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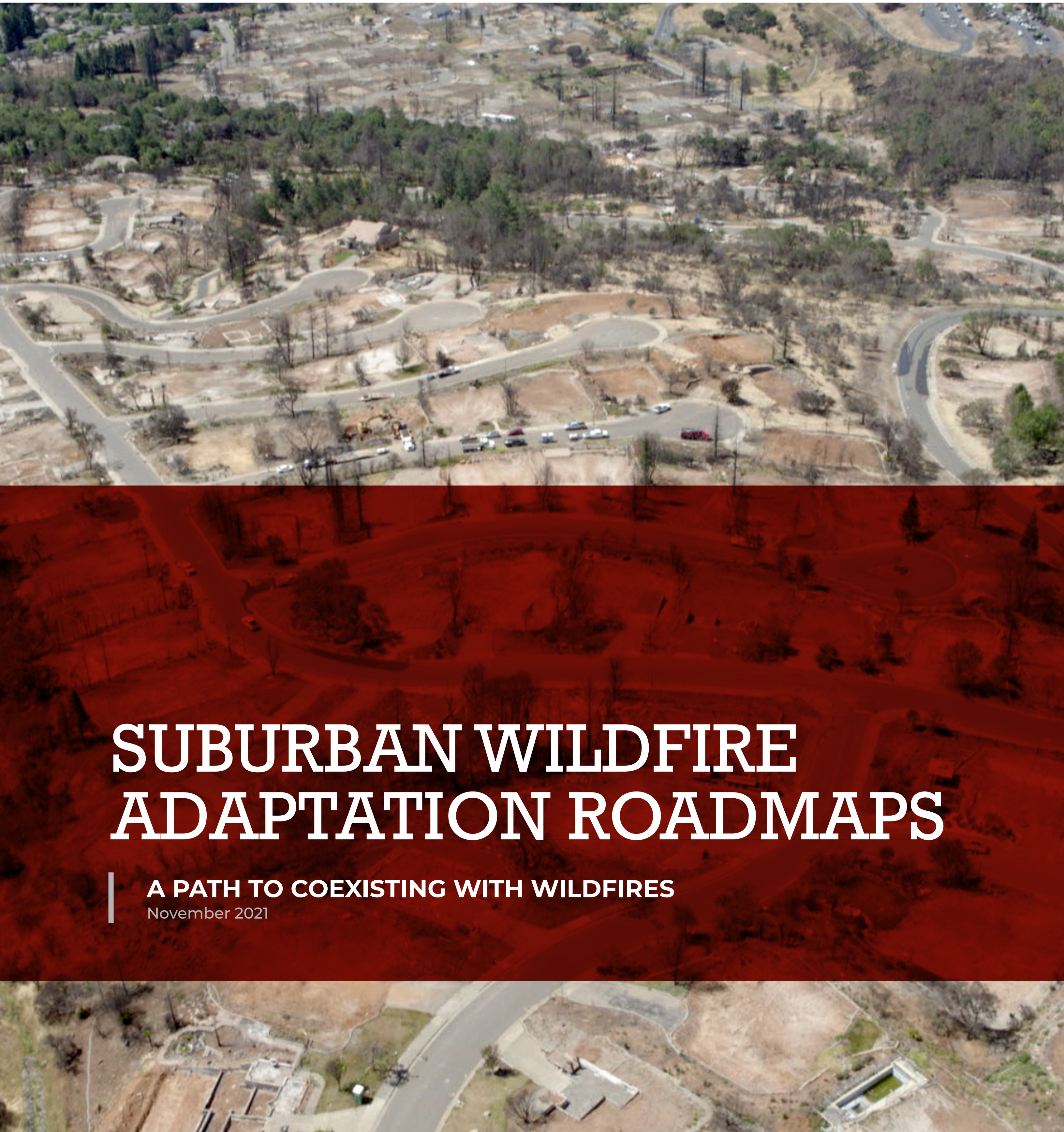

SUBURBAN WILDFIRE ADAPTATION ROADMAPS

A PATH TO COEXISTING WITH WILDFIRES

November 2021

REPORT UPDATES

AS OF NOVEMBER 2021

Recent IBHS research has identified an affordable and fire-resistant deck option. Using a metal walking surface that has no gaps reduces the oxygen supply for a fire that reaches the joists underneath. By blocking this pathway for the fire to spread and limiting the amount of oxygen available for the burning joists, the potential risk of a burning deck against a house is minimized.

In modern suburban settings, businesses are frequently in close proximity to homes to provide convenient services to residents. Recognizing this reality, IBHS has included light commercial guidance in the roadmaps to help businesses identify and evaluate changes to light commercial construction that can reduce their wildfire risk. The roadmaps provide guidance to help property owners identify the best and the most risky practices for light commercial structures.

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PREFACE

Wildfires are not new to us. Throughout history, wildfires have persisted across the United States, yet people, their buildings, and our affinity for natural spaces continues to increase the wildfire risk to the built environment. Despite substantial efforts to reduce exposure to the wildfire hazard, it continues to be a threat. Climate change factors are intensifying the threat. Suppression will continue to play a role in limiting the spread of fire; however, changes in the built environment are necessary to limit the destruction caused by wildfire.

Over the past two decades, the best practices for new construction in the Wildland-Urban Interface (WUI) have advanced significantly. Very effective techniques are being employed where defensible space can be extended 100 ft or more away from structures, and careful building design and material selection can significantly reduce wildfire risks.

Yet 99% of Americans live in homes that were constructed over the past century—not recently constructed structures that reflect the newest building codes. In California, 85% of residents in communities with a population over one million live in suburban neighborhoods[1] where there is no feasible way to implement 100 ft of defensible space.

In the pages that follow, IBHS lays out specific strategies for *suburban neighborhoods*. These insights build on findings the fire protection community has published and reflects the best experimental and field research to date. The current state of the science—when put into action—can limit the catastrophic reach of wildfire as it approaches neighborhoods.

Some actions are obvious and follow conventional wisdom; some vulnerabilities are less obvious and not apparent to the human eye. These roadmaps give specific attention to fuel management, decks, fences, building shape, walls, roofs, roof vents, and eaves. Individually and collectively, resilient choices in these eight areas reduce the likelihood of ignition for a given home, that can spread into a catastrophic wildfire.

While these insights, when put into practice, should bring a ray of optimism to this difficult peril, there are no 100% guarantees. Because there is a 90% chance of total loss if a single-family dwelling is ignited by embers, a suite of *must-change* actions need to be put in place first to have any reduction of risk—including addressing wood shake roofs, combustible siding, underdeck vulnerabilities, open vents, and combustible materials within 5 ft of the home. After those critical elements are addressed, choices can be made to align investment with mitigation. In almost every instance, the choices of neighbors can be crucial. Impeccable application of these strategies on one home in a suburban community can be negated by an ill-prepared neighbor. While these strategies bend down the risk curve, they do not entirely eliminate the risks.

We live in a society where structures make up neighborhoods, that create communities, that exist in an ecosystem. Action is needed at every increment of scale and, given our current climate and political environment at all levels of government, the solutions require all of the above.

1 *California's Dense Suburbs and Urbanization, NewGeography, https://www.newgeography.com/content/005908-californias-dense-suburbs-and-urbanization*

WHY

The wildfires of 2017–2018 across California were a stark reminder of what can happen when all the ingredients for significant wildfires come together and spread into the built environment. There was no better example of the damaging and deadly nature of the two-year stretch of wildfires in 2017–2018 than the Camp Fire. This event showed how quickly a fire can spread through a community when a worst-case scenario comes together. The two-year stretch saw $33 billion dollars in loss and put wildfire damages on par with annual losses from landfalling hurricanes and severe convective storms. While much of the wildfire focus in the last decade has been in California, in 2016 the Chimney Tops 2 Fire devastated Pigeon Forge and Gatlinburg, Tennessee, during an extended period of drought, causing over $900 million dollars in damage.[2,3] Other fires across the United States like the Waldo Canyon Fire (2012) in Colorado, or the Bastrop County Complex Fire (2011) in the Texas Hill Country have highlighted the reality of the threat across the United States when weather, fuels, and topography (Figure 1) come together with an ignition source.

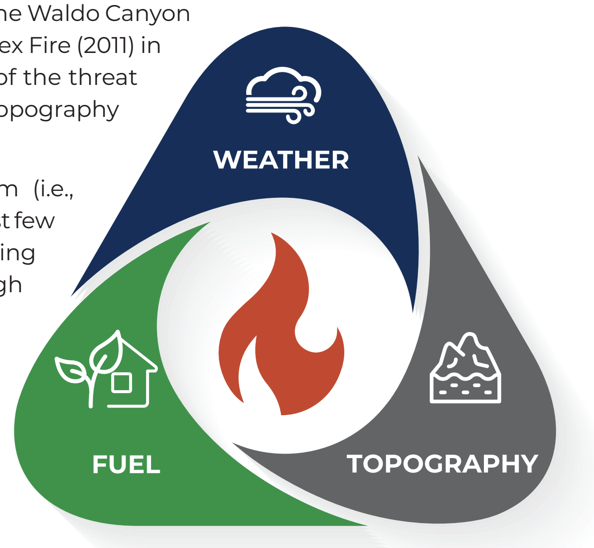

Figure 1. Fire behavior triangle.

