyon acts as a chimney, collecting hot gases and directing superheated

[9] https://www.nwcg.gov/

convection and radiant heat upslope. Canyons funnel winds that fan fires and lead to rapid spread, as shown in Figure 4. An entire canyon can pre-heat from rising hot air and gases and explode in flames, creating a firestorm.

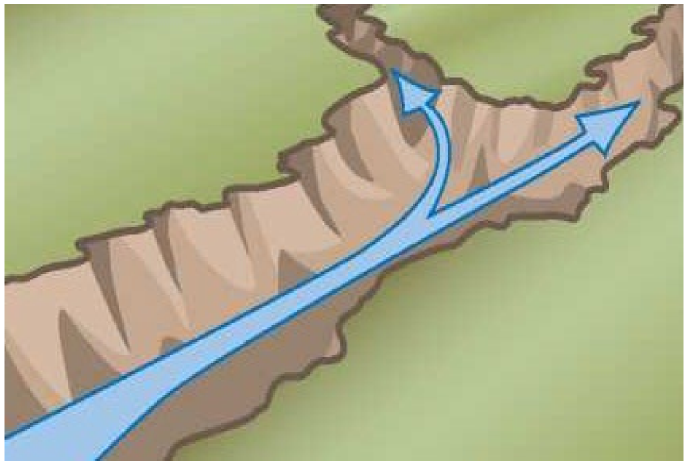

Figure 4. Wind behavior through a canyon.

2.2. Vegetation

Vegetation provides fuel for wildfires. Combustible vegetation both on and adjacent to a site can increase wildfire vulnerability. Vegetation characteristics such as density, continuity, and type can influence wildfire behavior (see Chapter 3 for more information). Fires on drier slopes tend to ignite more easily, travel more rapidly, and burn out faster as light fuels are consumed. More heavily vegetated moist slopes have a lower potential for ignition but can sustain a more intense fire of longer duration than dry slopes.

2.3. Best Practices

State and local wildfire hazard and risk maps as well as other wildfire-related planning documents provide a general understanding of "landscape" level fire hazards. Where state or local hazard maps are nonexistent, out-of-date, or of low spatial resolution, consider contracting a specialist to complete a project-specific wildfire hazard and risk assessment. A project-specific wildfire hazard assessment will provide a higher level of granularity of anticipated wildfire behavior, will highlight any vulnerabilities due to the presence of local topographic conditions (e.g. hilltops, ridges, steep slopes) and will show potential fire flow paths from neighborhood- or community-level features such as greenbelts, open spaces, or drainages. In recent fires, such as the 2021 Colorado Marshall Fire, drainages and other communal open spaces provided a pathway for wildfire to spread into urban/suburban environments (Figure 5).

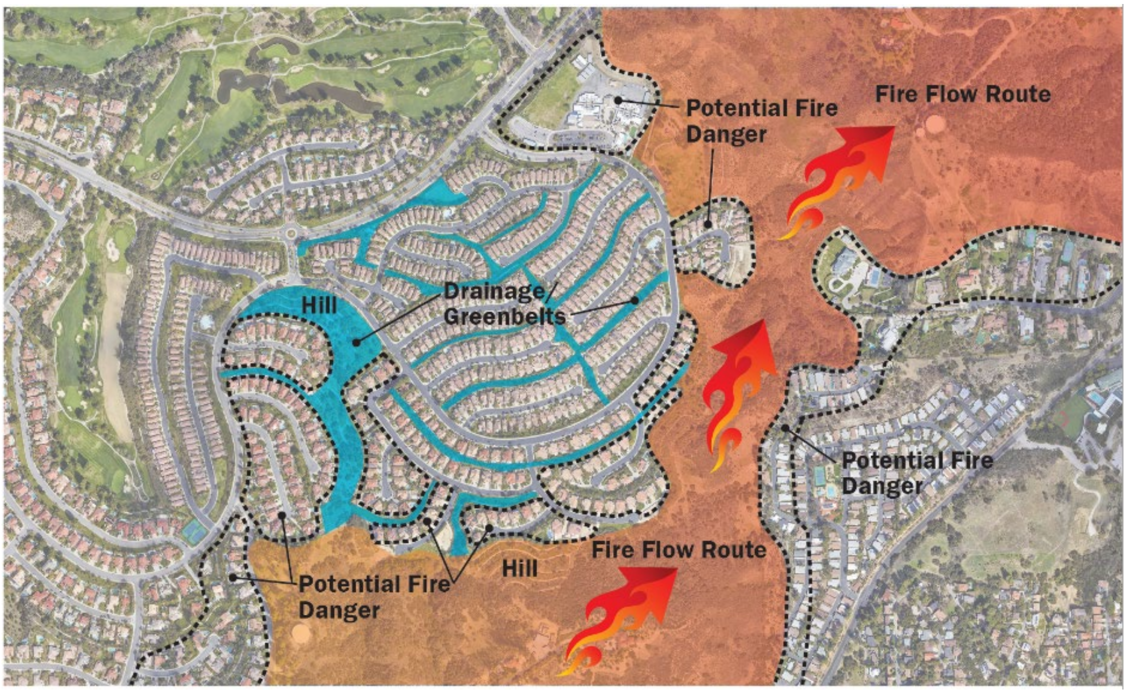

Figure 5. Drainages and greenbelts in or adjacent to communities can provide access for fire to flow into the urban/built environment (Marshall Fire Mitigation Assistance Team Report).

If a detailed wildfire hazard assessment is not available or feasible, the following best practices for siting a subdivision, development or individual home or building can help reduce wildfire risk:

- Avoid site selection along a gully or in a narrow canyon.
- Avoid construction site selection in or adjacent to a saddle or narrow mountain pass.
- Avoid new development adjacent to or on a mid or steep slope. If a ridgetop site is selected, consider the following:
- Orient the narrowest portion of the building toward the likely path of wildfire to minimize structure ignition risk (Figure 6). Consider possible wind direction and combustible fuel locations so that debris and embers do not accumulate next to the building's walls. Be sure to consider the inside corners of entries and other off-set walls that may increase risk of ignition of accumulated debris.
- Minimize the number of windows on the side of the building facing the likely wildfire path to reduce the risk of radiant heat or embers and flying debris breaking windows.
- Consider access to the home or building, as steep driveways and narrow roads can limit accessibility for fire suppression.
- Evaluate the vulnerability of neighboring properties to fire. If adjacent properties have fire hazards but the owners are unable to develop mutual defensible space, consider more protective mitigation measures for your building (Figure 7).

Figure 6. Orient the narrowest portion of the building toward the likely path of wildfire to minimize structure ignition risk (red circle).

Figure 7. Fire-resistant construction techniques.

- Storage of combustible materials on site can increase fire risk. Consider providing additional mitigation measures, such as larger setbacks and defensible space areas, secondary emergency water supplies, emergency power, and increased exterior wall fire-resistance rating (e.g., one-hour to two-hour). Consult with a fire-safety engineer, design professional, or local fire department for best practices.

Implementing fire-mitigation measures cannot entirely offset potential wildfire damage at high-risk sites with topographic and vegetation features that contribute to greater wildfire vulnerability. Although high-density development can efficiently include vegetative buffers and allow for fire suppression, additional risks are involved when structures are closely spaced. See *Maui Wildfires: Mitigation Assessment Team Compendium Report*[10] and the Marshall Fire Mitigation Assessment Team document *Best Practices for Wildfire-Resilient Subdivision Planning*[11] for information on mitigating risk for high-density neighborhoods and subdivisions.

[10] https://www.fema.gov/sites/default/files/documents/fema_rsl_p2425_maui-mat-compendium_06052025.pdf
[11] https://www.fema.gov/sites/default/files/documents/fema_marshall-fire-mat-best-practices-wildfire-resilient-subdivision-planning.pdf

3. Defensible Space

Wildfire travels rapidly, especially if vegetation is dry and abundant. Providing defensible space around a building can improve the probability that the building will survive a wildfire. Defensible space is the area where combustible material, including vegetation and outbuildings, has been reduced or eliminated to slow the rate and intensity of an advancing wildfire. Buildings surrounded by zones of non-vegetated areas or areas landscaped with fire-resistant vegetation have less risk of fire ignition and lower probability of severe damage. Defensible space, coupled with structure hardening, is essential to reducing or eliminating wildfire damage.

Defensible space is one of the most cost-effective ways to protect a building from wildfire; however, maintaining effective defensible space requires ongoing maintenance. Property owners are responsible for maintaining defensible space of their fire-resilient landscape. Maintaining defensible space includes specific actions for vegetative and combustible objects (e.g., trash cans, fencing and sheds) around a home up to 100 feet from the structure.

IMPORTANT NOTE: Defensible space is one of the most cost-effective ways to protect a building from wildfire; however, maintaining effective defensible space requires ongoing maintenance. Property owners must remain vigilant to maximize the effectiveness of defensible space.

Defensible space is generally categorized by three zones, where the most restrictive measures are prioritized for areas closest to the structure: Zone 0, Zone 1 and Zone 2, as detailed in Figure 8. The level of defensible space adequate for a specific property is also dependent on structure hardening. More details on this concept can be found in the NIST HMM.[12]

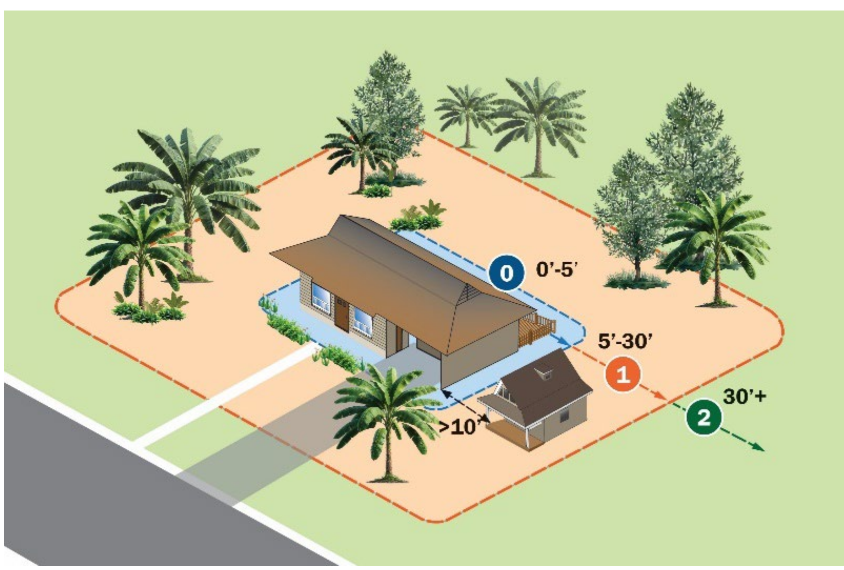

Figure 8. Defensible space is divided into three zones based on distance from a structure.

[12] https://www.nist.gov/el/fire-research-division-73300/resources/hazard-mitigation-methodology-hmm

The National Fire Protection Association (NFPA) defines the three defensible space zones and provides requirements and best practices for each zone, as detailed in Table 1.

Table 1. NFPA Wildfire Zones

Zone	Distance	Requirements
Zone 0	0-5 feet immediately surrounding the structure and/or under attached decks or overhangs.	▪ Use gravel, pavers, or concrete instead of combustible mulch. ▪ Clear dead weeds, grass, and debris; check roofs, gutters, and outdoor areas. ▪ Keep branches trimmed 10 feet away from chimneys and stovepipes. ▪ Minimize combustible items like furniture and planters on decks. ▪ Move firewood and lumber at least 30 feet away for safety. ▪ Replace combustible fencing and gates with noncombustible materials. ▪ Shift garbage and recycling containers to a safer area outside this zone. ▪ Relocate boats, recreational vehicles, and other vehicles away from this zone to reduce fire risks.
Zone 1	5-30 feet from the structure. Also includes 10 feet from driveways, access road, or public roads.	▪ Remove dead leaves, pine needles, and debris from your yard, roof, and gutters. ▪ Trim overhanging branches to at least 10 feet away from chimneys. ▪ Keep trees pruned to maintain spacing. ▪ Clear combustible vegetation and items from under decks, balconies, and stairs. ▪ Maintain space between trees and shrubs. ▪ Mow grass to a maximum height of four inches. ▪ Ensure outbuildings and propane tanks have 10 feet of clearance with no combustible vegetation nearby.
Zone 2	30-100 feet and beyond from the structure.	▪ Mow grass to a maximum height of four inches. ▪ Create horizontal spacing between shrubs and trees. ▪ Remove dead vegetation and fallen leaves. ▪ Prune lower branches of trees. ▪ Ensure outbuildings and propane tanks have 10 feet of clearance with no combustible vegetation nearby.

