Designing New Residential Structures to Decrease Wildfire Risk

This Recovery Advisory, focused on one- and two-family dwellings, presents important fire safety recommendations for design professionals, including architects, engineers, installation professionals and contractors to reduce the likelihood of ignition and structure-to-structure fire spread in single family homes during a wildfire, where building setbacks and defensible space may be limited. While most of the recommendations are best implemented during the design phase of a new home or community, some could also be implemented during a residential retrofit or mitigation. The recommendations in this Recovery Advisory are best practices and may exceed the requirements set forth in the adopted building codes and those specific to the Wildland Urban Interface (WUI)[1]. This Recovery Advisory does not address other important aspects of wildfire mitigation such as mitigation or renovation of existing homes, defensible space provisions, parcel-to-parcel fire spread, siting and non-building envelope attributes.

Important topics for protecting homes and communities are covered in the companion Maui Wildfires MAT Recovery Advisories listed below, and should be holistically implemented:

Maui Wildfires Mitigation Assessment Team Recovery Advisory #1 (RA-1) Wildfire Recovery Resources for Maui

Maui Wildfires Mitigation Assessment Team Recovery Advisory #2 (RA-2) Reducing Wildfire Risk to Your Home

Maui Wildfires Mitigation Assessment Team Recovery Advisory #4 (RA-4) Fire-Resistant Materials and Assemblies

Key Issues

- Ignition of a building and fire spread are two distinct considerations that must be addressed when designing a home. If the residential lot cannot accommodate defensible space or setbacks, the home can be subjected not only to ember exposure, but also to radiant heat and direct flame exposure, which can result in significant structure damage or complete loss if sufficient fire resistance is not provided.
- This Recovery Advisory focuses on items that can be incorporated during the design phase to harden the building envelope and reduce the risk of ignition and loss of the home. Because many neighborhoods on Maui are densely developed, this document provides guidance for situations where a home should include hardening measures when setbacks are not feasible. As Maui is subject to high winds, flooding, tsunami and seismic events, a multi-hazard approach should also be implemented with any building design.

[1] The WUI is the zone of transition between unoccupied land and buildings or communities. It is the line, area or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels.

Corrosion-Resistant Material Considerations

Maui's climate and proximity to salt water creates an environment that requires the use of corrosion-resistant metals for flashing, vents, connectors, or metal building components. Corrosion-resistant materials may include galvanized steel, stainless steel, aluminum, copper, or bronze. Refer to FEMA's NFIP Technical Bulletin 8: Corrosion Protection for Metal Connectors and Fasteners in Coastal Areas for additional details. While the materials listed above provide corrosion resistance to fasteners and other building components, only stainless steel, when available, should be chosen for screens.

Vulnerable building envelope components and systems that can contribute to structure ignition and fire spread can include the following:

- Roofs
- Exterior Walls
- Vents
- Windows, Doors and Openings
- Accessory Structures
- Areas Under Elevated Structures

The following sections describe recommended design components of new construction systems listed above.

Roofing Construction and Assemblies

Due to the complete destruction of more than 2,200 buildings in Lahaina and Kula during the 2023 fires, it is uncertain how roofing systems contributed to structure-to-structure fire spread. However, published research and studies of previous wildfires indicate that residential roofing systems are a key vulnerability to structure ignition because of their tendency to ignite due to radiant heat, embers and direct flame contact (impingement). When fires occur during high wind events, the roof covering can also become detached, exposing combustible elements of the roof substructure (e.g., underlayment, wood roof deck, weather resistant barriers, battens). To limit potential wind-driven fire vulnerability, roof systems should be able to resist the uplift forces associated with high winds per the Maui Building or Residential Code.

From a fire safety perspective, the entire roof assembly should satisfy the requirements for Class A when tested in accordance with ASTM E108 or UL 790. That is, the full roof assembly tested as an assembly should meet the requirements of Class A, not just tests of the roof covering alone. Common roof coverings that achieve Class A ratings include most asphalt shingles, concrete-, brick-, or masonry-tiles, or metal panel/shingles.

Additional Wind Considerations: Maui is subject to multiple hazards. Roof framing must be designed with continuous load path construction and support all gravity and wind loads corresponding to the site design wind speed, roof height, exposure category, building location, and all required load combinations in accordance with the applicable building code. Wood framing members for roofs, and their connections, should be designed to resist design loads in accordance with applicable codes and standards. Refer to the American Wood Council's 2018 Wood Frame Construction Manual (WFCM) for One and Two-Family Dwellings.