Looking back even to the Oakland Hills firestorm (i.e., Tunnel Fire) of 1991 and to the recent events of the past few years, we see a common factor in the most devasting fires: fire spreading from the wildlands, through the wildland-urban interface, and into suburban environments. Three different mechanisms can ignite structures: ember exposure, direct flame contact, and radiant heat from flames. Embers are hot flying particles that travel with wind ahead of the fire front.[4] Where embers land is mostly determined by the local wind pattern. Solid vertical surfaces (such as walls) stagnate or block the wind, which often causes debris and ember deposition at their base. When embers land and accumulate on something combustible, the fuel can ignite and create a sustained flame. Depending on the available fuel and wind, the flame can stretch and exceed the distance between the flame base and surrounding fuel. Once flame contact happens, fire can aggressively spread. However, flame contact is not a necessary part of fire spread, since a fire can also radiate heat to the surroundings and ignite nearby combustible materials without physical contact. When fire spreads into the suburban environment, all three mechanisms can work simultaneously to devastate communities. The speed at which fire can spread from structure to structure can resemble the rapid rate observed when fires spread through continuous vegetative fuels.[5]

Research over the past decade has shown us that one of the key ways to lower the risk to structures in the path of wildland fires is to reduce the available fuel and defend against the three ignition mechanisms. This is now commonly referred to as a structure's defensible space. The maintenance of defensible space and use of fire-resistant building materials has been shown to reduce the wildfire vulnerability of a structure.[6,7,8] Unfortunately, in suburban neighborhoods there has been

2 https://www.nfpa.org/News-and-Research/Data-research-and-tools/US-Fire-Problem/Large-loss-fires-in-the-United-States/Largest-fire-losses-in-the-United-States
3 Fire Loss in the United States, National Fire Protection Agency, https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/US-Fire-Problem/Old-FL-LL-and-Cat/FireLoss2017.ashx
4 Hedayati F., Bahrani B., Zhou, A., Quarles S., Gorham D., A Framework to Facilitate Firebrand Characterization, Front. Mech. Eng., 12 July 2019
5 Alexandre, P., et al. The relative impacts of vegetation, topography and spatial arrangement on building loss to wildfires in case studies of California and Colorado, Landscape Ecole (2016) 31:415–430
6 Gude, P., Rasker, R., Noort, J. Van Den, 2008. Potential for Future Development on Fire-Prone Lands, J.l of Forestry. 106(4) 198-205
7 Manzello, S.L., J. Shields, Y. Hayashi, and D. Nii, 2008: Investigating the Vulnerabilities of Structures to Ignition From a Firebrand Attack. Fire Saf. Sci., 9, 143–154. doi:10.3801/IAFSS.FSS.9-143
8 Manzello, S.L., S.H. Park, and T.G. Cleary, 2009: Investigation on the ability of glowing firebrands deposited within crevices to ignite common building materials. Fire Saf. J. 44, 894–900. doi:10.1016/j.firesaf.2009.05.001

Figure 2. Idealized diagram of a typical suburban street and cul-de-sac. The pink 0–5 ft noncombustible zone is provided for reference.

little consideration of these factors. Figure 2 shows a basic layout of a suburban street and the extent of the 0–5 ft home ignition zone (also referred to as the noncombustible zone) and how it can encroach on neighboring homes. In many situations, the zones beyond 5 ft included in classic defensible space concepts overlap with neighbors. This problem was underscored during the Tubbs Fire of 2017 when the Coffey Park neighborhood of Santa Rosa was decimated. Ember-driven ignitions quickly led to rapid structure-to-structure fire spread, destroying much of the neighborhood (Figure 3 and Figure 4). Homes were spaced only 10–20 ft apart with vegetation in the areas between structures. Across the United States neighborhoods are constructed like this, with structures spaced closely together to maximize land use. In this environment, the survivability of one structure becomes highly dependent on the surrounding buildings and the fuel they provide for a fire to grow and spread. It is clear that now is the time to adapt suburban neighborhoods to the threat posed by wildland fires, to keep them from entering and spreading in communities.

Wildland fire is a natural phenomenon and is necessary for the health of some ecosystems. When defending against this hazard, it is important to understand that despite best efforts to reduce the wildfire hazard, it will continue to be a threat. The key to preventing it from becoming a disaster is to

Figure 3. Street-level imagery from the Coffey Park neighborhood in Santa Rosa, California, (top) before the Tubbs Fire (2017), and (bottom) in 2019 as rebuilding is well underway. Note the home-to-home spacing and proximity of vegetation to homes in the image from Google Street View.

Figure 4. Aerial imagery of the Coffey Park neighborhood in Santa Rosa, California, (left) before the Tubbs Fire (2017) and (right) after the fire. Imagery courtesy of Google Earth.

prevent it from entering and spreading in our built environment. While the frequency of wildfires has decreased with time, the severity increased from the 1980s to the early 2000s, as the total surface area burned by fires increased.

However, the total area burned has remained effectively constant over the past decade[9] (Figure 5). Short (2014) estimated that just 3% of fires are responsible for 97% of the acreage burned.[10] The impact of climate change on patterns of wet and dry periods has led to more volatile wildfire conditions due to the increased availability of vegetative fuels from rapid vegetation growth during wet periods followed by the quick onset of drought. Anthropogenic factors are also playing a role. Population growth and development spreading into the wildlands or the wildland-urban interface has also increased the number of human-caused ignitions. Humans are now responsible for 80%–90% of the wildfires we see today.[11]

When wildland fires ignite, suppression efforts are often successful in the initial attack phase. In the last decade, approximately 95%–97% of fires are contained and the majority affect less than one-quarter acre of land. The remaining 3%–5% are those that are large and fast-moving because of extreme weather conditions and are difficult to control. These fires result in a large number of building ignitions and high losses of life and property.[5,10,11] The path toward adapting to this threat is to find ways to limit or prevent the ignition of structures.

This adaptation guide provides a series of roadmaps to help explain how decisions made about a home and its surroundings can change its vulnerability. It also provides a best-practices view about where gains can be made to reduce a home's vulnerability by addressing specific components of the property. The roadmaps are focused on the steps necessary to help adapt our suburban communities to this threat and represent the current state of wildland fire science and sound engineering judgment from experts at IBHS and the wildfire research community.

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9 https://www.nifc.gov/fireInfo/fireInfo_stats_totalFires.html
10 Short, K.C., 2014: A spatial database of wildfires in the United States, 1992-2011. Earth Sys. Sci. Data, 6, 1-27. doi:10.5194/essd-6-1-2014
11 Balch J.K., B.A. Bradley, J.T. Abatzoglu, R.C. Nagy, E.J. Fusco, and A.L. Mahood, 2017: Human-started wildfires expand the fire niche across the United States. Proceedings of the National Academy of Sciences of the United States of America, 114, 2946–2951. doi:10.1073/PNAS.1617394114

United States Annual Fire Occurrence Data: Interagency Fire Center

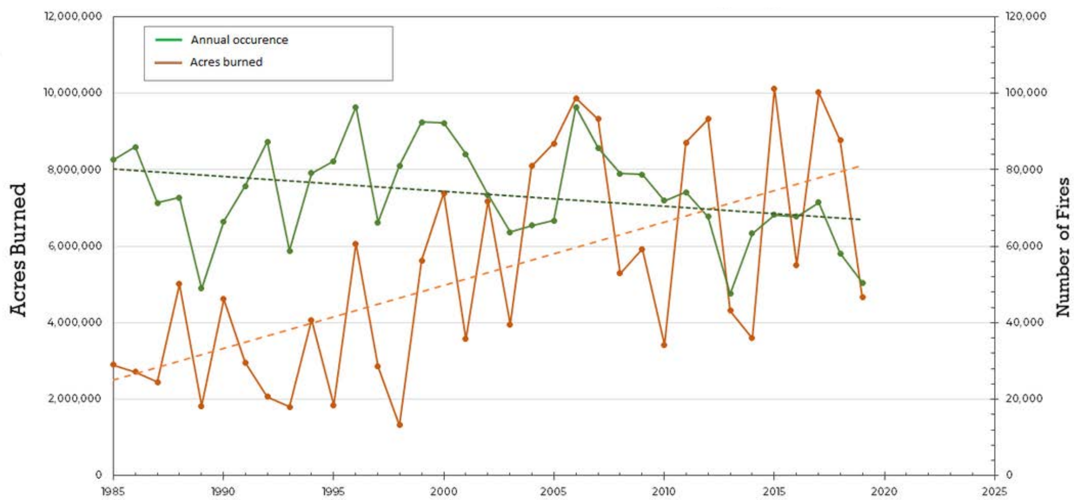


Figure 5. Number of fires (green) and acres burned (brown) since 1985. Linear trend lines (dashed) are also included. Data courtesy of the Interagency Fire Center.