Fires rapidly spread via flow paths that can ignite structures. Ignition can be exacerbated by combustible building materials and vegetation, topography, and other conditions (Figure 9).

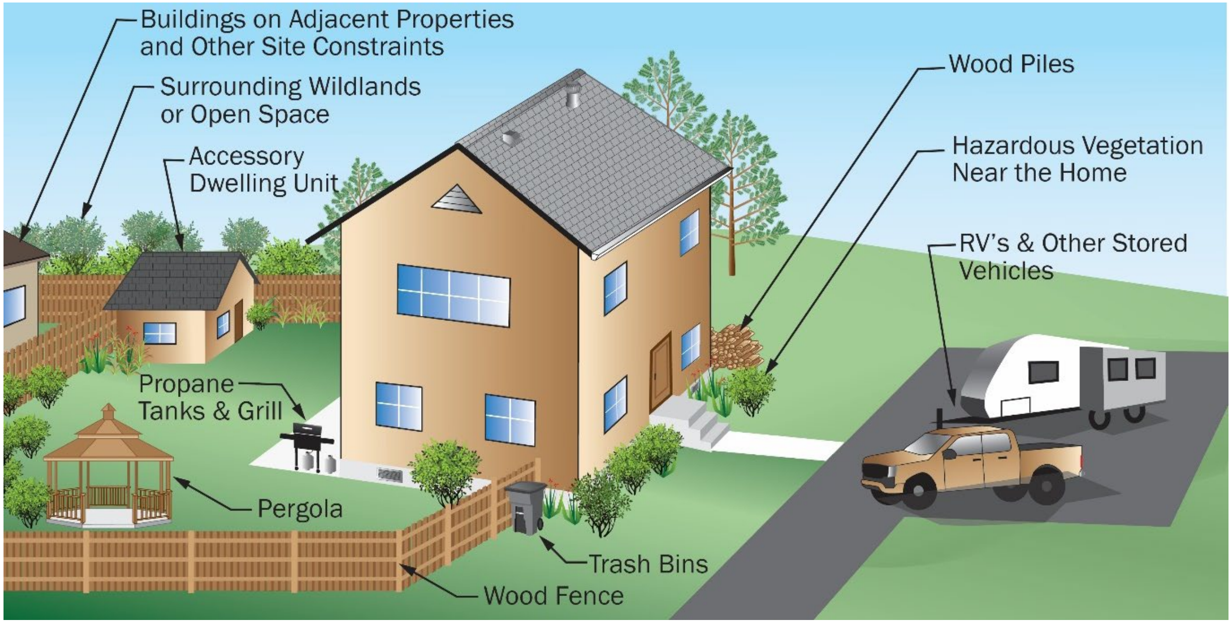

Figure 9. Key wildfire vulnerabilities near a home.

Combustibility of Vegetation: While some plants are marketed and described as "firesafe," "fire-smart" or "fire resistant," all vegetation will burn under the right conditions. The environment plants grow in and how they are maintained may have more influence on the combustibility of the plant than its inherent characteristics. Additional details on landscaping can be found on the California Department of Forestry and Fire Protection (CAL FIRE) Fire-Smart Landscaping page.[13] Many states have similar information dedicated to location specific fire-resistant vegetation.

3.1. Key Issues

Wildland vegetation can be extremely combustible and can burn with intensity, producing wind-borne embers. Grass, brush and timber in urban areas can be as combustible as vegetation in sparsely developed areas. Wildfire can also travel vertically from the ground up into the treetops via ladder fuels, resulting in a catastrophic crown fire (a fire that can travel rapidly through the forest canopy).

Accessory buildings, wood fences and structures and other items commonly found in yards pose a risk to otherwise fire-resistant buildings.

Combustible plants have these characteristics:

- Volatile resins and oils (generally aromatic when crushed)

[13] https://readyforwildfire.org/prepare-for-wildfire/fire-smart-landscaping/

- Narrow leaves or long, thin needles such as conifer needles
- Waxy or fuzzy leaves
- An accumulation of dead leaves and twigs on and under the plant
- Loose or papery bark

Combustible vegetation and materials around a building:

- Increase the risk of building ignition.
- Restrict safe structure protection and fire suppression operations.
- Increase the risk of wildfire spread to adjacent buildings and other areas.

3.2. Best Practices

Following the best practices listed below can reduce wildfire risk to residential properties:

- Choose an area that allows for a minimum 30- to 100-foot horizontal setback from wildland vegetation on the downslope side (see Figure 10). Increase the setback at sites with heavier fuels such as in a forested environment. Implement the measures in Marshall Fire Mitigation Assessment Team documents *Homeowner's Guide to Reducing Risk of Structure Ignition from Wildfire* and *Homeowner's Guide to Reducing Wildfire Risk Through Defensible Space*.[14]

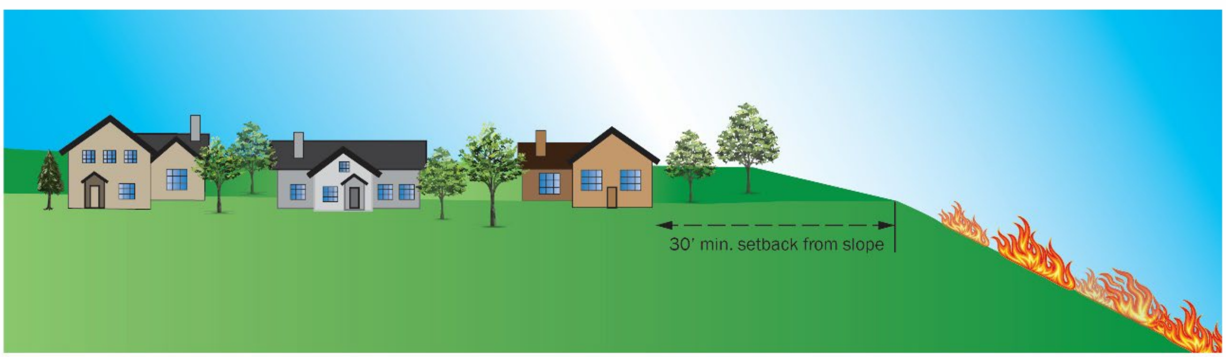

Figure 10. Topographic features, such as slopes, may increase wildfire risk. Appropriate mitigation actions, such as slope setbacks, should be undertaken.

  - Develop a fuel modification and long-term vegetation management plan for steep slopes near the development site. More than 100 feet of defensible space may be needed for specific sites with hazardous topography or vegetation. Consult with officials (i.e., authority having jurisdiction) for site-specific best practices and/or local ordinance requirements. In some jurisdictions, at least 200 feet may be required (e.g., Los Angeles County, Orange County in California). Refer to the Marshall Fire Mitigation Assessment Team document *Homeowner's Guide to Reducing Wildfire Risk Through Defensible Space* as well as additional best practices documents in the references section.

[14] https://www.fema.gov/sites/default/files/documents/fema_rsl_marshall-mat-homeowners-guide-to-reducing-wildfire-risk-through-defensible-space_042025.pdf

- Avoid siting new development adjacent to unmanaged open or wildland space where 50 to 100 feet of defensible space cannot be provided. If the building site is near unmanaged open or wildland areas, consider:
  - Fuel break integration with fruit orchards, irrigated landscaping/greenbelts, golf course or other similar low-wildfire hazard features.
  - Where perimeter defensible space is not feasible, provide increased structural hardening measures for structures adjacent to wildland areas such as 6-foot noncombustible perimeter walls or one-hour fire-resistant exterior walls and protected openings.
  - Refer to Marshall Fire Mitigation Assessment Team document *Decreasing Risk of Structure-to-Structure Fire Spread in a Wildfire*[15] for additional siting recommendations for buildings (e.g., building orientation relative to fire flow paths, debris and ember accumulation, window number, and orientation).

- Where high density designs cannot be avoided, 100 feet of defensible space should be provided around the perimeter of the entire development site, while also considering the following integrated design features.
- Assess the horizontal (horizontal separation of vegetation to combustion) and vertical (vertical separation between vegetation and combustibles, including other vegetation) vegetative conditions during defensible space design.
- Thin shrubs and trees to eliminate branch intersection and create space between shrubs and trees to reduce risk of fire spread. At a minimum, thinning shrubs and trees should be done bi-annually.
- Prune lowest tree branches to maintain vertical separation between grasses, shrubs and trees.
- Consult the state forester's office, Cooperative Extension Service, fire department or qualified fire management specialist about codes, requirements, and standards related to defensible space. Codes, requirements, and standards normally represent the minimum that should be done. Enhanced protection measures beyond minimum requirements may be needed.
- Maintaining a defensible space requires routine maintenance of vegetation, which includes pruning and removing dead branches and leaves. Vegetation modification must be performed in compliance with local, state, and federal environmental regulations, in addition to local homeowners' association regulations.

[15] https://www.fema.gov/sites/default/files/documents/fema_rsl_marshall-mat-decreasing-risk-of-structure-to-structure-fire-spread-in-a-wildfire_042025.pdf

4. Structural Hardening

This publication guides placement, design, materials specification, and construction of new (and in some cases, existing) buildings. Guidance that is applicable to existing buildings is noted as such. Accessory Dwelling Units (ADUs) or accessory structures may not have been designed to meet wildfire safety measures, possibly presenting risk to surrounding properties for wildfire ignition and spread. All ADUs should be considered when determining wildfire mitigation options. These guidelines, coupled with building codes and wildfire-specific fire codes, should be followed to increase wildfire protection.

Helpful information about building envelope vulnerability is available in the Insurance Institute for Business and Home Safety (IBHS) Primer Series on Wildfire, *Part Two: The Built Environment.* The Wildfire Home Assessment and Checklist on this website is a helpful tool to determine specific risks of a particular building and measures to mitigate those risks.[16] Additionally, the *Society of Fire Protection Engineers (SFPE) and SFPE Foundation WUI Virtual Handbook* provides details on wildfire mitigation.[17]

Many communities enforce regulations on building siting, design, and construction. Although regulations provide minimum standards, property owners are encouraged to exceed minimum standards which may increase a building's wildfire survival probability. Structures that have been designed and constructed to be fire-resistant and incorporate defensible space are less vulnerable to ignition, even though they may still suffer wildfire damage.

4.1. Roofs

Roof assemblies are vulnerable building envelope components. Embers can ignite debris on the roof, roof covering, and roof components. Once a roof is burning, fire commonly spreads to the building interior, resulting in damage or total loss. Key issues for roof systems and recommendations for reducing the chance of ignition and fire spread are detailed in the following sections.

4.1.1. KEY ISSUES

Residential wildfire building survivability is improved by fire-resistant design and fire classification of the roof assembly. The type and arrangement of roof components determine ignition potential and heat transfer to the building's interior. The complexity of the roof's shape also influences ignition potential. A roof with valleys and roof/wall intersections where combustible debris like leaves and needles collect has a greater ignition risk than a simple roof.