When designing a roof for new residential structures, important fire-resistant considerations include:

- Limiting the number of joints, abrupt geometry changes and elevation changes. Joints and elevation changes in a roof, along with eaves and valleys, can accumulate debris, increasing roof ignition vulnerability. Where possible, avoid a flat roof where debris accumulation is common.
- Using proper flashing at the joints between walls and porch roofs/lower roofs and roof edges.
- Using noncombustible materials to construct roof expansion joints.

Ash, embers, sparks and other burning material can lodge in unprotected roof penetrations, igniting a combustible roof deck or underlayment. Designers should specify the use of an approved penetration firestop system installed with a minimum positive pressure differential of 0.01 inch (2.49 Pascals) of water and tested in accordance with ASTM E 814 or UL 1479.

Design considerations for specific roof systems or materials are described in the following table.

Roof System or Material	Design Considerations
Roof Mounted Solar Panels	▪ Where building integrated photovoltaic (BIPV) systems or rooftop mounted photovoltaic panels (PV) are planned, they should meet the requirements of the Class A system, NFPA 70, and the wind loads set forth in ASCE 7-22. ▪ Ballasted PV panels should not be installed. ▪ 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	▪ Consider installation of a solar hot water heater system where the solar collector mounts flush to the roof. An angled solar collector can cause debris accumulation.
Wood Shakes or Shingles	▪ Fire-retardant treated wood shakes or shingles meet the Class A rating. However, there is uncertainty around the long-term weathering of fire-retardant wood products in hot humid climates like Maui, so these materials are not recommended.
Asphalt Shingles	▪ Most asphalt shingles can meet the requirements for a Class A roof assembly per ASTM E108 or UL 790. ▪ Asphalt shingle roof coverings must also be high wind rated: ASTM D3161 Class F or ASTM D7158 Class G or H. Consider installing asphalt shingles in accordance with the following FEMA document: Hurricane Harvey in Texas Recovery Advisory 2, Asphalt Shingle Roofing for High-Wind Regions.

Roof System or Material	Design Considerations
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 of 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 is recommended. ▪ 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.
Clay or Concrete Tiles	▪ Clay and concrete tiles have a high thermal mass and are noncombustible. These materials can meet the requirements for a Class A roof assembly per ASTM E108 or UL 790. ▪ 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 between a wood deck and the roof covering. ▪ Provide bird-stops or mortar at open ends of tile roofs to avoid debris accumulation. For other types of roof edges, provide a noncombustible underlayment that is continuous to the roof edge and non-corrosive metal flashing at the roof edge. ▪ Choose clay or concrete roof tiles rated for the local wind zones in accordance with the Maui Residential Code. Consider designing for wind in accordance with the Florida High Wind Concrete and Tile Installation Manual.
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 enclosed soffits or 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, at low points where two roof slopes converge (called valleys), at roof protrusions (such as skylights), and along roof edges (called rakes and eaves). Flashing can be shaped into various designs depending on where it is needed along the roof.
Underlayment/ Sheathing	▪ Install a fire-resistant underlayment, such as fiberglass or mineral wool. ▪ Provide fire-resistant sheathing material, such as gypsum or fiber cement.

Exterior Walls

Many houses on Maui are spaced closely together, reducing the ability to meet defensible space recommendations. On all exterior walls, consider providing at least a 1-hour fire-resistant exterior assembly per ASTM E119. For areas that are within 15 feet of an adjacent structure (such as a shed or a neighbor's home), combustible storage, or unmanaged vegetation, designers should consider if a 2-hour fire resistance rated exterior wall is feasible. Additionally, designers should choose products that meet or exceed the 10-minute direct flame exposure test in accordance with ASTM E2707. Designers should specify the use of noncombustible insulation inside of wall cavities and seal exterior wall openings with fire-resistant caulk.