APPLICABILITY

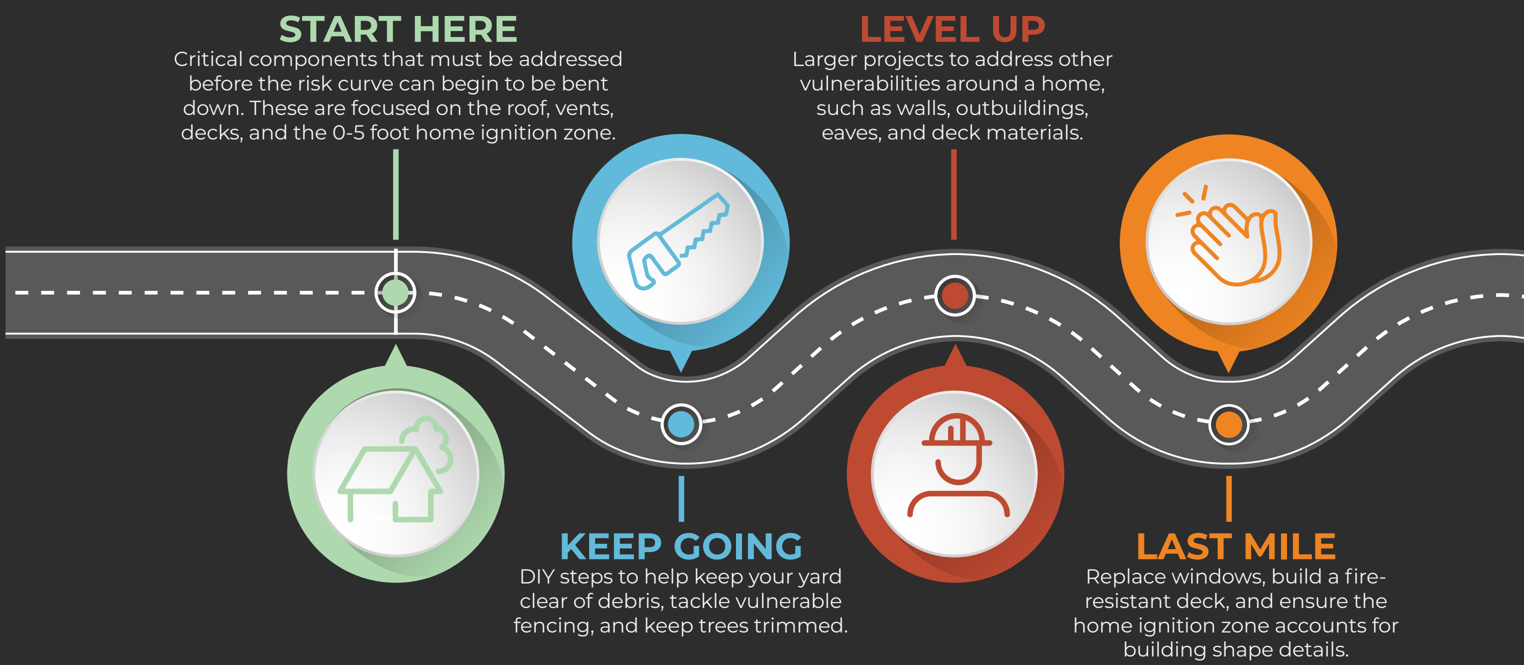
The information and recommendations provided in this report are intended for single-family homes that may be single- or multi-story. We have provided a light commercial construction supplement as *Appendix A* towards the end of this report. The information is intended for suburban neighborhoods, where housing spacing may be close enough that full defensible space recommendations extending 30 or 100 ft[12,13,14,15] may not be realistic. In these cases, the choices of the neighbors and community affect the vulnerability of each individual property. This differs from many other sources of information, and to some extent even building codes, that focus heavily on buildings in the WUI, not traditional suburban communities.

The information included here is applicable for existing homes and new construction, but the recommendations to reduce vulnerability may be different for the two. There are some recommendations that can only be used as a building is designed and built or they are not practical for retrofitting existing buildings because of cost or access issues. Some of the retrofit options are low-cost, easy, “do-it-yourself” (DIY) options, while others require a significant investment of time and/or money to appreciably reduce the wildfire risk to a home.

Maintenance, or lack thereof, plays a huge part in wildfire risk. In addition to fixing or replacing damaged siding, roofing, and other components, a home that is properly maintained for wildfire should be free from debris accumulation in gutters and vents, on roofs and decks, and the below-deck area of low decks (less than 4 ft high). A home that does not prevent debris accumulation is vulnerable to debris being ignited by embers or flame contact, and then igniting another part of the house when there is a nearby wildfire. Constant vigilance is required to remove debris to lower the wildfire risk of a home. Maintenance also includes trimming tree branches, removing dead vegetation, and sealing gaps in the home. When there is a wildfire threat, maintenance could also include temporarily relocating items such as patio furniture and grill supplies away from the home and off combustible decks. Ideally, hot tubs would be removed and stored as well, although this could be difficult if they are permanently installed with plumbing and electrical utilities.

12 CalFire Ready for Wildfire, https://www.readyforwildfire.org/prepare-for-wildfire/get-ready/defensible-space/
13 FIRESafe Marin Defensible Space, https://www.firesafemarin.org/defensible-space/
14 NFPA Preparing homes for wildfire, https://www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire/Preparing-homes-for-wildfire/
15 IBHS Maintain Defensible Space, https://disastersafety.org/wildfire/defensible-space/

THE ROADMAPS



GETTING FROM HERE TO THERE

Understanding and mitigating against wildfire vulnerability for an individual home is a complex problem. Not all building components or systems have the same level of risk or likelihood of exposure to flames, radiation, or embers. It is also very possible to have one part of a house that is wildfire resistant, while another component is highly vulnerable. Considering this, roadmaps were created for eight key parts of a house and its surroundings.

These roadmaps were created by IBHS scientists and engineers based on existing scientific and engineering literature, experimental testing, post-disaster investigations, and engineering judgment. A workshop was conducted with external stakeholders to gather input from other experts in the field regarding the framework and technical details. While the systems and components are interdependent, for the purposes of the roadmaps they are treated separately. In almost all instances, a homeowner could change one of the components and make some progress in reducing their wildfire risk without having to change all the components. However, the best approach is to improve all high-risk scenarios and recommendations to do this are provided for both new builds in the design phase as well as existing homes. There are several critical conditions described in the Recommendations section that must all be corrected to reach a minimum acceptable condition before anything else is done. There is also a list of "must-do" or critical changes that represent some of the first steps a homeowner should take after reaching the minimum acceptable condition.

Many of the roadmaps refer to components that are Chapter 7A compliant based on the California Building Code.[16] This label is used for brevity, acknowledging that the code allows multiple ways to achieve compliance such as inherently noncombustible, standard test method, or by design. Each method results in different levels of performance. Describing all the various options allowed by Chapter 7A would be cumbersome and make the roadmaps difficult to understand.

16 *California Building Code (2016). Chapter 7A—Materials and Construction Methods for Exterior Wildfire Exposure*

ADAPTATION ROADMAPS

Nearly all aspects of wildfire mitigation strategies collapse into two correlated categories:

- Hardening the structure by using fire-resistant materials
- Reducing the intensity of a potential fire around the structure

IBHS has developed wildfire adaptation roadmaps for the following key parts of a suburban home that address both categories (Figure 6).

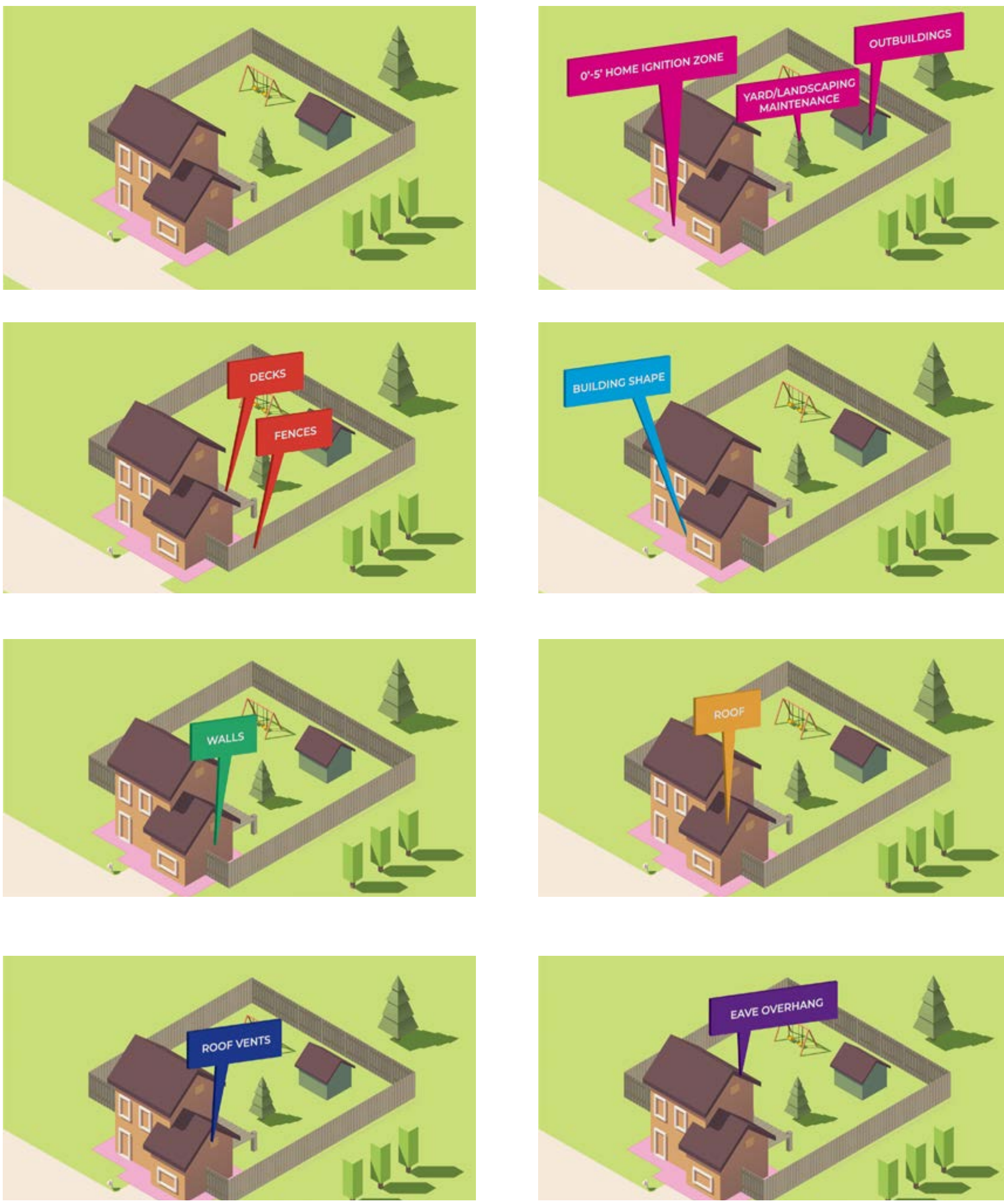


Figure 6. Idealized view of a suburban home identifying the critical lanes of mitigation.