[16] https://ibhs.org/wildfire/primer-series-on-wildfire/
[17] https://www.nfpa.org/-/media/Project/Storefront/Catalog/Files/Certification/CWMS/SFPE-WUI-Virtual-Handbook.pdf?rev=42b2c5b469eb484b94eb91505d267b9d&hash=22DE4B6CADADB906B04042D858184A9F

4.1.2. FIRE-RATED ROOF ASSEMBLIES

Roof assemblies fire classifications are listed in accordance with the American Society for Testing and Materials using test method E108 (American Society for Testing and Materials E108, Standard Test Methods for Fire Tests of Roof Coverings). The method includes measurements of the surface spread of flame, the ability of the roof assembly to resist fire penetration from the exterior of the building to the underside of the roof deck, and the potential for the roof covering to develop embers. It should be noted that ASTM E108 test conditions do not replicate actual wildfire conditions; in many cases, actual wildfire exposures are much more severe than test conditions. While ASTM tests for fire conditions, it does not assess the impact of wind on the shingle performance. Asphalt roof shingles are often found displaced on the ground after wildfires, largely due to loss of strength, stiffness, and adhesion under high heat radiation.

Roof assemblies are classified as Class A, B, or C. Class A provides the greatest degree of fire-resistance within a protection range. Some Class A roof assemblies have noncombustible roof coverings (such as clay or concrete tiles and metal panels), while others have combustible coverings (such as low-slope membranes). Roof assemblies that fail to meet Class A, B, or C criteria are not classified.

A roof assembly includes the roof deck, substrate or thermal barrier, insulation, vapor retarder and roof covering. While a roof covering may be classified as Class A, full fire protection is provided by ensuring the entire roof assembly meets this rating.

4.1.3. ADDITIONAL WIND CONSIDERATIONS

Many areas susceptible to wildfire are also subject to other hazards, including high winds. Roof framing must be designed with continuous load path construction that supports full gravity and wind loads corresponding to the site design wind speed, roof height, exposure category, building location, and all required load combinations compliant with the applicable building code. Wood framing members and connections for roofs should be designed to resist design loads per applicable codes and standards. To limit potential wind-driven fire vulnerability, roof systems should be able to resist the uplift forces associated with the local wind speeds specified in the International Building Code (IBC) or International Residential Code (IRC). Refer to the American Wood Council's *2024 Wood Frame Construction Manual (WFCM) for One and Two-Family Dwellings* for more information.[18]

4.1.4. DESIGN CONSIDERATIONS

Design considerations for new and existing roof systems are described in Table 2, and design considerations for roof coverings are described in Table 3.

[18] https://awc.org/publications/2024-wfcm/

Table 2. Design Considerations for Roof Systems

Roof System or Material	Design Considerations
Underlayment	▪ Install a fire-resistant underlayment, such as fiberglass or mineral wool that is continuous to the roof edge and non-corrosive metal flashing at the roof edge.
Roof Mounted Solar Panels	▪ Building integrated photovoltaic (BIPV) systems or rooftop mounted photovoltaic panels (PV) should meet the requirements of the Class A system, NFPA 70, and the wind loads set forth in American Society for Civil Engineers (ASCE) 7-22. ▪ Ballasted PV panels should not be installed in areas subject to high wind due to potential uplift risks or areas that are known to have a history of wind driven wildfire. ▪ Designers should consider specifying solar panels that mount flush to the roof system or are an integral part of the roof system (BIPV) to avoid debris accumulation under the panel. ▪ The design should call for all roof penetrations to be protected with noncombustible caulks, flashing or assemblies. ▪ No additional screening or baffles should be installed, as they may impact a solar panel's ability to maintain a safe temperature.
Roof Mounted Solar Water Heater	▪ If a solar water heater or other solar device is installed, consider where the solar collector mounts flush to the roof. An angled solar collector can accumulate debris.
Gutters	▪ Choose noncombustible gutters or a roof system that incorporates rain chains, metal drip edge and french drains. ▪ Gravel stops should be avoided. ▪ All gutters should be installed with a noncombustible corrosion-resistant screen to prevent the accumulation of debris.
Chimneys	▪ Use ember-resistant stainless steel vent screens and spark arresters where chimneys exist.
Flashing	▪ Where required, use a non-corrosive metal valley flashing continuous to the roof edge. Flashing should be at least 0.019-inch No. 26 gage galvanized sheet installed over one or more layers of mineral-surfaced cap sheet running the full length of the valley. ▪ Flashing should be installed where a roof abuts a wall, such as with a dormer wall, at low points where two roof slopes converge (called valleys), at roof protrusions (such as skylights), and along roof edges (called rakes and eaves).
Geometry	▪ When designing new construction, limit the number of joints, abrupt geometry changes and elevation changes. Joints and elevation changes in a roof, along with eaves and valleys, accumulate debris, increasing roof ignition vulnerability. ▪ Avoid flat or low slope roofs where possible.
Expansion Joints	▪ Use noncombustible materials to construct roof expansion joints.

Roof System or Material	Design Considerations
Edge	▪ A metal drip edge or flashing to protect the roof edge (particularly at all rake and eave edges) should be installed to minimize ember entry to the attic via rain gutters or wind-blown embers impinging on the edge of the roof, as shown in Figure 11.

Table 3. Design Considerations for Roof Coverings

Roof System or Material	Design Considerations
Wood Shakes or Shingles	▪ Fire-retardant treated wood shakes or shingles may meet the Class A rating; however, there is uncertainty around the long-term weathering of fire-retardant wood products in hot humid climates so these materials are not recommended.
Asphalt Shingles	▪ Most new asphalt shingles can meet the requirements for a Class A roof assembly per ASTM E108 or Underwriters Laboratories (UL) 790. It should not be assumed that existing asphalt shingles meet Class A rating. ▪ Asphalt shingle roof coverings should be high wind rated: ASTM D3161 Class F or ASTM D7158 Class G or H. Consider installing asphalt shingles in accordance with *Best Practices for Minimizing Wind and Water Infiltration Damage.*[19]
Metal Shingles and Panels	▪ Many metal shingles and sheets can meet the Class A rating individually and as part of an assembly per ASTM E108 or UL 790. ▪ Use metal roof panels and other roofing products that provide uplift resistance equal to or greater than the design uplift pressure for the roof based on the site design wind speed and exposure category. ▪ Metal roofs in high-wind regions require 3/4-inch, 7/8-inch, or thicker roof decking to support high loads. ▪ Do not install metal roofs adjacent to a mineral cap sheet as there is a risk of corrosion. ▪ Where metal shingles or roofs are installed over a wood deck, install a minimum of 5/8-inch Type X gypsum roof board tested in accordance with ASTM C-1177 over the decking.

[19] https://www.fema.gov/sites/default/files/2020-07/best-practices-minimize-wind-water_hurricane-michael-florida.pdf

Roof System or Material	Design Considerations
Clay or Concrete Tiles	▪ Clay and concrete tiles can meet the requirements for a Class A roof assembly per ASTM E108 or UL 790 and rated for the local wind zones in accordance with the applicable Building or Residential Code. Consider designing for wind in accordance with the *Florida High Wind Concrete and Tile Installation Manual*.[20] ▪ Consider an enhanced underlayment such as mineral surface cap sheet rated for use in a Class A roof assembly. ▪ Install a layer of fiberglass gypsum panelized product between a wood deck and the roof covering. ▪ Ensure that the gaps between the tiles are sealed to prevent embers from accumulating beneath them. ▪ Install bird stops at eaves and fully mortar hips and ridges; these are both recommended to avoid the accumulation of debris under tiles and to keep embers out.

For existing structures with roof assemblies not classified as Class A, the only long-term, reliable way to reduce roof vulnerability to wildfire is to replace the roof. Roof replacement includes removal and replacement of materials above the roof deck. Roof deck replacement may be required to achieve a full Class A fire classification. Where considering repair or replacement of greater than 25% of the roof surface, replacement to meet new construction codes and standards is recommended.

Additional details on roof design can be found in the *Marshall Fire Mitigation Assessment Team: Homeowners Guide to Reducing Risk of Structure Ignition from Wildfire*[21] and the *Maui Wildfires Mitigation Assessment Team Recovery Advisory #3: Designing New Residential Structures to Decrease Wildfire Risk.*[22]

Existing Roof Covering Vulnerabilities: Some roof coverings, such as wood or fiberglass-reinforced asphalt shingles, become more vulnerable to fire as they age. The roof covering should be replaced before deterioration significantly reduces ignition resistance.

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[20] https://www.tileroofing.org/installation-guides.html
[21] https://www.fema.gov/sites/default/files/documents/fema_rsl_marshall-fire-mat-report-p-2320_042025.pdf
[22] https://www.fema.gov/sites/default/files/documents/fema_rsl_p2425_maui-mat-compendium_06052025.pdf

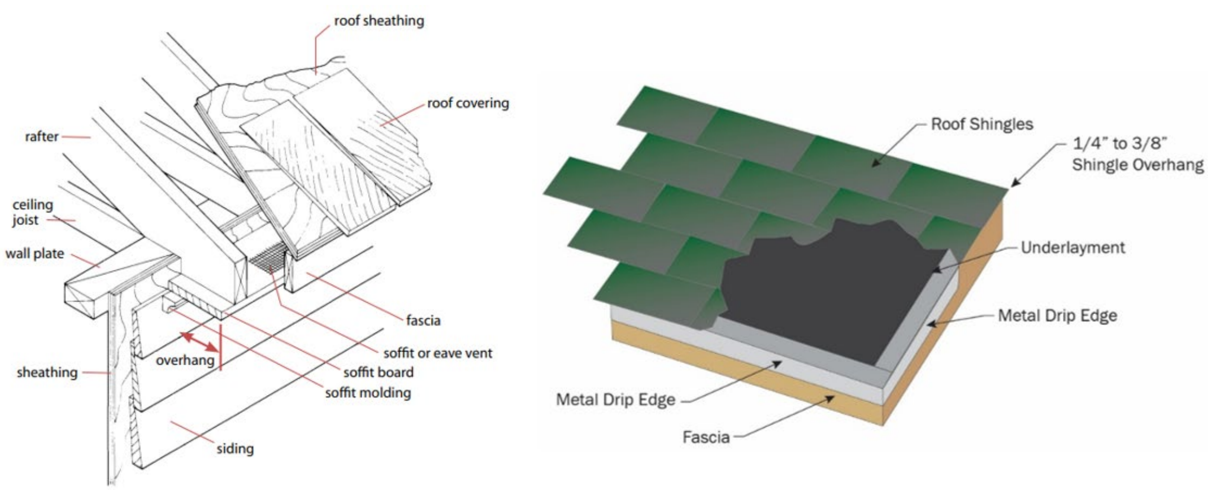

Figure 11. Schematic of the edge of roof detail (left) (adapted from Sherwood and Stroh, 1989). Use of metal drip edge to limit embers from entering gaps at the roof edge, particularly at the fascia where gutters are attached (right) (adapted from the WUI Virtual Handbook for Property Fire Risk Assessment & Mitigation, Society of Fire Protection Engineers).

4.2. Eaves, Roof Overhangs and Soffits

Best practices presented in this section for eaves, overhangs and soffits pertain to both new and existing buildings.

4.2.1. KEY ISSUES

- Typical construction materials for eaves, overhangs, and soffits are not fire-resistant and increase the risk of ignition by embers and hot gases.
- Overhang length plays a critical role in the accumulation of trapped heat, radiation and flame beneath the eaves and soffits. Larger overhangs may increase the susceptibility to ignition and flame spread.
- Windborne embers, convective heat, and radiant heat can be trapped under overhangs, such as eaves and soffits, and in the upper portion of exterior walls. Overhangs and walls constructed of combustible materials can ignite.
- Once an eave, overhang, or soffit has ignited, fire can spread onto the roof, into the attic, or onto and through the exterior wall. Fire can enter the attic space through gaps and openings, potentially igniting the roof assembly.
- Soffits normally have vents as part of the attic ventilation system. Unprotected or inadequately protected vents can allow both fire and embers to enter attics. While most eave vents are typically covered with mesh screens to prevent insects and birds from entering, these screens may not be sufficient for wildfire exposure.

4.2.2. DESIGN CONSIDERATIONS

Design considerations for eaves, overhangs and soffits are outlined in Table 4.