While ASTM E119 considers heat penetration through the wall, it does not address fire spread on the surface. Avoid the use of combustible exterior cladding such as vinyl siding, which may melt, or wood siding, as there is uncertainty on the long-term performance of fire treated wood products on exteriors in hot humid climates. Additionally, care should be taken when specifying the use of a metal siding material, as it may warp when exposed to heat. Noncombustible exterior wall covering such as concrete (CMU blocks), cement board, masonry, three coat stucco or ignition resistant exterior is recommended. Note that the use of a noncombustible or ignition-resistant exterior wall covering does not supersede the need for fire resistance, where there is a potential for radiant heat and direct flame exposure. Consider limiting the number of aesthetic or architectural features that may trap embers or debris.

In neighborhoods with small lots and homes within close proximity, the home should be designed so that windows, doors and other openings are minimized or protected on sides adjacent to other structures.

Vents

Vents for plumbing, crawlspaces, dryers, soffits, attics and other openings without proper design or screening can allow for ember intrusion, which can cause a home to ignite. In residential design, reduce the number of vents if possible. Consider alternatives such as replacing under-eave vents with a soffited eave or an enclosed eave using noncombustible weather-resistant material.

Where vents are required, specify the use of ember and flame-resistant vents, if available. While not required by the Maui Building Code, the California Building Code Chapter 7A provides a list of vents that have been tested by the California State Fire Marshal (SFM) or 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.* It is important that the vent is corrosion resistant. Where these vents are not available, the designer should specify covering the vent with 1/8-inch stainless steel (choose stainless steel when available or corrosion resistant when stainless steel is not available) and noncombustible mesh. Dryer vents should include a metal flapper that remains closed when not in use. Exterior paint should not touch vent screening to avoid clogging the vent screen. All penetrations and space surrounding a vent should be finished with fire-resistant caulk.

Where flood openings (hydrostatic openings) are necessary, the design should be consistent with the National Flood Insurance Program (NFIP), Maui Residential Building Code, and Maui 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.

Windows and Doors

Windows can break due to radiant heat, direct flame impingement or flying debris. Jalousie and single pane windows are at substantial risk of breakage during a fire event. Combustible doors or those with non-fire rated windows can also pose a risk for breakage and ignition.

The designer should review whether the home is sited in a windborne debris region which may require additional window protection. Windows and doors should meet the design requirements for the applicable windborne debris region.

Recommended strategies for windows and doors are described in the table below.

System	Design Consideration
Entry Doors	▪ Consider choosing an entry door without glass, as the glass may break during a fire event. ▪ 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 ¾-inch thick are recommended. ▪ Avoid side panels on either side of the door that are constructed of glass or other combustible materials. If glass is necessary, choose tempered glass.
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 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. ▪ Ensure the door frame's perimeter is sealed providing no openings that could allow ember intrusion and debris accumulation.

Garage Doors	▪ Specify the use of noncombustible (e.g., metal) garage doors without windows.
	▪ Garage doors meeting a minimum of 20-minute fire resistance rating are recommended.
	▪ Add metal flashing at the base of the framing for the first six inches to reduce the possibility of ember intrusion and ignition.
	▪ Seal any cracks or openings around the garage door frame with fire-resistant caulk or weather stripping and make sure that the garage door closes flush to the ground.
	▪ Consider finishing the interior of the garage with drywall to reduce the threat of ignition from the combustible studs.
	▪ Due to the propensity for high winds on Maui, consider reinforcing 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 to the garage door motor so that the garage can be opened or closed if power is interrupted.

System	Design Consideration
Windows	▪ When designing and siting a home, consider reducing the number of windows and doors on the sides of the home with the highest fire exposure. This may be proximity to a neighbor, dense vegetation or other possible exposure. ▪ Specify tempered-glass and double-pane glazing systems. Avoid jalousie and single pane windows. ▪ Choose windows with metal framing, not those that contain wood or vinyl frames. ▪ Seal all joints between the window frame and exterior wall with fire resistant material. ▪ Due to the propensity to keep windows open in the Maui climate, install fiberglass or corrosion-resistant metal screens with a maximum spacing of 1/8-inch in all operable windows.
Skylights	▪ Consider a roof design without skylights. This is especially important on steep slope roofs where the skylight is more susceptible to radiant heat or direct flame impingement. ▪ Where a skylight is included in the design, specifications should require multiple, tempered glass panes surrounded by non-flammable flashing with no exposed wood. Ensure the exterior frame is sealed with noncombustible caulks, flashing or assemblies. ▪ If the skylight is operable (opens), specify that a stainless steel metal screen with a minimum opening of at least 1/8-inch should be installed on the inside.
Shutters	▪ Choose noncombustible shutters such as metal roll shutters. Avoid vinyl shutters as they may melt and expose the windows. ▪ Where wood structural panels for wind/debris impact are provided, consider using solid fire-retardant wood. The fire-retardant wood should be labeled for exterior use. ▪ Slatted or louvered exterior shutters should be avoided.