These systems, along with a few others, were also described by FEMA's Home Builder's Guide to Construction in Wildfire Zones,[17] published in 2008. Some of the information presented here regarding risk and mitigation may be similar, but specific events and additional experimental testing over the last 12 years have expanded the current state of knowledge. Many of these same systems are also a focus in NFPA's Firewise USA® program,[18] Rancho Santa Fe (California) Fire Protection District's Shelter-in-Place program,[19] and others.

The Suburban Wildfire Adaptation Roadmap project is aimed at defining and comparing the risk for specific components to help policymakers, insurers, risk modelers, homeowners, and the construction and landscaping industries understand the risk factors. It also seeks to develop a path for homeowners and communities to make progress in reducing their risk, even if it is just one component at a time. The project can also assist designers and architects in making the best choices for new homes. The roadmaps use colors to indicate relative levels of risk, with green colors being the best options, yellow or orange being moderate options, and red being the worst or most risky options. Things identified in blue do not represent a final choice, merely a category of details or choices.

Many specific parts of a home are referred to in the roadmaps and Figure 7 identifies these components.

Common Parts of a Home

Figure 7. Idealized home diagram showing roof and building components that are referred to in the roadmaps.

17 FEMA (2008). Home Builder's Guide to Construction in Wildfire Zones. Technical Fact Sheet Series, P-737, Washington, DC, 80 pp.
18 NFPA. "How to Prepare Your Home for Wildfires," Quincy, MA, 1 pp., https://www.nfpa.org/-/media/Files/Firewise/Fact-sheets/FirewiseHowToPrepareYourHomeForWildfires.pdf
19 Rancho Santa Fe Fire Protection District (2016). "Shelter-in-Place...If You Can't Evacuate," Rancho Santa Fe, CA, 7 pp., https://www.rsf-fire.org/wp-content/uploads/2016/09/SIP_for_web.pdf

FUEL MANAGEMENT

The risk to a home from a nearby flame depends on burning fuel characteristics, the distance between the flame and the building, and oxygen supply (local wind). Low-density fuels (leaves, pine needles, windblown debris) are extremely susceptible to ignition. When ignited, they can preheat high-density fuels (larger vegetation or structures) around them and eventually ignite those fuels. Larger vegetation and structures create a more intense thermal exposure on a home. This sequence of ignitions is called a fuel ladder. Fuel management is a way to break this chain by choosing low-flammability vegetation or landscape materials with adequate spacing.

As tall high-intensity flames (that are often started by flying embers) approach a home, they can be converted to short flames with effective fuel management. Short flames can be suppressed to a small slow-moving fire (creeping fire) and eventually stop.[20] A fire-resistant structure is more likely to withstand a creeping fire than one with tall flames. Moreover, suppression efforts by first responders are more effective against a creeping fire.

The roadmap for fuel management focuses on three zones surrounding a home:

- 30–100 ft zone
- 5–30 ft zone
- 0–5 ft noncombustible immediate home ignition zone

The overarching goal of fuel management in suburban areas is to reduce flame intensity as it gets closer to a home through three stages:

1. Converting tall continuous flames into sparse fires with shorter flames within 30–100 ft of the home.
2. Converting short and sparse flames into low-intensity creeping fire within 5–30 ft of the home.
3. Stopping the creeping fire from reaching the home by using noncombustible materials within 0–5 ft of the home.

Depending on the characteristics of a home (surrounding fuel, distance to property line) fire size reduction might not go through all three stages, but rather skip to the second or third stage.

As shown in the roadmap (Figure 8), homes with no combustibles located within 100 ft are the best option to reduce the likelihood of wildfire effects. However, this is not practical in a suburban setting, where a neighbor's house is likely to be within this zone. Additionally, most homeowners enjoy trees, plants, decks, fences, and other things that can be combustible around their home. Therefore, the roadmap focuses on maintenance, and vegetative and structural fuels in these zones.

Starting from 100 ft (or the property line in the case of smaller lots) to 30 ft from the home, the available fuel (vegetation and combustible structures) should be managed to suppress the potential fire. Low-flammability vegetation[21,22] is resistant to ignition, burns for less time, and generates less heat when ignited, and is therefore less risky. Adequate distance between the vegetation (in both horizontal and vertical directions[12]) significantly reduces the potential of fire spread due to flame contact and flame radiation. These actions would be most effective once the creation of the fuel ladder is stopped.

Structural fuels burn longer than vegetation and pose a higher risk. Large structures such as in-law suites, sheds, or gazebos located in the 30–100 ft zone increase a home's fire risk, especially if they are larger than about 25 sq ft. Boats and recreational vehicles are also vulnerable to wildfire.

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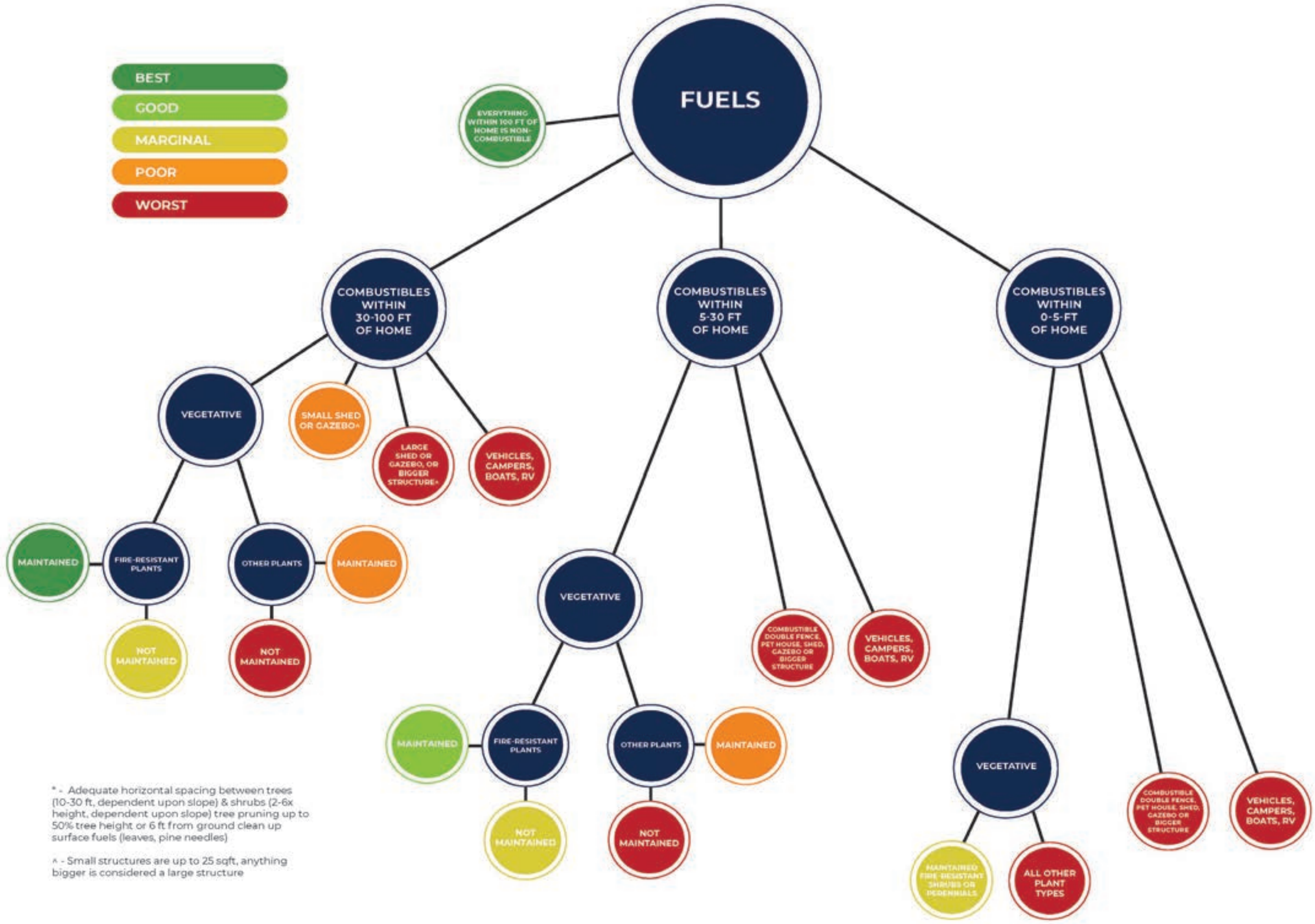
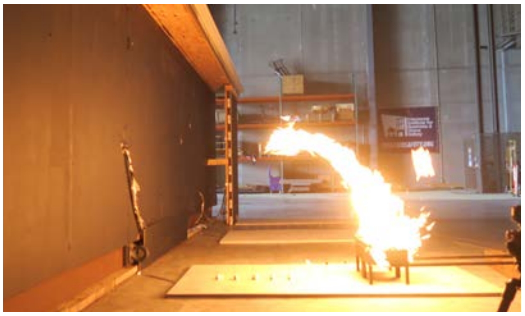
20 Ascoli D., Russo L., Giannino F., Siettos C., and Moreira F., 2019 WUI encyclopedia, Firebreak and fuel break
21 Behm A., Long A., Monroe M., Randall C., Zipperer W., and Hermansen-Báez A., Fire in the Wildland-Urban Interface: Preparing a Firewise Plant List for WUI Residents
22 Fire-retardant plants for home landscape; Selecting plants that may reduce your risk from wildfire, USDA, 2006



* - Adequate horizontal spacing between trees (10-30 ft, dependent upon slope) & shrubs (2-6x height, dependent upon slope) tree pruning up to 50% tree height or 6 ft from ground clean up surface fuels (leaves, pine needles)

^ - Small structures are up to 25 sqft, anything bigger is considered a large structure

Figure 8. Fuel management roadmap.