Table 4. Design Considerations for Eaves, Overhangs and Soffits

Roof System Component	Design Considerations
Overhangs	▪ Consider designing the building without overhangs to avoid the fire-related problems associated with soffits to reduce the potential for entrapment of embers and hot gases. ▪ If overhangs are necessary for aesthetics, consider the following options to protect the walls from rainfall or windows from the sun: ○ Protect the exterior side of one-hour fire-resistance rated soffits with noncombustible materials. ○ Use flat, horizontal soffits (see Figure 12) instead of attaching the soffits to sloped joists, which creates sloped soffits. A flat soffit reduces the potential for entrapment of embers and hot gases. ○ Shorten the overhang. ▪ For existing buildings, enclose overhangs with soffits with a minimum one-hour fire-resistance rating to prevent embers and hot gases from contact with joists, rafters or trusses, or the underside of the roof decking. Enclosing overhangs and soffits with 5/8-inch Type X gypsum board typically meets the one-hour fire-resistance rating.
Fascia	▪ Use noncombustible or fire-resistant fascia material (e.g., fire-retardant-treated lumber, fiber-cement board).
Soffits	▪ For existing buildings, evaluate the fire-resistance of existing soffits and replace soffits that are not fire-resistant. Install exterior 5/8-inch fire-resistant gypsum board between existing soffit framing and new soffit material for enhanced fire-resistance. ▪ Consider protecting the exterior side of one-hour fire-rated soffits with noncombustible materials.

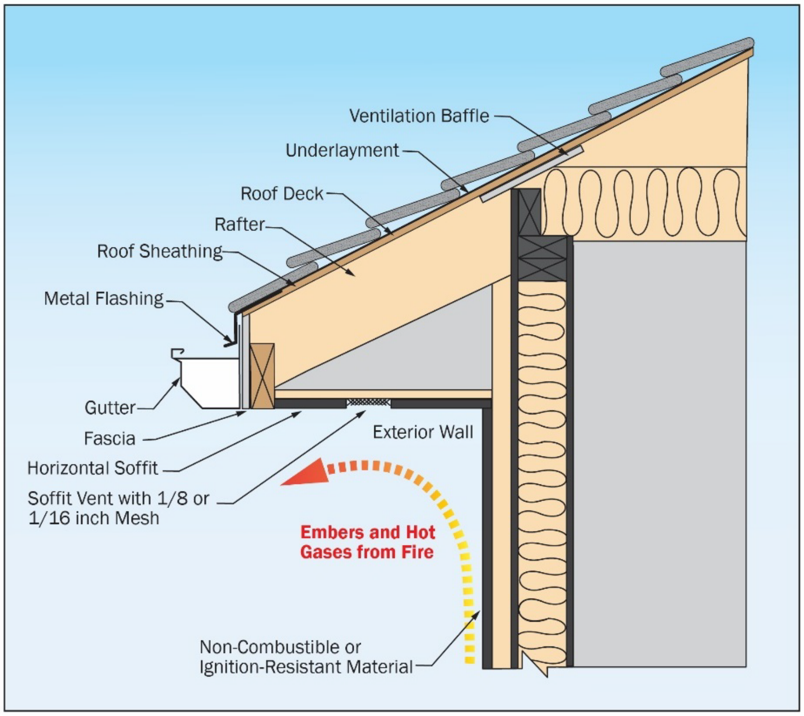

Figure 12. An enclosed overhang with a horizontal soffit.

4.3. Exterior Walls

Exterior walls are susceptible to flames and heat from wildfires. Flames and heat can ignite combustible wall coverings. When exterior walls ignite, fire can spread to other building components such as the roof, soffit, windows, and doors, resulting in substantial damage or total loss of the building. Key issues and design considerations for exterior walls are detailed below.

4.3.1. KEY ISSUES

- Windborne embers are also sources of ignition. Embers can become trapped in cracks in walls, window openings, and door trim boards and ignite combustible materials. Windborne embers can ignite wall coverings.
- Exterior wall fire-resistance depends on construction material type and presence of nearby combustible material. Some construction materials such as vinyl siding do not burn but melt when exposed to high temperatures, allowing fire to reach underlying wall components.

4.3.2. DESIGN CONSIDERATIONS FOR EXTERIOR WALLS

Design considerations for exterior wall components are described in Table 5.

Table 5. Design Considerations for Exterior Walls

Exterior Wall Component	Design Consideration
General	▪ Where the defensible space recommendations cannot be achieved and maintained, at least a one-hour fire-resistant exterior assembly per ASTM E119 or use of applicable local building code fire rating requirements (if higher than a one-hour) is recommended. ▪ For areas within 15 feet of adjacent structures (sheds, combustible fencing or adjacent buildings), combustible storage, or unmanaged vegetation, designers should consider two-hour fire-resistance rated exterior wall feasibility. ▪ Choose products that meet or exceed the 10-minute direct flame exposure test in accordance with ASTM E2707. ▪ Specify the use of noncombustible insulation inside of wall cavities and seal exterior wall openings with fire-resistant caulk.

Cladding	▪ Combustible exterior cladding such as vinyl, wood and polypropylene siding should not be used.
	▪ Wood products should be avoided, even when listed as fire retardant treated wood, should not be used due to uncertainty surrounding the long-term performance of the fire retardant.
	▪ Noncombustible exterior wall covering such as concrete masonry units (CMU blocks), cement board, masonry, three coat stucco is recommended.
	▪ If metal wall coverings are used, install one layer of 5/8-inch type X exterior gypsum board with taped joints underneath house wrap.
	▪ Although vinyl siding is not recommended, install one layer of 5/8-inch type X exterior gypsum board with taped joints underneath house wrap under vinyl siding if used.
	▪ Use noncombustible or fire-resistant material such as fiber-cement for trim boards around doors, windows, eaves, and corners.
	▪ For existing buildings: Replace exterior wall coverings that are combustible, susceptible to melting, or readily transmit heat with one of the previously recommended coverings. Examples of coverings that need to be replaced are wood siding, vinyl siding, metal siding, and an exterior insulation finish system.
	  ○ Before replacing vinyl or metal siding, check whether there is an underlying gypsum board substrate. If so, remedial work may not be needed.
	  ○ Where full remediation of the exterior wall covering may not be feasible, consider keeping the existing covering and covering it with 5/8-inch type X gypsum board and a new noncombustible covering or replacing five feet from the ground with fire resistant exterior wall covering. Metal flashing should be installed at the bottom of the siding for all claddings, including noncombustible.

Caulk	▪ Seal exterior wall openings with fire-resistant caulk.

For residential construction, the minimum requirements for fire-resistance are typically provided in the applicable residential code. See Chapter 3 of the IRC for more details on the minimum requirements for fire-resistance. Additional details are provided in the *FEMA Maui Wildfires: Recovery Advisory #3, Designing New Residential Structures to Decrease Wildfire Risk.*[23]

Examples of prescriptive fire-rated (e.g., one- and two-hour rated) wall-assemblies are provided in Chapter 7 of the 2024 IBC for residential home construction. Refer to the IBC Tables 721.1(2) and 721.2(3) for details and additional examples. This table is not inclusive of all possible methods to achieve a fire-rated wall assembly. While the IRC is the code that is most often utilized for residential design, the IBC provides more comprehensive details on fire resistant design.

> Maintaining and regularly removing combustible debris such as vegetation, wood mulch, leaves and firewood near the exterior walls reduces a building's vulnerability to ignition during a wildfire.

4.4. Vents

Vents help create proper air flow in interior building spaces such as attics and crawl spaces, which helps to reduce moisture and hence prevent moisture-related problems such as mold (Figure 13). Unfortunately, these openings can provide an entry point for embers and hot gases to be blown or pulled into the house, resulting in interior ignition.

Where flood openings (hydrostatic openings) are necessary, the design should be consistent with the National Flood Insurance Program (NFIP), local Residential Building Code, and local Floodplain Management Ordinances and all applicable code and ordinance appendices. Flood opening covers should be noncombustible and open automatically when exposed to floodwaters. Care should be taken to remove any debris accumulation in flood openings. Consider choosing engineered flood openings with a solid metal exterior flap to reduce the chance of debris accumulation, which could ignite upon contact with embers or flames.

[23] https://www.fema.gov/sites/default/files/documents/fema_rsl_p2425_maui-mat-compendium_06052025.pdf

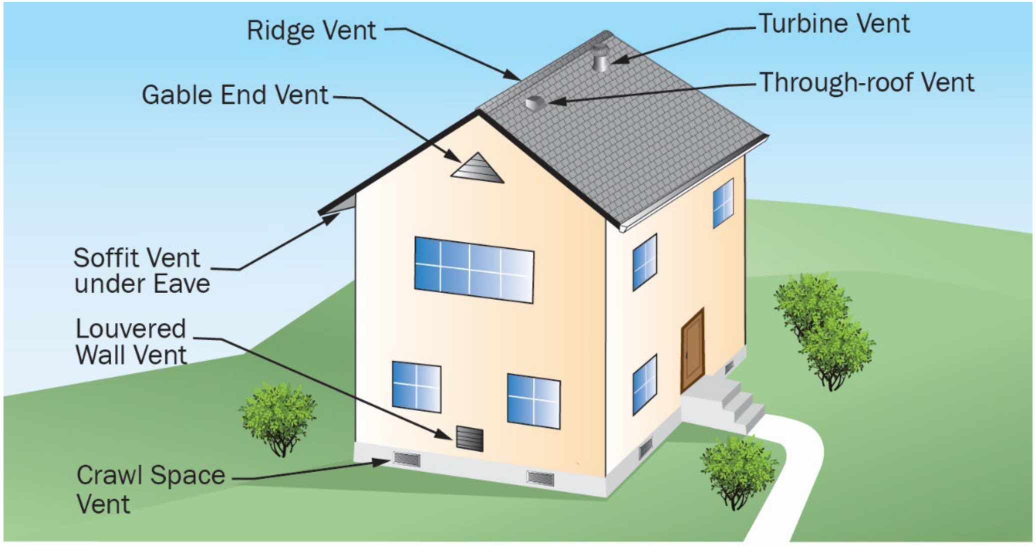

Figure 13. Embers can enter a home through vents.

4.4.1. KEY ISSUES

- Embers, hot gases and direct flame intrusion into vents can lead to ignition of the interior of the building (Figure 14).
- Debris can accumulate at vent openings and ignite during a wildfire.

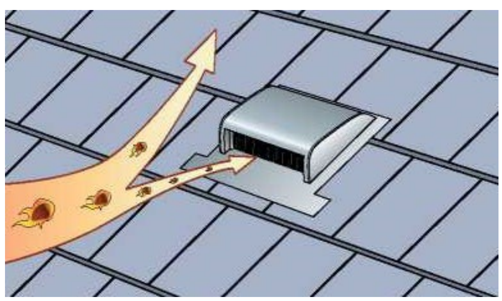

Figure 14. Embers or hot gases can be blown or pulled into vents. Through-roof vents are not recommended.

4.4.2. DESIGN CONSIDERATIONS

For new and existing construction, vents containing corrosive-resistant noncombustible mesh screen with openings less than 1/8-inch can help reduce the possibility of embers entering the house. The following measures can reduce the likelihood of embers and hot gases entering the house through vents. Design considerations for vents are detailed in Table 6.