Accessory and Detached Structures

Residential design recommendations that reduce exposure also apply to detached and accessory structures, such as an ohana. Ensure that defensible space considerations are included when choosing accessory structure locations. Accessory structures, such as sheds, should be sited at least 30 feet from the home or other combustible structures, storage areas or combustible materials like fences. The design of the accessory structure should follow the recommendations in this Advisory. It is recommended that accessory structures be protected to the same level as the residence.

Sheds pose a risk to fire spread during a fire event. Consider replacing small plastic or wood storage sheds with a metal shed. Position the shed so that the door does not face the main structure on the parcel. Design defensible space surrounding the shed.

Carports are often used for storage of materials in addition to cars and are highly vulnerable to ignition. These structures are often placed adjacent to the lot line between homes, which increases the potential for fire spread. Carports must be open on at least two sides; otherwise, the design considerations for a garage should be met. When designing a carport, the roof should be provided with a Class A roof assembly and the floor should be noncombustible. The carport ceiling and walls should also be designed with noncombustible materials.

Elevated Homes/Open Foundations

Elevated homes with open foundations are common for flood protection, for siting on a slope, or to maintain views. Elevated homes are at an increased risk of ignition and fire spread as the open space below the floor exposes more flammable surfaces. Recommended strategies for designing an elevated home for fire safety are described in the table below.

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.
Fire-Resistance Rated Construction	▪ All designs should follow the Maui Residential Code and the adopted Maui Fire Code, NFPA 1, and FEMA best practices. ▪ Fire resistant construction should be approved by the local building official. ▪ It is recommended that a minimum 1-hour fire resistance is provided between the floor of the lowest level and 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. It is recommended that the piles and piers are constructed from noncombustible materials, such as concrete or CMU block. ▪ Where concrete piles or CMU piers are not provided, the design should include wrapping the wood piles/piers with a flood-resistant 1-hour fire-resistant jacket. ▪ Consideration should be taken to protect the steel reinforcement from corrosion.
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 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 1/4-inch. A corrosion resistant mesh of no more than 1/4-inch could be used.

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

Resources and Useful Links

Maui County Building Code: https://www.mauicounty.gov/1308/Building-Plans-Review-Section

Insurance Institute for Business & Home Safety (IBHS):

- IBHS Wildfire Prepared Home Standard: https://wildfireprepared.org/wp-content/uploads/WFPH-Standard-2022-Final.pdf
- IBHS Suburban Wildfire Adaptation Roadmaps: https://ibhs.org/wildfire/suburban-wildfire-adaptation-roadmaps/
- Wildland Fire Embers and Flames: Home Mitigations That Matter: https://ibhs1.wpenginepowered.com/wp-content/uploads/Home-Mitigations-that-Matter-FINAL.pdf

International Code Council (ICC) 2021 International Wildland-Urban Interface Code (IWUIC): https://codes.iccsafe.org/

National Fire Protection Association®. NFPA 1140, 2022 Edition: Standard for Wildland Fire Protection: https://www.nfpa.org/codes-and-standards/nfpa-1140-standard-development/1140

National Institute of Standards and Technology (NIST): WUI Structure/Parcel/Community Fire Hazard Mitigation Methodology. NIST Technical Note 2205: https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2205.pdf

Society of Fire Protection Engineers (SFPE): WUI Virtual Handbook for Property Fire Risk Assessment & Mitigation: https://www.sfpe.org/wuihandbook/home

U.S. Department of Housing and Urban Development (HUD):

- Designing for Natural Hazards Series: https://www.huduser.gov/portal/publications/Designing-for-Natural-Hazards-Series.html
- Volume 1 Wind: https://www.huduser.gov/portal/sites/default/files/pdf/Natural-Hazards_Volume-1-Wind.pdf
- Volume 3 Fire: https://www.huduser.gov/portal/sites/default/files/pdf/Natural-Hazards_Volume-3-Fire.pdf