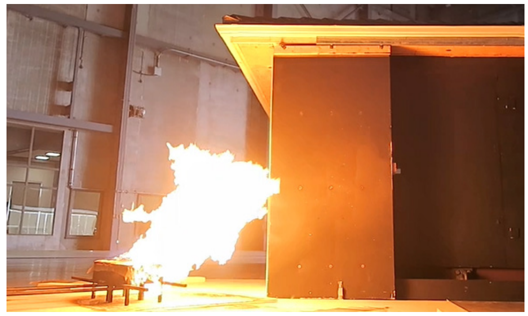


Figure 9. Flame profile when the fire is aligned with the center and corner line of the structure.

If ignited, they can cause a fire exposure to the home like burning sheds. Accessory structures located along the corner line of the home also increase the risk of fire propagation[23], as shown by recent IBHS research. This study showed the wind wrapped around the structure and caused the flame to stretch and tilt toward the house,[23] as shown in Figure 9.

Similar concepts apply within 5–30 ft of the home, but the risk is higher in this zone since it is closer to the home. Sparser vegetation can reduce the risk. Trees close to a home will result in more vegetative debris on or near the home and therefore require a greater maintenance effort. Accumulation of tree droppings at the base of larger fuels such as structures and plants create a fuel ladder. For example, as shown in Figure 10, leaves can accumulate between neighboring fences and create a fuel ladder. Any structural fuels larger than a single fence create a high risk in this zone.

The zone within 0–5 ft from a home plays an important role in preventing deposited embers from transitioning into flames near the home (Figure 11). This is often implemented in wildland fuel management through firebreaks, where mechanical operations or prescribed burns totally remove the fuels down to mineral soil. Having no combustibles in this zone is ideal. Having small shrubs or perennials increases the risk, depending on the home's level of fire resistance—keeping these maintained is key to managing the risk. Any type of combustible structural fuel or vehicles in this area creates a high risk. Additionally, embers can ignite a house directly if there are combustible building materials at ground level.

In some cases, the property size or unmovable surrounding structures can limit fuel management activities in the three zones. The risk increases as the distance between the fuel and the home decreases. While it is generally true that a higher focus should be given to the areas closest to the home, there is not enough scientific understanding to prescribe exact distance recommendations for spacing of accessory structures. As a result, a multi-year collaborative project with CalFire, NIST and USFS has been initiated to investigate the effect of size, material, and separation distance between structures under wildland-urban fire conditions. The results of this study will improve the definition of the risk in each of the three zones and expand the boundaries of fire science. This new information will provide better guidance and recommendations regarding structure separation for use in developing and retrofitting wildfire resilient communities.

Fuel management recommendations are similar for both new and existing homes. In all three zones, fuel type and fuel continuity should be controlled. Breaking the fuel ladder is a relatively inexpensive and important[24]

Figure 10. Creation of fuel ladder between two fences. Photo courtesy of J. Cohen.

23 Hedayati F., Stansell C., Gorham D., Quarles S., Near Building Noncombustible Zone, IBHS technical report, December 2018
24 Heinsch F., 2019 WUI Encyclopedia, Fences and Accessory Structures

Figure 11. Importance of 0–5 ft noncombustible zone (home ignition zone) for a home under ember attack.

task that should be done both horizontally and vertically. The horizontal distance that should be open between trees depends on the terrain. On flat terrain, the trees should be pruned to ensure canopy-to-canopy distance is at least 10 ft. On a steep slope, the distance should be increased to 30 ft. For shrubs, the spacing on flat terrain should be double the shrub height. On a slope, this should be triple the height. The vertical distance between ground vegetation and overhead fuel should be three times the vegetation height of ground vegetation. More effort should be devoted to areas closer to the house, with sparse plantings and frequent debris clean up.

Surface fuel management is extremely important at the base of vertical solid surfaces such as walls and fences. Having a 0–5 ft noncombustible zone prevents the conversion of embers to flames around the home. As shown in Figure 10, debris clean up in between double fences is often troublesome, and these should be modified by removing one layer of the fence.

Structural fuels and recreational vehicles should not be stored in the 0–5 ft zone; this includes pet houses, combustible fences, attached sheds, gazebos, boats, and campers. If the property size allows, these should be stored beyond 30 ft and the vegetation should be maintained around them. They should not be aligned with the corner of the house. If the property size is small and the structural fuels are large, those items should be permanently relocated. Potential fuel around smaller structures should be managed in the same way as for the main home.

FENCES

Combustible fences are among the vulnerable components of a house in WUI areas. Reportedly, first responders defended them several times during the 2011 Amarillo, Texas fire.[25] Depending on their design, they can stagnate or block the wind, which causes accumulation of windblown debris at their base. Windblown embers that accumulate at the base of the fence can ignite the debris and, with little or no clearance at the base of a combustible fence, ignite the fence. Embers can also ignite a combustible fence directly by accumulating at the joint of planks and support members[26] or by touching the bottom of the fence (posts or fence boards). Once ignited, the vertical supply of fuel allows the flames to rapidly grow and consume the fence.[27] If the wind direction is aligned parallel with the fence, flames can reach the house very quickly.

The roadmap for fences only addresses the immediate 5 ft portion of the fence that is in contact with the home. Most of a fence is away from the home at the boundaries of the property and this is addressed in the Fuel Management section.

The roadmap for fences (Figure 12) focuses on the wildfire vulnerability based on design and material of the part of the fence that is attached to the home. IBHS research has shown the effectiveness of the immediate noncombustible zone in reducing the risk of wildfire damage to a house.[23] The best option to reduce the risk caused by fences is to use a noncombustible or an ignition-resistant material (such as metal, concrete, stone, or masonry) for at least the first 5 ft of the attached fence. Fuel management at the base of the fence is important (Figure 13). Combustible plastic lattice fences and wood fences that are used in the 0–5 ft zone can be mitigated somewhat if they are elevated with no combustibles at the ground (breaking the potential fuel ladder). In this case, the possibility of flame spread from the bottom to top is minimized but the fire can still spread along the length of the fence.[28] Plastic lattice fences contain less fuel than plastic privacy fences. Therefore, lattice fences may melt and cause a gap in the fuel, making them a lower risk than any wood fence. Any plastic or wood fence that touches the ground is a high fire risk.

Figure 13. Fuel ladder ignition of vinyl fencing (left) during testing at the IBHS Research Center and (right) following the Waldo Canyon Fire in Colorado in 2012.

For new construction homes, noncombustible materials should be used throughout but at a minimum they should be used in the immediate 5 ft sections attached to the home—any fence design is an acceptable option. For existing fences, combustible sections in the 5 ft zone attached to the home should be replaced with noncombustible materials, as shown in Figure 14.

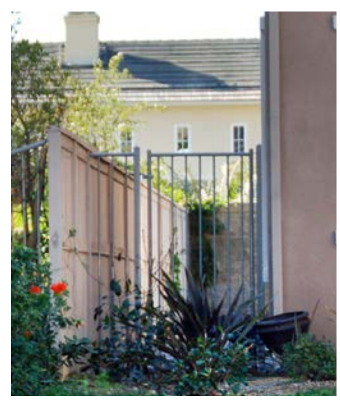


Figure 14. Replace combustible fence sections in the 0–5 ft zone with noncombustible material. Photograph by Stephen Quarles.

Beyond the 0–5 ft home ignition zone, while it may be preferable to have noncombustible materials, the wildfire risk can be reduced through regular cleaning of the windblown debris that accumulates at the base of the fence and between the planks. Homeowners can also consider adding a vertical clearance from the base of their combustible fence if it does not inhibit the functionality of the fence (pet containment). If a fence is being fully replaced for functional or aesthetic reasons, noncombustible materials are the best option, followed by plastic lattice, then hardwood. Plastic privacy and softwood fences should be avoided.

25 Maranghides A., McNamara D. (2011) Wildland urban interface Amarillo fires report #2 – assessment of fire behavior and WUI measurement science, NIST technical note, National Institute of Standards and Technology, Gaithersburg, MD USA, vol 1909, p 2016
26 IBHS/NFPA factsheet on fences
27 Johnsson E., 2019 WUI Encyclopedia, Fences and Accessory Structures
28 Leonard J., Blanchi R., White N., Bicknell A., Sargeant A., Reisen F., Cheng M. (2006) Research and investigation into the performance of residential boundary fencing systems in bushfires, CMIT-2006-186