Table 6. Design Considerations for Vents

Vent System	Design Consideration
All exterior vents	▪ Use fire-resistant caulk in vents to seal around the edges of the vent to prevent fire and ember intrusion between the vent and the exterior wall. ▪ All vents should be noncombustible. Corrosion resistant metal products are recommended for vents and vent flashing. ▪ A piece of a noncombustible mesh screen with openings less than 1/8-inch at the bottom of the roof sheathing at the opening for the vent can prevent ember entry into vents. ▪ Place all vent openings at least 10 feet from other buildings or property lines to avoid ignition from direct flame and hot gases from an adjacent building that has ignited. ▪ Where vents are required, specify the use of ember- and flame-resistant vents. The California Building Code (Chapter 7A) lists vents tested by the California State Fire Marshal or that meet the requirements of ASTM E2886, *Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement*. ▪ For existing construction, replace existing vents with noncombustible flame- and ember-resistant vents. The CAL FIRE Building Materials Listing Program maintains a *WUI Products Handbook* which lists products that meet the State's Building Code requirements for "vents for WUI." Many of these products and materials are appropriate for use outside of California, as are recommendations included in their Low-Cost Retrofit List. ▪ Check the flashing around vents on the roof. Replace missing, loose, or corroded flashing using noncombustible screening materials. Seal using a fire-resistant caulk, noncombustible mortar, or fire-rated expanding foam. ▪ Install shutters over gable-end vents, crawlspace vents, and wall louvers. If the existing wall or soffit is combustible, shutters may not be effective. In this case, installing shutters is practical only when upgrading walls and soffits.
Wall Vents	▪ Replace existing non-fire-rated louvered wall vents for clothes dryers with noncombustible or fire-resistant wall louver vents to minimize the entry of embers from entering through the vent. Louvers should open and close properly.
Ridge Vent	▪ Typical ridge vents are not recommended unless the attic configuration or size requires ridge vents to ventilate the attic effectively. If ridge vents are used, metal vents with internal baffle media are recommended, but there is a risk of the internal baffle material melting and allowing embers entry during wildfire.
Soffit Vent	▪ Typical soffit vents are not highly fire-resistant, but soffits are a necessary element of a vented attic. Soffit vents must be located 10 feet away from property line and constructed with vents approved in accordance with ASTM E2886 to resist against ember and flame intrusion.

Vent System	Design Consideration
Through Roof Vent	▪ Through-roof vents are not recommended. Instead, extend the ductwork to an exterior wall where it can be fitted with a wall louver and shutter. If it is necessary to penetrate the roof, however, install a fire damper in the duct at the plane of the roof assembly.
Gable End Vent	▪ Instead of using ridge vents, specify and install gable-end vents with specially designed metal shutters. A hinged shutter that can be latched in an open or closed position is recommended. Detachable shutters can be used but require prompt homeowner installation during wildfire warnings. Shutters should have a gasket that provides a tight seal between the shutter and gable-end vent. ▪ When gable-end vents are combined with soffit vents, effective attic ventilation can be achieved when the attic space is simple and relatively small, such as a small, gable-roofed house. If the house has a complex roof area or the attic is too large to be effectively ventilated by gable-end vents, ridge vents or through-roof vents should be used.
Crawlspace Vent	▪ Specify and install specially designed metal shutters over crawlspace vent openings. Noncombustible mesh screen with openings less than 1/8-inch should also be installed over the vent opening. A hinged shutter that can be latched in an open or closed position is recommended but will require manual intervention when the threat of wildfire exists.
Flood Vents	▪ Where flood vents/hydrostatic openings are required, use openings that stay closed when not in use but open automatically when exposed to floodwaters. ▪ The design of flood vents should be consistent with the NFIP, the applicable Residential Building Code, Floodplain Management Ordinances and all applicable code and ordinance appendices. Additional information on the NFIP and implementation of the flood vent requirements can be found in the NFIP Technical Bulletins. ▪ Flood opening covers should be noncombustible and open automatically when exposed to floodwaters, as required by the NFIP.[24] Debris should not be allowed to accumulate at flood openings and should be removed promptly. Engineered flood openings with a solid metal exterior flap will reduce debris accumulation, which can ignite upon contact with embers or flames.

[24] https://www.fema.gov/emergency-managers/risk-management/building-science/national-flood-insurance-technical-bulletins

Vent System	Design Consideration
Wall Louvers	▪ Specify and install specially designed metal shutters over wall louvers or specify and install wall louvers that have adjustable tight-fitting blades that can be closed when a wildfire threatens. As an additional conservative measure with either shutters or adjustable blades, specify and install fire dampers within the ducts immediately behind the wall louvers. If sufficiently high heat penetrates beyond the louver, the fire damper will automatically close and prevent high heat from penetrating farther.

Unventilated Attics: The most conservative approach to preventing embers and hot gases from entering attics is to eliminate attic ventilation, but unventilated attics are controversial. Although allowed by the IRC, provided the Code's criteria are met, unventilated attics may not comply with local building codes.

However, when unventilated attics are allowed by the building code or code compliance is not an issue, and when climatic and interior humidity conditions (e.g., no indoor swimming pools) are conducive to an unventilated design, an unventilated attic is a reliable way to prevent embers and hot gases from entering the attic.

4.5. Windows and Skylights

Glazing in homes is typically vulnerable to wildfire. "Glazing" refers to the glass, plastic, or fiberglass-reinforced translucent material in windows, sliding glass doors, door vision panels, and skylights. Key issues and design considerations for windows and skylights are detailed below.

4.5.1. KEY ISSUES

Failed glazing allows easy passage of embers, hot gases, and flame into the interior of the building. Glazing is vulnerable to fire in two ways:

- Flame impingement and radiant heat can be severe enough to melt or break many types of glazing. A single pane of typical residential glass can fail within five minutes of exposure to fire.
- Windborne embers and debris can have sufficient momentum to break many types of glazing.

The frames for windows, sliding glass doors, and skylights are constructed of metal, plastic, wood, or a combination of these materials. Plastic and wooden frames are susceptible to failure from burning or melting. If the frame or sash fails, the glazing may fall out.

4.5.2. DESIGN CONSIDERATIONS

Jalousie and single pane windows have an increased risk of breakage during a fire. Combustible doors or those with non-fire-rated windows can also pose a risk for breakage and ignition.

Recommended glazing includes:

- Laminated glass: Laminated glass provides resistance to windborne embers.
- Tempered glass: Tempered glass is more resistant to heat and flames than laminated glass or annealed glass.
- Low-emissivity (low-e) coating: Glass with low-e coating provides a higher level of resistance to radiant heat than other types of glazing because the coating reflects radiant heat, reducing the probability that the heat will be able to enter the building.
- Proprietary fiberglass-reinforced translucent glazing: This product is available for skylights and walls. The skylight material has a Class A rating.
- Insulated glazing unit (IGU): An IGU consists of two or three panes of glass that are separated by a sealed air space.

The designer should review whether the home is sited in a windborne debris region requiring additional window protection. Windows and doors should meet design requirements for the applicable windborne debris region. Design considerations for window components are outlined in Table 7.

Table 7. Design Considerations for Window Components

Window Component	Design Consideration
General	▪ In existing buildings, Windows and sliding glass doors, including frames, susceptible to wildfire damage should be replaced with the components recommended above and/or protected by shutters. ▪ Door vision panels susceptible to wildfire damage should be replaced with low-emissivity coated tempered glass or proprietary reflective coating, provided the door has sufficient fire-resistance (see Section 4.7) or protected with a noncombustible storm door. ▪ Skylights with plastic glazing should be replaced with one of the recommended types of glazing listed in the glazing section of this table. ▪ Window assemblies with 3/4-hour minimum ratings are effective in all areas at risk of wildfire.
Glazing	▪ Recommended glazing includes laminated glass, tempered glass, low-emissivity coated glass, proprietary fiberglass-reinforced translucent glazing and insulated glazing units. : ▪ Avoid the use of annealed glass, ceramic glass and plastic glazing.
Frames	▪ Frames should be constructed of metal or metal clad wood. ▪ Avoid the use of plastic and wood frames. ▪ Metal cladding on metal clad-wood frames may become distorted during wildfire exposure and require replacement.

Window Component	Design Consideration
Exterior Window Shutters	▪ Exterior window shutters can provide protection for windows and sliding glass doors during a wildfire as shown in Figure 15. Solid metal shutters are unlikely to ignite or melt so are recommended over wooden or plastic shutters. For enhanced protection, an insulated metal shutter can be designed and fabricated. If the building is in a windborne debris region within a hurricane-prone region, the shutter should meet the windborne debris criteria in ASCE 7-22 and the fire performance criteria in 2024 IBC Section 716.2.1. ▪ Temporary shutters are effective only if the homeowner has sufficient time to put the shutters into place.

4.5.3. FIRE-RATED ASSEMBLIES

If a fire-rated wall is specified, windows and sliding glass doors consistent with the wall rating specifications are recommended. For example, a window with a 1.5-hour rating is intended to be used in a wall with a two-hour rating, and a door with a 3/4-hour rating is intended to be used in a wall with a one-hour rating. However, a window with a higher fire rating may be used. See Section 4.3 for information about fire-rated walls.

Figure 15. This metal shutter has top and bottom tracks that are permanently anchored to the wall (FEMA 577).

4.6. Exterior Doors

Types of exterior doors include solid entrance doors, entrance doors with glass vision panels, sliding glass doors, storm doors, screen doors, garage doors, and cellar doors.

4.6.1. KEY ISSUES

- Exterior doors are subject to the same types of wildfire exposure as exterior walls. Exterior doors are typically much thinner and less fire-resistant than exterior walls.
- Flames and hot gases can ignite combustible materials in a door and door frame.
- Flames and hot gases can penetrate openings between the door and frame and between the door and threshold (or floor if there is no threshold).

- Embers can become lodged in openings between the door and frame and between the door and threshold (or floor). Embers can also be blown through doors into the building.
- Flames, convective or radiant heat, airborne embers and windborne debris can break glass in a door (Figure 16).

Figure 16. Sources of Exterior Door Wildfire Vulnerability.

4.6.2. DESIGN CONSIDERATIONS

Combustible doors are susceptible to ignition and those with non-fire-rated windows are at risk of breakage. Recommended strategies for doors are described in Table 8.

Table 8. Design Considerations for Doors

System	Design Consideration
General	▪ If a fire-rated exterior wall is specified, the door and frame fire rating should be at least 75-percent of the wall rating with fire-rated hardware. ▪ To avoid embers and hot gases penetrating the interior of the building between the door and the door frame, use adjustable weatherstripping on the interior side of the door frame with an automatic door bottom or threshold weatherstripping. The weatherstripping and door bottom should be rated in accordance with UL Standard 10C.

System	Design Consideration
	▪ Exterior trim that covers the opening between the door frame and exterior wall should be comprised of noncombustible or ignition-resistant material such as fire-retardant-treated wood or fiber-cement board. ▪ For existing buildings: Add weatherstripping to doors, as described above. ▪ Replace vision panels and glazed side panels adjacent to doors in doors, if necessary, as described in Section 4.6. ▪ Ensure the door frame's perimeter is sealed providing no openings that could allow ember intrusion and debris accumulation. ▪ Metal and metal-clad door frames can transmit heat during a fire which can ignite the surrounding exterior wall if the wall is not constructed to fire-resistant standards. For more information, see Section 4.3. ▪ Avoid placing combustible items, such as doormats and plants, adjacent to doors, windows and other entry ways.
Entry Doors	▪ Consider choosing an entry door without glass, as the glass may break during a fire event. ▪ Replace wooden hollow core egress/ingress doors with solid doors with the recommended fire-resistance rating. ▪ Doors meeting a minimum 20-minute fire-resistance rating are recommended. It is also recommended to use metal door jams, specifically the bottom plate. Embers can accumulate at this interface. ▪ Where fire-resistance rating information is not available, steel doors or solid core wood doors of at least 1.75-inch thick are recommended.
Sliding and French Doors	▪ Where possible, reduce the use of glass sliding and French doors as they are vulnerable to breakage. If glass sliding or French doors are necessary, choose doors that contain double paneled tempered glass. ▪ Place glass sliding and French doors on the side of the house with the least vulnerability to fire exposure from vegetation, adjacent structures or other flammable material.
Garage Doors	▪ Garage doors typically made of wood, aluminum, or steel are insulated or non-insulated. Unlike standard egress/ingress doors, garage doors are not normally rated for fire-resistance. To protect the garage door and entire building, follow the following best practices, as shown in Figure 17. ○ Specify and install insulated, metal garage doors without windows. ○ To avoid embers and hot gases penetrating the garage, install weatherstripping that has been rated per UL Standard 10C around the entire garage door. ▪ Where feasible, garage doors meeting a minimum of 20-minute fire-resistance rating are recommended. ▪ Add metal flashing or kick plate at the base of the exterior door for the first six inches to reduce the possibility of ember ignition.