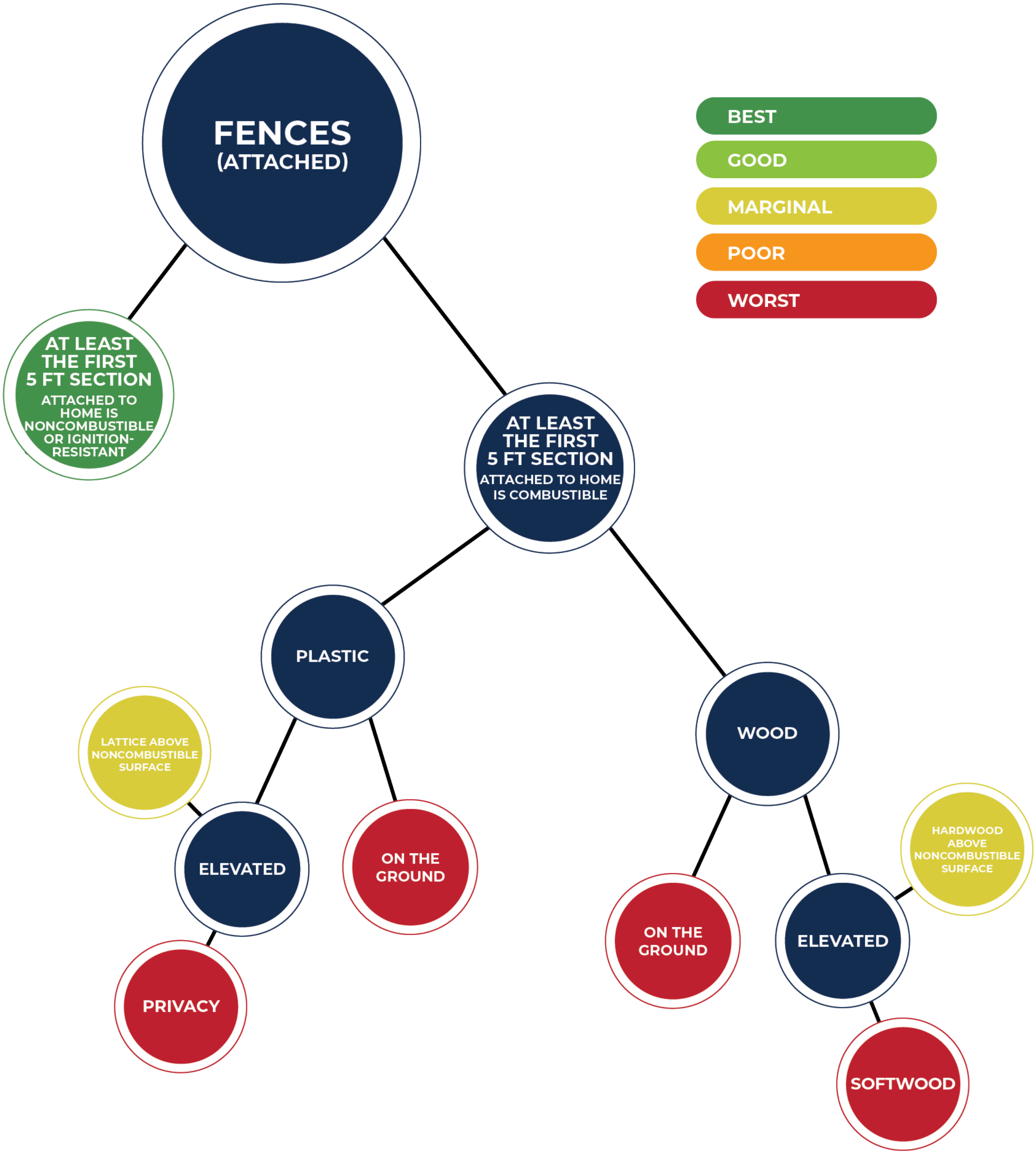


Figure 12. Fences roadmap.

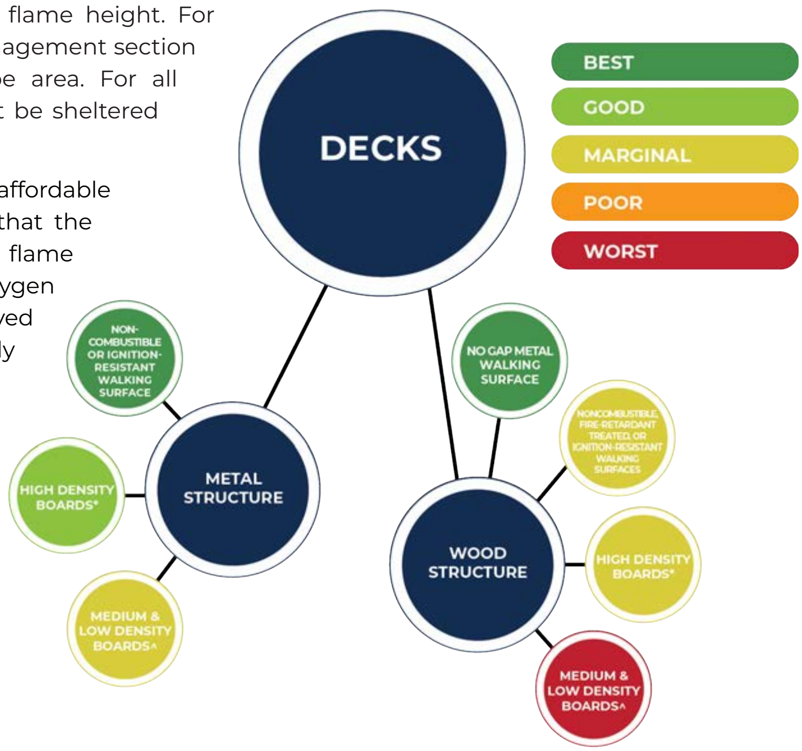
DECKS

Studies by IBHS and others have shown that attached decks can ignite from above-deck ember exposure and underdeck flame exposure.[29,30] This provides a pathway for fire to spread from a burning deck to a home. The burning intensity depends on available fuel above and underneath the deck, wind speed, and deck material. Furniture (especially wicker) and items such as hot tubs, charcoal, lighter fluid, propane tanks, lumber, etc., can cause debris and embers to accumulate around them. These items can also act as additional fuel for the fire.

The roadmap for decks (Figure 15) focuses on the vulnerability based on design and material of the deck. IBHS research has demonstrated that combustible joists provided a potential pathway for fire spread towards a home, whether through above-deck ember ignition or from an underdeck flame impingement.[29] Underdeck flame impingement (caused by ignition of stored combustible material underneath the deck) resulted in a more aggressive fire spread because joists are the lowest horizontal part of the deck assembly and more susceptible to short underdeck flames, and they support the entire walking surface of the deck. Therefore, a noncombustible substructure limits the ability of short flames to ignite the walking surfaces. If flames cannot reach the underside of the deck, the deck only needs to resist an above-deck ember exposure. IBHS research[30] showed that embers accumulated between the boards were incapable of igniting high-density deck boards such as plastic composite, ipe, and other tropical hardwoods.

For new decks, a metal substructure with noncombustible walking surfaces (lightweight concrete, tile, metal) should be used. The next best option is high-density deck boards. For existing decks less than 4 ft from the ground, a vertical 1/8-in. mesh screening should be installed around the outer edge of the deck to limit debris accumulation and ember intrusion. For existing decks higher than 4 ft, a defensible space should be maintained in the underdeck area to minimize flame height. For decks on a slope, follow the Fuel Management section recommendations in the downslope area. For all decks, combustible accessories must be sheltered when wildfire is threatening.

Our new research in 2021[31], provides an affordable retrofit option. The research shows that the vulnerability of decks to underdeck flame can be reduced by limiting the oxygen supply for the fire. This can be achieved by using a new deck system specifically engineered to be installed with no gap between the boards. Flame is a gravity driven phenomenon and it always tends to stretch up vertically. By blocking its pathway, the amount of available oxygen for the burning joists reduces and the potential risk of a burning deck against a house is minimized.



* - Plastic composites, ipe, tropical hardwood

^ - Redwood, red cedar, southern yellow pine

Figure 15. Decks roadmap.

29 Maranghides A., McNamara D., Vihnanek R., Restaino J., Leland C. A Case Study of a Community Affected by the Waldo Fire – Event Timeline and Defensive Actions [Internet]. Gaithersburg, MD: 2015

30 Quarles S.L., Standohar-Alfano C.D. Wildfire Research Ignition Potential of Decks Subjected to an Ember Exposure Ignition Potential of Decks Exposed to Embers Technical Report. 2018

31 https://ibhs.org/wp-content/uploads/wpmembers/files/Addendum_Deck_Ignition-Testing_11-17-2021.pdf

BUILDING SHAPE

Figure 16. Mulch, shrubs, and combustible siding led to a large fire in a reentrant corner of a test home during an IBHS demonstration in 2011.

The walls of a home stagnate the wind, which, like fences, often causes debris and embers to collect. This is further exacerbated by complex building shapes with reentrant corners (Figure 7). An IBHS demonstration in 2011 highlighted the reentrant corner vulnerability when combustible siding, vegetation, and mulch are present, and the largest and most severe flame exposure occurred in this area, as shown in Figure 16. IBHS post-event investigations of the 2007 Witch Creek wildfire in California[32] and the 2012 Waldo Canyon wildfire in Colorado[33] identified reentrant corners as a vulnerability because they serve as a place to collect debris and embers. A complex shape that includes a bay window or bumpout also creates a vulnerability if it is open below,[32] providing a place for debris or embers to accumulate.

The roadmap framework for building shape (Figure 17, p. 22) is fairly simple, and ultimately comes down to the shape itself, as well as the materials that are attached or adjacent when there is a complex shape. Simple building shapes, such as squares, rectangles, or circles, do not have a reentrant corner, and are thus less risky for wildfire. A complex shape with no combustibles in the reentrant corner can be a good option. A complex shape with noncombustible enclosed bay windows is also an option. Reentrant corners with combustible siding are highly vulnerable, especially if there is a window, door (see Walls section), deck, and/or combustible mulch or vegetation in the corner as shown in Figure 18.

Figure 18. Example of a reentrant corner with combustible siding, windows, bark mulch, and noncompliant vegetation in the corner, which can make a home more vulnerable to wildfire.

For new construction, the best option is to use a simple building shape and avoid the use of reentrant corners or open bay windows. An alternative would be to use only noncombustible siding in any reentrant corners and to ensure bay windows are enclosed (see Figure 7). For existing homes, it would be unrealistic to remove a reentrant corner or bay window unless the homeowner was doing a major renovation to increase their home's size. For existing homes, the best options are to:

- Replace wall claddings in the corner with noncombustible materials
- Replace any windows or doors in the corner that do not comply with Chapter 7A with windows or doors that do comply (see Walls section)
- Remove combustible decks in the corner
- Remove combustible landscaping materials in the corner
- Enclose bay windows with noncombustible materials

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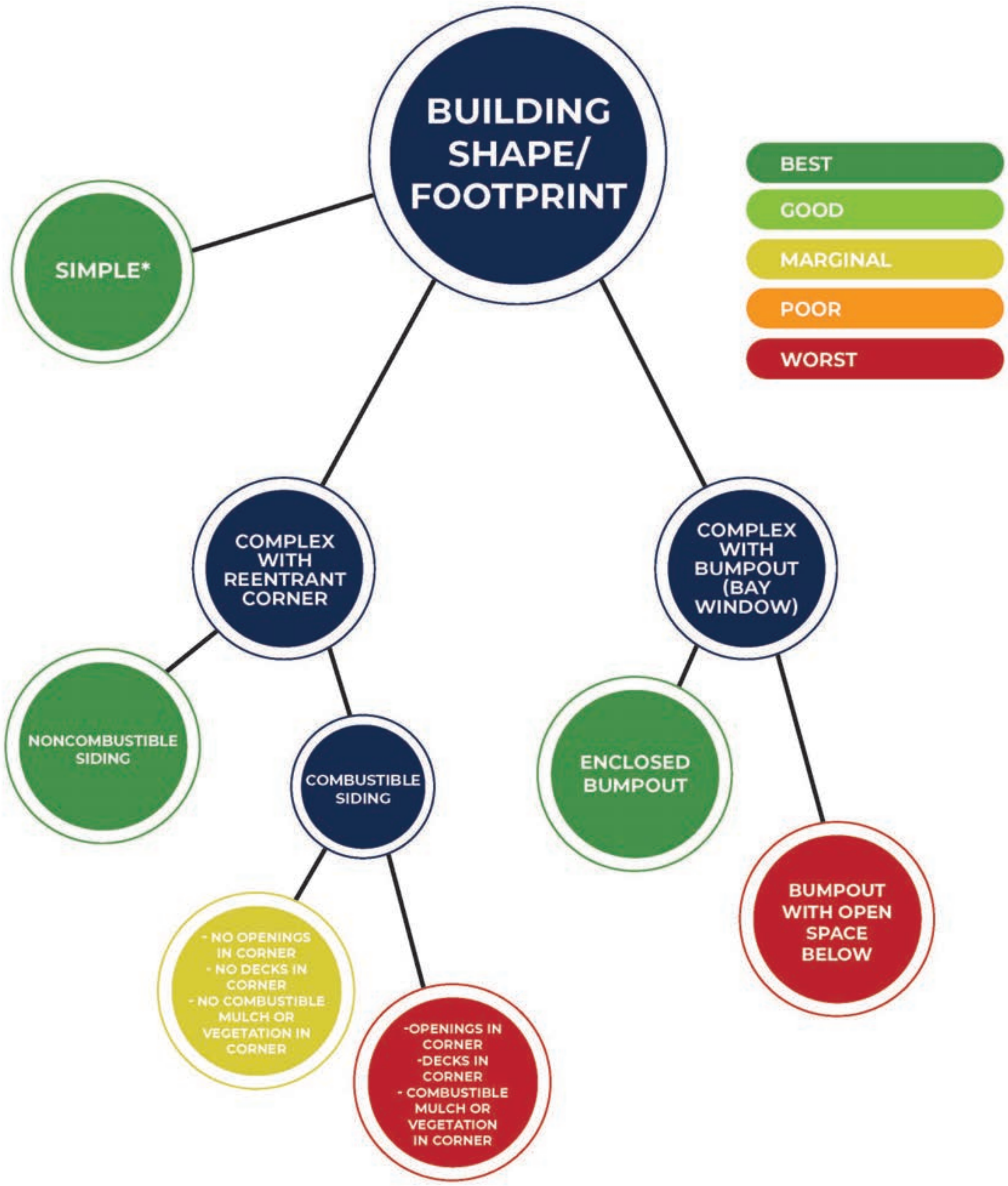
32 IBHS (2008). "Mega Fires: The Case for Mitigation," Insurance Institute for Business & Home Safety, Tampa, FL, 48 pp.
33 Quarles, S., P. Leschak, R. Cowger, K. Worley, R. Brown, C. Iskowitz (2013). "Lessons Learned from Waldo Canyon," Mitigation Assessment Team Findings, Fire Adapted Communities, 48 pp.



*SQUARE, RECTANGLE, CIRCLE, ETC.

Figure 17. Building shape roadmap.

WALLS

For this report walls include the following components:

- Base sheathing material and cladding (siding)
- Openings such as windows and doors

The roadmap for walls (Figure 19) first evaluates whether there is a 6-in. vertical noncombustible zone between the wall and the ground, including siding, sheathing, and framing. If this zone does not exist, the walls are considered to be highest risk no matter what other features are present. This 6-in. vertical noncombustible zone has the highest importance because even if noncombustible siding is used, combustible sheathing is still commonly used behind the cladding as shown in Figure 20. This combustible sheathing can meet ignition sources such as burning mulch or embers

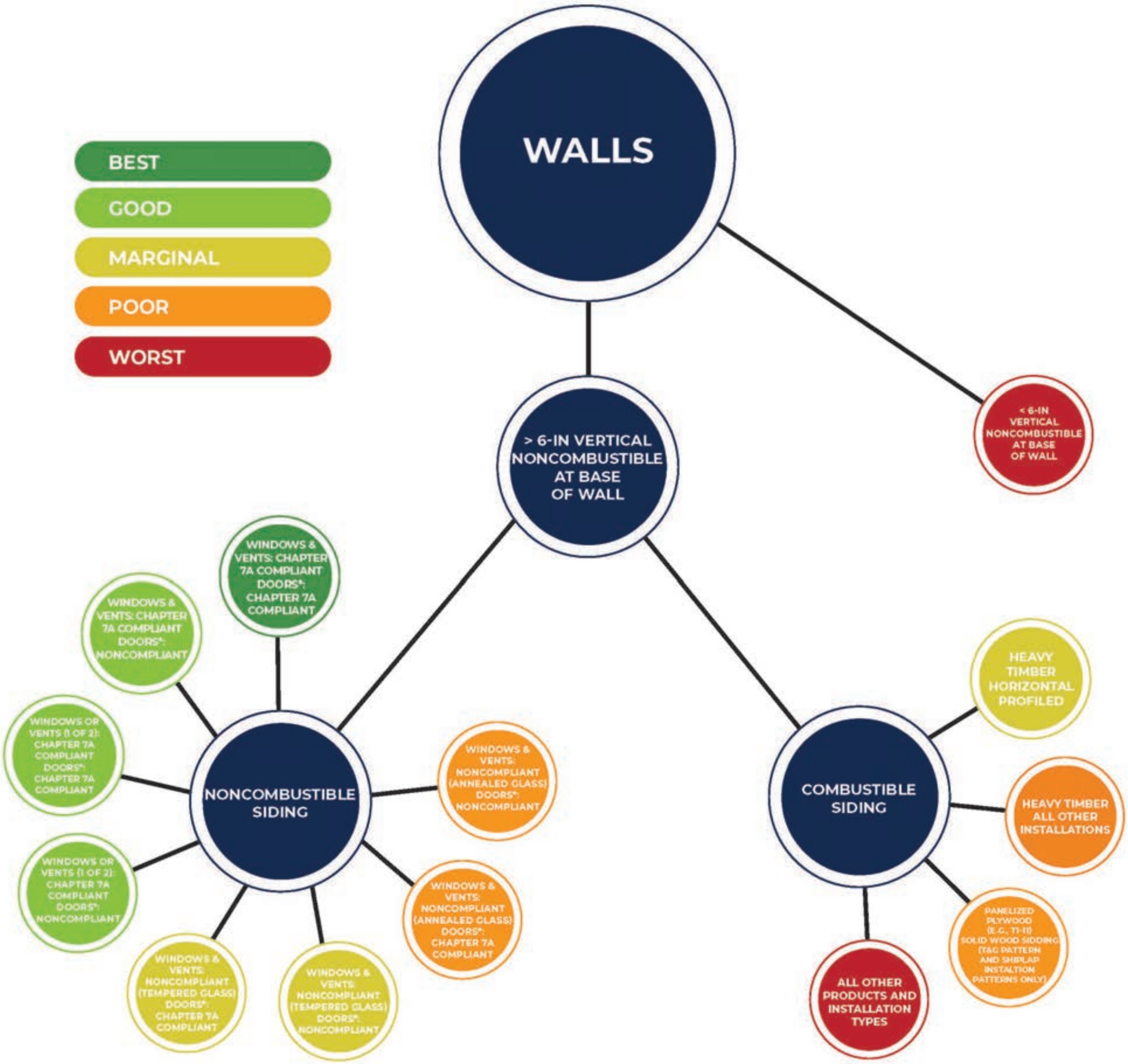


Figure 19. Walls roadmap.

* - Pedestrian & garage

***Figure** 20. Wall details show that even with noncombustible siding, combustible sheathing and wall framing can be exposed. Without the 6-in. vertical noncombustible zone, the sheathing and framing are susceptible to ember accumulation or may be in contact with combustible fuels at the base of the wall.*

that accumulate at the base of the wall posing a high risk to the structure.[35]

Figure 21. Gap between noncombustible siding and ground where debris and embers can accumulate.