System	Design Consideration
	▪ Consider finishing the interior of the garage with drywall to reduce the threat of ignition from the combustible studs. ▪ In areas with high winds, consider reinforcing wind rated garage doors with girts and strengthening the wheel tracks. Look for doors that meet or have been tested in accordance with one of these standards: ○ ASTM E330 ○ ANSI/DASMA 108 ○ Florida Building Code TAS 202 ▪ Add a battery back-up or manual option to the garage door motor so that the garage can be opened or closed if power is interrupted.

4.6.3. EXTERIOR DOOR CHARACTERISTICS AND RATINGS

Solid exterior doors are typically made of wood or metal. Doors with a solid, noncombustible mineral core are classified as fire-rated doors and are rated by the length of time they can resist fire (UL Standard 10C) (UL, 1998). UL classifications for interior and exterior fire-rated doors and their frames range from 3-hour to 20-minute ratings. Exterior fire-rated doors are available with a rating of 3/4- or 1.5-hour.

The fire rating for doors is intended to equal three-fourths of the fire rating of the surrounding wall. For example, a door with a 1.5-hour rating is intended for use in a wall with a two-hour rating, and a door with a 3/4-hour rating is designed for use in a one-hour rating wall. However, doors with higher fire ratings are always recommended.

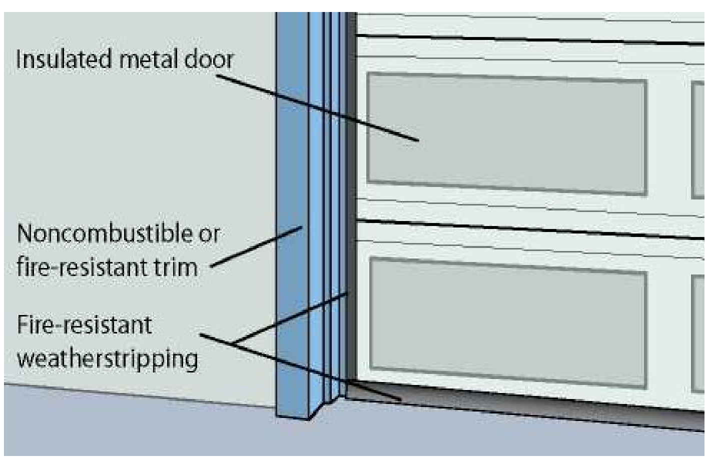

Figure 17. A garage door with noncombustible and fire-resistant components.

4.7. Foundations

Depending on the foundation type, fire can propagate from the exterior of the home to the interior increasing the chance of loss. The following sections detail the key issues and design considerations for foundations.

Flood-prone Foundation Considerations: If the building is in a floodplain, as designated by the NFIP, criteria set forth in Title 44 Code of Federal Regulations Part 60 should be followed.

4.7.1. KEY ISSUES

<u>Closed Foundations</u>

- Direct flame, embers, or hot gases can enter through crawlspace vents or breached basement windows.
- The crawlspace wall or wall covering or the exposed portion of the basement wall or wall covering can be ignited by direct flame, embers, or hot gases. Once the wall is ignited, the fire can penetrate the crawlspace or basement and climb up the exterior wall.
- Combustible items stored in basements or crawlspaces, such as household goods in cardboard boxes, can become fuel in a fire.
- Mulch and other combustible landscaping materials surrounding the foundation, especially in front of basement windows, can lead to fire intrusion.

<u>Open Foundations</u>

- The underside of the first floor can be ignited by direct flame, embers, or hot gases. Timber piles and piers are normally thick enough to resist fire, but they can transfer fire to underfloor areas where combustible floor deck, and beams are located.
- Wood lattice screens can be ignited by direct flame, embers, or hot gases. Lattice screens often trap combustible debris such as leaves and paper, increasing the potential for ignition. Ignition of a lattice screen can spread to the underside of the first floor.
- Walls and wall coverings around enclosures such as elevator shafts and storage areas can be ignited by embers or hot gases, igniting the underside of the first floor.
- Combustible debris or storage items (such as firewood or gas in a container) in an open foundation can be ignited, leading to ignition of the underside of the first floor.
- Skirting around the perimeter of manufactured homes can be ignited, leading to ignition of the underside of the floor and spread of a fire up the exterior wall.

4.7.2. DESIGN CONSIDERATIONS

Some foundations are susceptible to ignition and fire spread. Recommended strategies to reduce the chance of ignition and fire spread for foundations are in Table 9.

Table 9. Design Considerations for Homes with Open Foundations and Elevated Homes

Vulnerability	Design Consideration
Storage	▪ Storage of combustible goods and other objects under the elevated portion of a home is not recommended. ▪ Where storage is provided, limit storage to noncombustible materials. ▪ Do not store vehicles, lawnmowers or other fuel-fired devices under homes.
Fire-Resistance Rated Construction	▪ All designs should follow the applicable Residential Code and the adopted Fire Code, NFPA 1, and FEMA best practices. ▪ It is recommended that a minimum one-hour fire-resistance is provided between the floor of the lowest level and the ceiling of the elevated portion. The purpose of the assembly is to prevent fire from a vehicle or flammable/combustible material from spreading to the living space.
Foundation	▪ Elevated homes are often built on wood piles and piers. Piles and piers should be constructed from noncombustible materials, such as concrete or CMU block. ▪ Consideration should be taken to protect the steel reinforcement from corrosion. ▪ Where concrete piles or CMU piers are not provided, the design should include wrapping the timber piles/piers with a one-hour fire-resistant jacket. In flood zones, the jacket should also be flood resistant.
Open Foundation	To avoid ignition of first-floor framing members (joists) and floor decking, the underside of framing should be sheathed as follows: ▪ Attach 5/8-inch-thick exterior type X gypsum board to the underside of joists. For energy conservation, install batt insulation between the joists. ▪ Attach fire-retardant-treated plywood, fiber-cement panels, or metal siding panels over gypsum board. ▪ Do not install lattice screens. If screens are necessary, chain-link fencing with metal privacy slats should be used instead of wood. ▪ For existing buildings: If the first-floor timber framing members are less than three inches thick (nominal) or if the floor decking is combustible, sheath the underside of the framing as described above. ▪ Evaluate floor beams and joists that are constructed of steel (not common in residential construction). Depending on a variety of conditions, it may be prudent to sheath the underside of the framing as previously described or protect the steel with suitable fireproofing. ▪ Remove existing lattice screens or replace them with chain-link fencing with metal privacy slats. ▪ The homeowner should periodically remove combustible debris under buildings with open foundations.

Vulnerability	Design Consideration
	▪ In areas where dry rot is a concern, fire-retardant-treated plywood can be attached over the gypsum board on the underside of the floor joists.
Closed Foundation	▪ See Section 4.3 for best practices on exterior walls and wall coverings. ▪ See Section 4.4 for best practices on crawlspace vents. ▪ See Section 4.5 for best practices on windows.
Enclosing Elevated Space	▪ When enclosing the space under a home in a special flood hazard area, make sure that all requirements are met for homes in flood-prone regions (breakaway walls, flood damage-resistant materials, etc.). ▪ Any enclosure material should be flood- and corrosion-resistant, noncombustible in nature and constructed from the bottom of the elevated floor to the ground. If non-solid material (individual board) is used for the enclosure, the space between each board should not exceed 1/8-inch. A corrosion resistant mesh of no more than 1/8-inch could be used.

In addition to designing for wildfire, all seismic, flood and wind loads should be considered in any design.

4.8. Decks and Other Attached Structures

Decks and other attached structures are a key vulnerability for any home and structure. The following sections detail the key issues and design considerations for decks and attached structures.

4.8.1. KEY ISSUES

- In traditional construction, boards that form the walking surface of structures are usually spaced about 1/8-inch apart. Gaps between the planks and between the deck, porch, or balcony and the house will trap combustible debris and embers. These structures are often elevated, which makes them susceptible to wildfire from both above and below.
- The upper surface can ignite from ember exposure, while the under-surface can ignite from flame exposure.
- Decks are often built at the top of a slope (where wildfire risk is greatest) increasing deck ignition risk. Deck design and orientation is important for wildfire risk reduction (see Chapter 2).
- Decks constructed of dimensional lumber are combustible and subject to quick ignition.
- Embers and hot gases can become lodged or trapped under decks and other attached structures, and in the gaps between board decking. Embers can also settle against exterior walls and accumulate at railing edges, increasing ignition risk.

4.8.2. DESIGN CONSIDERATIONS

Best practices are applicable to deck, balcony, porch, stair, and ramp construction. These structures are also a source of wildfire fuel. Ignition of decks or attached structures can lead to ignition of the building. Suggested mitigation measures and best practices to enhance wildfire resistance for attached structures are outlined in Table 10.

Table 10. Best Practices to Enhance Wildfire Resistance for Attached Structures

Component	Best Practice
General	▪ Install a fire-rated soffit at the underside of balconies, decks, stair landings, or ramps when skirting is not installed. ▪ Poured concrete decks are also fire-resistant.
Siting	▪ Decks and other attached structures should be oriented to avoid exposure to likely wildfire pathways. These structures should not be built close to heavily vegetated areas and steep slopes, gullies, canyons, saddles, ridge tops, and narrow mountain passes (see Chapter 2).
Underfloor area enclosure	▪ For elevated decks less than four feet from the ground, enclose open spaces beneath decks and stairways with a noncombustible and corrosion resistant mesh of at least 1/8-inch. Enclosures should extend the full height of the structure from the ground surface. ▪ Where underfloor area is fully enclosed to the ground with exterior walls, to prevent moisture build-up that can accelerate decay, ember and flame-resistant vents should be installed to reduce moisture degradation in the under-deck area (e.g., corrosion of metal fasteners and wood fungal decay). Cover exposed floor framing at the underside of attached structures with fire-resistant soffits such as fiber-cement panels. The soffit should have weep holes with a maximum diameter of 1/4-inch to allow drainage. ▪ For columns, use a minimum six-inch x six-inch timber *or* concrete block or steel. If timber columns are chosen, provide noncombustible, corrosion-resistant flashing for a minimum of two feet from the ground. ▪ For floor joists and beams, use heavy timbers, three- to four-inch fire-retardant-treated wood, *or* concrete block or steel framing. ▪ Plastic or composite decking in wildfire-prone areas is not recommended. ▪ Isolate attached structures from surrounding vegetation using noncombustible material such as gravel, brick, or concrete pavers to prevent vegetation growth and fuel reduction (see Figure 18).
Decking	▪ See Figure 19. ▪ Composite decking should be used only if the manufacturer provides documentation that the materials are noncombustible. It is recommended that combustible walking surfaces be replaced with

Component	Best Practice
	noncombustible, ignition resistant materials or fire-retardant treated wood. ▪ Some decking material such as metal can be installed without gaps, decreasing the circulation of oxygen that feeds the fire. Gaps should be 1/8-inch or less between new surfaces. Gaps greater than 1/8-inch can increase the accumulation of combustible debris beneath the deck and allow embers to pass through, raising the risk of ignition. ▪ For existing buildings, if existing decking will not be completely replaced, combustible deck boards parallel to and within one foot of the adjacent exterior wall of the house should be replaced with noncombustible decking. ▪ If the existing deck is built with combustible materials and the surface decking is being replaced, apply foil-faced self-adhering bitumen tape along the length and tops of the joists supporting the deck and allow only a 1/8-inch gap between deck boards, which will increase the ember resistance. Position the tape on each side of the joist near the top where deck boards are attached. ▪ Install flashing on ledger boards that are attached without gaps, to create a barrier to embers and to prevent water penetration.
Framing	▪ For existing structures, if the existing deck frame is structurally sufficient, replacement of deck boards with noncombustible material, such as aluminum, steel, autoclaved aerated concrete, tile or fire-retardant treated wood will increase fire resiliency. ▪ If existing siding is combustible, replace the bottom two to three courses of siding with noncombustible siding (Figure 20). If this is not feasible, install metal flashing extending 18 inches from the top of the deck over the existing siding to provide fire-resistance. Tuck the top of the flashing behind the siding to prevent water seepage.
Railing	▪ Replace combustible railings with noncombustible railings. ▪ For railings, use minimum three-inch fire-retardant-treated lumber *or* metal, cables, or tempered glass.
Stairs	▪ For decking and stair treads: Use exterior three-inch fire-retardant-treated lumber (minimum), or brick or concrete pavers and a suitable drainage mat over wood decking, or metal grates.

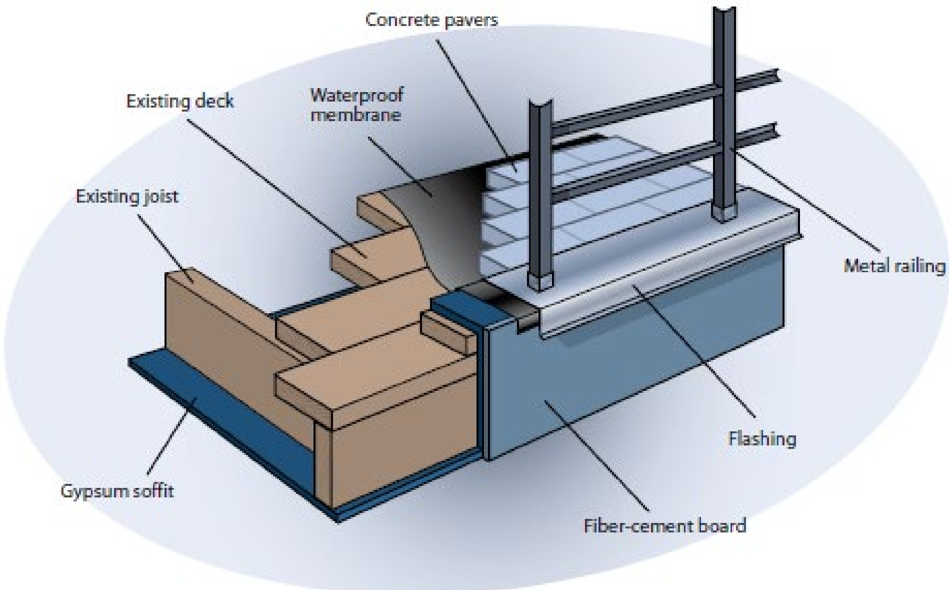

Figure 18. Concrete pavers over an existing deck.

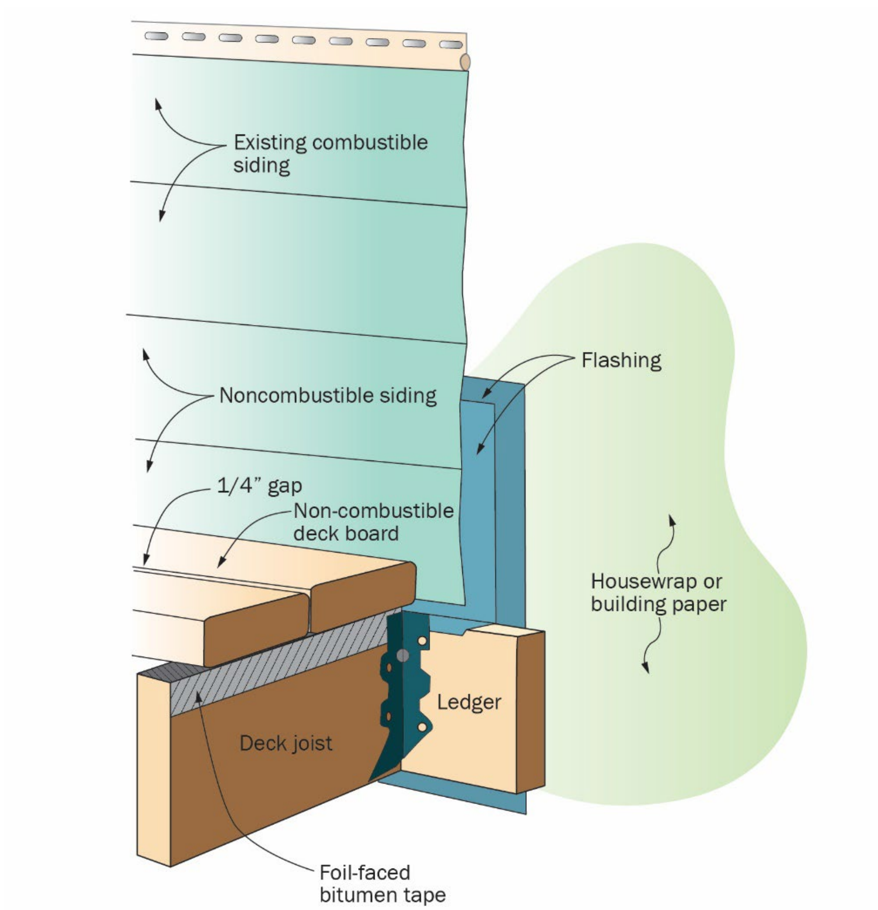

Figure 19. Replacing two to three courses/rows of combustible materials with noncombustible materials where a deck is adjacent to the residence will help protect against ember ignition.

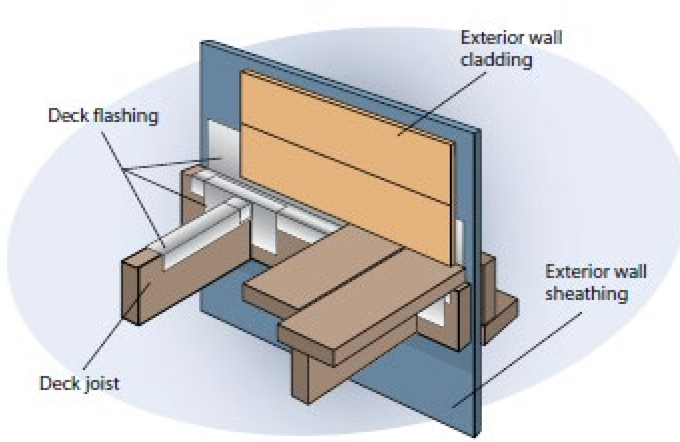

Figure 20. Deck flashing.

See Section 4.11 for related maintenance considerations.

4.9. Landscape Fences and Walls

This section provides best practices about landscape fencing and walls attached to or near buildings in wildfire zones to reduce the potential for damage. Fences are often constructed perpendicular to the home and extending to property lines. They can be built from a variety of materials following many different designs. Soft woods such as cedar and redwood are often selected for aesthetics and installation and maintenance ease; however, these woods ignite easily when exposed to radiant heat or embers. Hardwoods are more ignition-resistant than softwoods but are still combustible. Masonry, concrete, stone, and metal landscape fence and wall materials are fire-resistant.

Regardless of fence material, vegetative debris can accumulate along fences, providing an additional source of fuel that increases risk of ignition. Debris and embers can become trapped between slats in fences, resulting in ignition. In areas susceptible to wildfires, fences built of combustible material can be a source of fuel “wicking” fire toward the house.

4.9.1. KEY ISSUES

Common post-and-board wood fences can become wildfire fuel, especially when the fence has deteriorated. Wood fencing can also collect embers during wildfires and act as a horizontal ladder fuel as the fire moves along the fence toward combustible vegetation, debris and structures (see Figure 21). Once ignited, fences or walls built of combustible materials attached to or near a building can ignite the building through radiant heat or direct flame contact.

Figure 21. The fence that was attached to the home ignited, causing fire spread to the home.

4.9.2. DESIGN CONSIDERATIONS

Walls and fences should be built of noncombustible material, described in Figure 22. Fences and walls vary in shape, size, and construction materials, providing varied wildfire resistance. Typical fence and wall materials are wood, plastic, composite, metal, wire, concrete, stone, and masonry. Wood is the most combustible, while concrete, stone, and masonry are noncombustible.

- **Wood.** Wood fences and components are combustible and provide no fire-resistance. Softwoods such as pine treated with preservatives should be avoided if the fence is attached to the building.

- **Plastic.** Plastic fences can melt or distort during wildfires.

- **Metal.** Metal fences are more fire-resistant than wood and plastic fences. Barbed wire, hog wire, and chain link fences do not affect fire spread. However, if combustible materials have accumulated in or around the fence or the fence contains combustible materials such as wooden posts, the fence can act as a horizontal ladder fuel when fire travels along the fence toward the main building.

- **Concrete, stone, or masonry.** Concrete, stone, and masonry fences and walls are noncombustible and can provide a barrier to wildfire by deflecting flames away from a building, but the passage of airborne embers will not be significantly altered. Concrete, stone and masonry are the most effective fence and wall material for wildfire resilience.

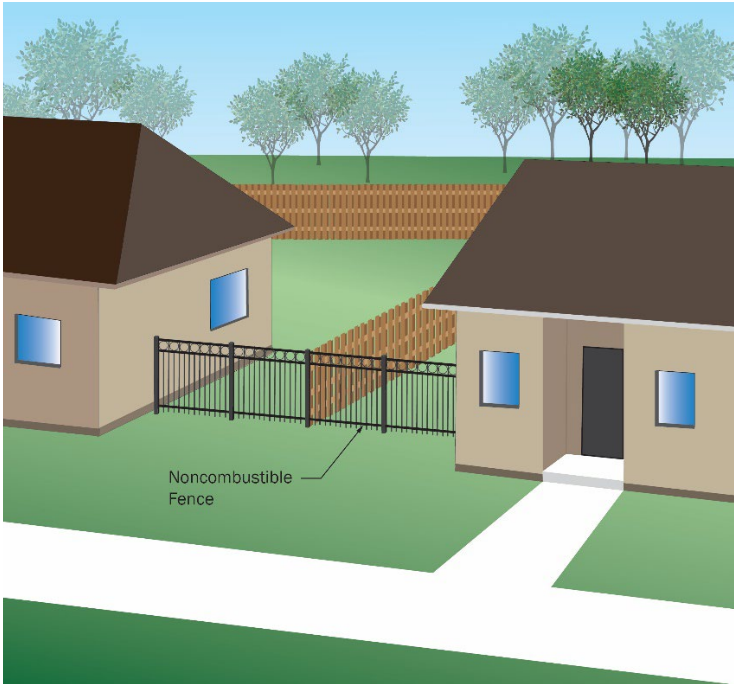

Figure 22. At least the first five feet of fencing adjacent to structures should be noncombustible. However, for best protection, ensure that all fencing is noncombustible.

Combustible fencing and walls should not be attached to buildings. If fences and walls are attached to buildings, combustible components should be at least 10 feet from the building or building overhangs, whichever is closer, to prevent heat and flames from igniting the building. Additional design considerations for landscape fences and walls are described in Table 11.

Table 11. Design Considerations for Landscape Fences and Walls

Vulnerability	Design Consideration
Landscape Fences and Walls	▪ Combustible fences along both sides of property lines should be avoided, as fire intensity and the spread of the fire is intensified by dual combustible fences. ▪ Combustible vegetation should be at least five feet away from combustible fences. Ignition-resistant materials such as stone near potentially combustible fences are recommended. See Marshall Fire Mitigation Assessment Team document *Homeowner's Guide to Defensible Space*[25] for additional information. ▪ Avoid fences with gaps, such as wooden slat fences, since embers can become trapped in the gaps and ignite the fence.

[25] https://www.fema.gov/sites/default/files/documents/fema_rsl_marshall-mat-homeowners-guide-to-reducing-wildfire-risk-through-defensible-space_042025.pdf

See Section 4.11 for related maintenance considerations.

A Note About Residential Sprinklers

Interior fire sprinklers can detect fire quickly, activate automatically and have shown to be an effective mechanism to reduce the risk of fire spread in the residential setting. However, standards such as NFPA 13D, *Standard for the Installation of Sprinkler Systems in One-and Two-Family Dwellings and Manufactured Homes*, do not directly cover wildfire protection. The *2024 International Wildland Urban Interface Code (*IWUIC) requires an approved automatic sprinkler system to be installed in all occupancies in new buildings in accordance with nationally recognized standards. Limited data exists to assess the efficacy of interior sprinklers for wildfire defense where multiple ignition sources may be present, substantial fire is penetrating the home from the exterior or where water may be limited. It is recommended that a homeowner follow their local codes and standards when choosing and designing an interior sprinkler system.

Exterior sprinkler heads are typically designed to saturate a full building, thus reducing the probability of ignition. While exterior sprinklers have anecdotally shown to reduce chance of ignition by pre-wetting the building or quenching embers, the technology is relatively new and there is limited published research on the efficacy of these systems. In a controlled environment, the external sprinkler systems have been proven effective. However, in a real-world scenario with increased winds, high temperatures and limited water supply, the level of success of these systems is unclear. Additionally, technical guidance on the design and implementation of an exterior sprinkler system is not available. No standardized test methods currently exist for assessing the effectiveness nor are there minimal performance requirements for such a system.

While residential sprinklers may prove effective in reducing the risk of ignition and fire spread in a home, they should never replace the mitigation strategies presented in this document including defensive space, hardening and ongoing maintenance.

4.10. Utilities and Exterior Equipment

This section provides measures to protect utilities and exterior equipment from wildfire. Best practices pertain to both new and existing buildings.

Utilities that penetrate buildings can decrease building wildfire resistance. Exterior equipment, such as solar panels and satellite dishes, can be vulnerable to damage from fire's high temperatures. Electrical equipment and natural/propane gas lines and components are particularly vulnerable to wildfire damage.

In most homes and buildings, electricity is delivered through above ground conductors and drop lines or through underground cables. Power is then provided to exterior equipment by cables connected to equipment inside the home.

Many residences feature pressurized gas (propane, butane, or natural gas) or liquid fuel (fuel oil or kerosene) for heating, hot water, and cooking. Propane and butane are stored in pressurized vessels. Natural gas is delivered through pressurized pipes connected to the home. Liquid fuel is delivered by gravity from nearby storage tanks.

4.10.1. KEY ISSUES

<u>General</u>

- Exterior equipment often contains combustible components that increase equipment and building ignition risk.
- Most exterior equipment requires building envelope penetration for ducting and conduit (see Figure 23). The openings can allow heat, hot gases, and embers to enter the building, igniting interior combustible materials.
- Combustible debris can collect around exterior equipment, increasing the probability of ignition.

Figure 23. The gap around utility penetrations such as this one should be sealed with a fire-resistant material.

<u>Electrical Utility Equipment</u>

- Wildfires can affect power transmission by conduction, convection, direct flame contact, and heavy smoke. Wildfire can damage power poles and power lines or cause short circuits.
- Power surges and outages caused by wind and fire can damage electrically powered equipment in buildings that are miles away.
- As with any electrical power supply system, water well power supplies are vulnerable to wildfire damage. Water well systems are essential to domestic users as well as for fire protection and suppression.
- Roof-mounted equipment is vulnerable to wildfire.

<u>Fuel-related Utility Equipment</u>

- Exposed, combustible utility equipment, including delivery lines, are vulnerable to wildfire. For example, gas meters are vulnerable to wildfire damage if pipe connections include rubberized gaskets.
- Pressurized and liquid fuels are flammable and explosive.
- Venting under pressure may cause significant damage or destruction of a building, depending on the location of the fuel container. Venting fuel is flammable and may ignite nearby combustibles.

4.10.2. DESIGN CONSIDERATIONS

Table 11 details design considerations for fuel and exterior equipment.

Table 12. Design Considerations for Fuel and Exterior Equipment

Equipment.	Design Considerations
General	▪ Install utility and equipment connections underground, including all building entry points. ▪ If a utility or equipment connection cannot be installed below grade, gaps and penetrations in exterior walls and roofs should be sealed with fire-resistant caulk, mortar, or fire-rated expanding foam. Large gaps should be filled with intumescent or fire-protective sheets or pillows. Fire-resistant wrap may be used around ventilation features that are built into and penetrate exterior walls, such as air conditioners.
Electrical Utilities and Equipment	▪ Power cables and other wiring should be shielded with noncombustible or fire-resistant materials to protect the cables and wiring from convection, radiation, and conduction heat, and direct flame contact. ▪ Use noncombustible or fire-resistant materials for mounting systems of roof-mounted equipment. ▪ Install Class A rated solar cell systems for the greatest wildfire resistance. Solar cell systems are rated under the same conditions as roofing assemblies and are available with Class A and Class C ratings (see Section 4.1).
Fuel-related	▪ Bury or shield fuel lines to protect them from radiation, conduction heat, and direct flame contact. ▪ Bury pressurized storage vessels underground (see Figure 24). ▪ If possible, locate fuel tanks 30 feet from the home, building or other combustibles, away from downhill slopes, and enclose behind a noncombustible masonry wall. ▪ Shield gas meters from heated air and gases, convection and radiant heat, and direct flame contact using noncombustible materials such as masonry or concrete.

Equipment.	Design Considerations
	▪ Ensure pressurized storage tanks have a pressure relief valve. As the outside temperature rises in a wildfire, the pressure inside the tank can increase. When the pressure setting is exceeded, the valve will open and relieve the pressure, preventing an explosion. Mind the direction of the vent such that if venting occurs, it is not in the direction of combustibles. ▪ Owners or occupants should know the location of the shutoff to the gas supply prior to the wildfire. During a wildfire, shut off the gas supply.

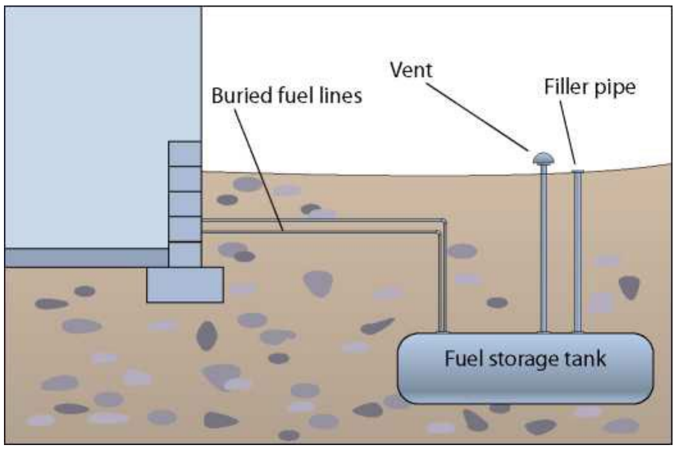

Figure 24. Buried fuel storage tank.

4.10.3. OTHER CONSIDERATIONS

- Fire-resistant sealants and noncombustible mortar must be removed and replaced each time a cable or pipe is reinstalled.
- Consider locating utilities and exterior equipment such as electric water pumps and fuel tanks within the defensible space area (see Chapter 3).

4.11. Maintenance

Building owners should perform regular maintenance on homes and buildings to protect against wildfire. There are several ways owners can reduce the likelihood of embers and hot gas from entering structures:

- Regularly remove vegetation and other debris from roofs, gutters, joints, where the foundation meets the ground surface, and along fences. Debris is a combustible fuel easily ignited by embers and often found directly on or next to the house, which increases the chances of home ignition.
- Clean vents periodically so that each vent can perform its moisture management function properly. Remove accumulated debris from vent openings, vent screens, and louver blades.

- Do not store flammable materials in attics, on or under decks, under porches, or in crawl spaces.
- Remove vegetation near vents, exterior stairs, overhanging roofs and balconies, fences, and other places within five feet of the house (see the Marshall Fire Mitigation Assessment Team document *Homeowner's Guide to Reducing Wildfire Risk Through Defensible Space* for additional information).
- Bird stops should be inspected annually to ensure that they remain in position.
- Periodically remove combustible debris under buildings with open foundations.
- Do not store combustible items such as gas and firewood under buildings with open foundations.
- To minimize the possibility that embers and hot gas will be pulled into the home during a wildfire, the HVAC system (including exhaust fans), should be turned off. Attic exhaust fans should also be turned off. Attic exhaust fans controlled by a thermostat may need to be deactivated by tripping the circuit breaker.
- Grass height should be maintained so that it is no taller than four inches.
- Trim trees to keep branches and canopy 10 feet away from the home and its roof, chimneys, and stovepipes. Remove all tree branches for the first six feet above the ground.
- Store trash and recycling bins at least five feet from the home in noncombustible bins.
- Provide an irrigation system for plants and trees where possible. Review local water conservation policies.
- Replace missing, loose, or corroded flashing with noncombustible corrosion-resistant materials.
- Regularly check for any loose or missing shingles or roof tiles, and repair or replace them to help prevent trapped embers.
- Deteriorated attached structure components should be replaced prior to fire-resistance loss.
- Decks enclosed with fire-resistant skirting must be vented for moisture control.
- While vegetation is not recommended to be planted within 5 feet of the fence, if vegetation does exist next to a fence or wall, it should be fire-resistant and regularly trimmed. Unmanaged combustible vegetation close to fences and walls can increase the risk of fence ignition, especially if the fence is wood. For more information on defensible space, see Chapter 3.
- Consider the use of rock mulch or gravel around fences to reduce the need for ongoing maintenance.

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American Wood Council. (2024). Wood Frame Construction Manual (WFCM) for One and Two-Family Dwellings. https://awc.org/publications/2024-wfcm/

CAL FIRE Building Materials Listing Program: https://osfm.fire.ca.gov/what-we-do/fire-engineering-and-investigations/building-materials-listing

FEMA's Marshall Fire Mitigation Assessment Team:

- Homeowner's Guide to Risk Reduction and Remediation of Residential Smoke Damage: https://www.fema.gov/sites/default/files/documents/fema_marshall-fire-mat-homeowners-guide-risk-reduction-remediation-residential-smoke-damage.pdf

- Homeowner's Guide to Reducing Risk of Structure Ignition from Wildfire: https://www.fema.gov/sites/default/files/documents/fema_marshall-fire-mat-homeowners-guide-reducing-risk-structure-ignition.pdf

- Homeowner's Guide to Reducing Wildfire Risk Through Defensible Space: https://www.fema.gov/sites/default/files/documents/fema_marshall-fire-mat-homeowners-guide-defensible-space.pdf

- Decreasing Risk of Structure-to-Structure Fire Spread in a Wildfire: https://www.fema.gov/sites/default/files/documents/fema_marshall-fire-mat-decreasing-structure-fire-spread.pdf

- Mitigation Strategies to Address Multi-Hazard Events: https://www.fema.gov/sites/default/files/documents/fema_marshall-fire-mat-mitigation-strategies-address-multi-hazard-events.pdf

- Best Practices for Wildfire-Resilient Subdivision Planning: https://www.fema.gov/sites/default/files/documents/fema_marshall-fire-mat-best-practices-wildfire-resilient-subdivision-planning.pdf

- Wildfire-Resilient Detailing, Joint Systems and Interfaces of Building Components: https://www.fema.gov/sites/default/files/documents/fema_rsl_marshall-mat-wildfire-resilient-detailing-joint-systems-and-interfaces-of-residential-building-components_042025.pdf

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Acronyms and Abbreviations

ADU	Accessory Dwelling Unit
ASCE	American Society for Civil Engineers
ASTM	American Society for Testing and Materials
BIPV	building integrated photovoltaic
CAL FIRE	California Department of Forestry and Fire Protection
CMU	concrete masonry unit
CWPP	Community Wildfire Protection Plan
FEMA	Federal Emergency Management Agency
HMM	Hazard Mitigation Methodology
HVAC	Heating, Ventilation and Air Conditioning
IBHS	Insurance Institute for Business and Home Safety
IBC	International Building Code
IGU	insulating glazing unit
IRC	International Residential Code
IWUIC	International Wildland-Urban Interface Code
MAT	Mitigation Assessment Team
NFPA	National Fire Protection Association
NFIP	National Flood Insurance Program
NIST	National Institute for Standards and Technology
NWCG	National Wildfire Coordinating Group
PV	Photovoltaic
UL	Underwriters Laboratories
WUI	Wildland-Urban Interface