In certain cases, as shown in Figure 21, door enclosures might be combustible and fall within 6 in. of the ground. While this type of feature adds a potential vulnerability, if it makes up a very small portion of a wall, a home can still be considered to have a 6-in. vertical noncombustible zone for the purposes of the roadmap. The risk of these combustible elements is considered in other parts of the walls roadmap (i.e., through Chapter 7A compliance of doors and windows).

The next most critical parameter for wall vulnerability is the siding material. In most instances, combustible siding materials pose the highest risk to the wall. However, expert opinion based on experimental observations [34,35,36] showed that specific combustible materials, or combustible materials with a specific installation, can reduce the risk to the wall marginally as indicated in the roadmap. In the case of solid wood siding, two specific installation patterns have been shown to reduce vulnerability:[33] tongue and groove; and shiplap (see Figure 22).

Building openings such as windows, doors, and vents are also vulnerable to windblown embers, radiant heat, and direct flame contact from wildfires. For all openings, Chapter 7A compliant windows, vents, and doors are the best option to reduce the risk due to wildfires. Based on expert opinion derived from experimental tests, windows and vents pose a greater risk to a home than doors.

34 Heavy Timber from char rate information and acceptance in building codes. For char rate, Wood Handbook, Chapter 15
35 ASTM E2707, Standard Test Method for Determining Fire Penetration of Exterior Wall Assemblies Using a Direct Flame Impingement Exposure – Commentary
36 Quarles S.L., Gorham D.J. (2019) Sidings, Windows, and Glazing. In: Manzello S. (eds) Encyclopedia of Wildfires and Wildland-Urban Interface (WUI) Fires. Springer, Cham

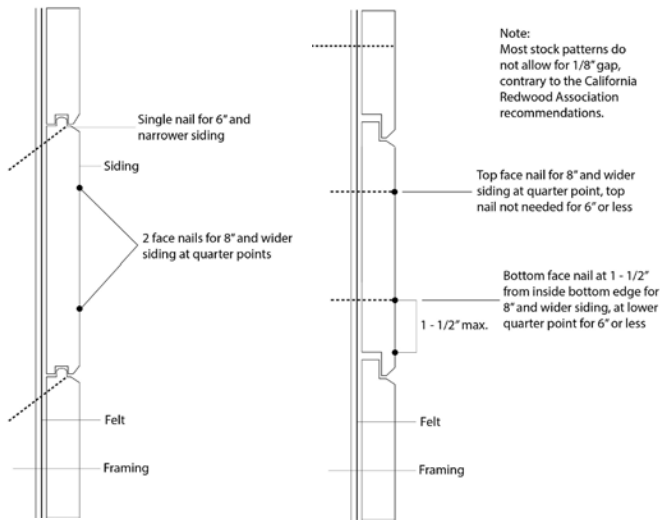


Figure 22. Installation details for solid wood siding that have a reduced vulnerability: (a) tongue and groove (T&G) siding pattern; and (b) shiplap siding pattern.

Windows are a vulnerable area of walls due to the potential for glass breakage from direct flame contact or radiant heat, particularly if the glass in the windows is annealed glass. A study by Babrauskas[37] has shown that tempered glass is more than four times more resistant to radiant heat exposure than annealed glass. Annealed and tempered glass are not specifically shown for Chapter 7A compliant windows in the roadmap since it is unlikely an annealed glass window would be able to meet the testing requirements for compliance. However, this detail is shown for noncompliant windows in the roadmap. Windows with tempered glass will have an etched label on the glass (see the example in Figure 23).

Figure 23. Example of etched label found on tempered glass windows. This is typically found in the bottom corner of the window glass.

While glass has typically been found to be the most vulnerable part of a window, one exception is vinyl frame windows without metal reinforcement, where the vinyl frame can deform prior to the glass failing.[38] Figure 24 shows the difference in radiant heat exposure performance for a vinyl frame window with and without the metal reinforcement. Any window whose manufacturer produces an American Architectural Manufacturers Association (AAMA) certified window will have metal reinforcement that mitigates this risk as part of their certification. For the sake of simplicity, this detail was not included in the roadmap.

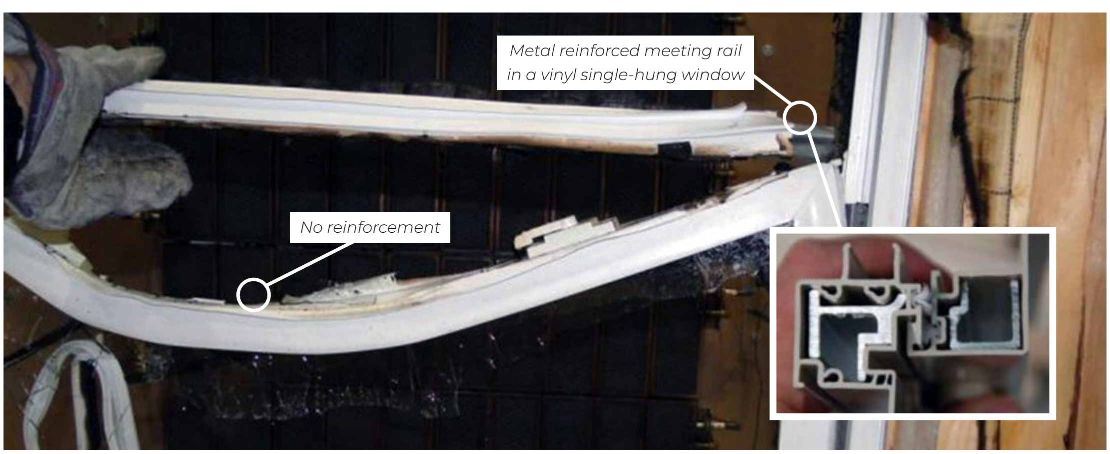


Figure 24. Damage caused by radiant heat on two vinyl window frames, one with no metal reinforcement where the frame failed, and one with metal reinforcement where the frame did not fail.

37 Babrauskas, V. 2003. Ignition Handbook. Fire Science Publishers. Chapter 11, page 533-534
38 Mowrer, F.W. 1998. Window breakage induced by exterior fires. NIST-GCR-98-751. Gaithersburg, MD

The use of Chapter 7A compliant entry and garage doors can reduce the wildfire vulnerability of walls. It is possible for combustible doors to meet the requirements of Chapter 7A, provided they do not burn through within a specified period. Although a compliant noncombustible door would be preferable, the IBHS team did not feel the risk reduction was significant enough to include this type of door in the roadmap. Beyond door type, observations from IBHS experiments have revealed combustible weather stripping or seals around entry doors as being vulnerable to ember attack, which can cause ignition of the door or frame.

Foundation vents can allow both wind-driven embers and flames to enter the building, potentially causing ignition of any combustible materials in crawl spaces. In addition, direct flame contact could ignite the combustible sheathing or structures within crawl spaces. Chapter 7A compliant vents reduce the wildfire risk, as can the use of fine 1/8-in. mesh in vents.[39] However, since the 1/8-in. mesh does not protect against the vulnerability of direct flame contact, it was not included in the roadmap for walls.

For new homes, noncombustible siding should be used. If not, a minimum 6-in. vertical noncombustible zone on the wall should be incorporated and should have very little impact on the design or cost.[40] Using Chapter 7A compliant vents, windows, and doors will reduce the risk in all cases.

For existing homes, it might be impractical to add a 6-in. vertical noncombustible zone to the walls. Therefore, any further mitigation measures to walls themselves will not significantly reduce the overall risk of ignition of the walls as indicated in the roadmap and the building owner should focus on mitigation measures in other areas to reduce their risk, specifically, a meticulously maintained 5-ft noncombustible zone around the perimeter of the home as shown in the Fuel Management roadmap. Adhering to these guidelines can mitigate the added risk of not having a 6-in. vertical noncombustible zone on the wall itself. Once this risk is addressed, replacing combustible siding with noncombustible material should be completed to reduce the risk to walls.

To retrofit wall openings, homeowners should start by replacing windows and vents with Chapter 7A compliant options to reduce the risk, followed by replacing doors. Although replacing all windows and doors on a home is a significant expense, unlike siding, this is something that can be done incrementally (i.e., one window or door at a time) to reduce the risk.

39 Quarles, S.L. (2017). "Vulnerability of Vents to Wind-Blown Embers," Insurance Institute for Business & Home Safety, Tampa, FL, 24 pp.
40 https://headwaterseconomics.org/wp-content/uploads/building-costs-codes-report.pdf

ROOFS

The phrase "having a roof over your head" is often used to describe the most basic level of need and, as a building component, it is a top priority for IBHS.[41] The roof is a large and complex part of a home and factors that affect its performance in a variety of hazards include shape, complexity, coverings, and features such as skylights and gutters, as shown in the roadmap in Figure 25 (roof vents are addressed in a separate section). In addition to wildfire-resistant building materials on the roof, constant attention is required to remove debris to lower the wildfire risk of a home.

A common metric for evaluating wildfire resistance of a roof is the classification from a standard test method.[42] The standard results in a Class A (most resistant), B, or C (least resistant) fire rating. Thus, a Class A–rated roof is less risky than B or C, or worse, an unrated roof covering. However, a known limitation of using standard testing results is that they may not be representative of real-world conditions for buildings subject to natural hazards.

Asphalt shingles are the most common roof covering option for residential structures in the United States. Other noncombustible roof coverings such as tile and metal may be more common in certain areas, such as Southern California where tile is popular. Metal coverings provide a continuous noncombustible surface so that if debris accumulates and is ignited by embers it will not contribute to the burning. While tiles are noncombustible, they are susceptible to cracking

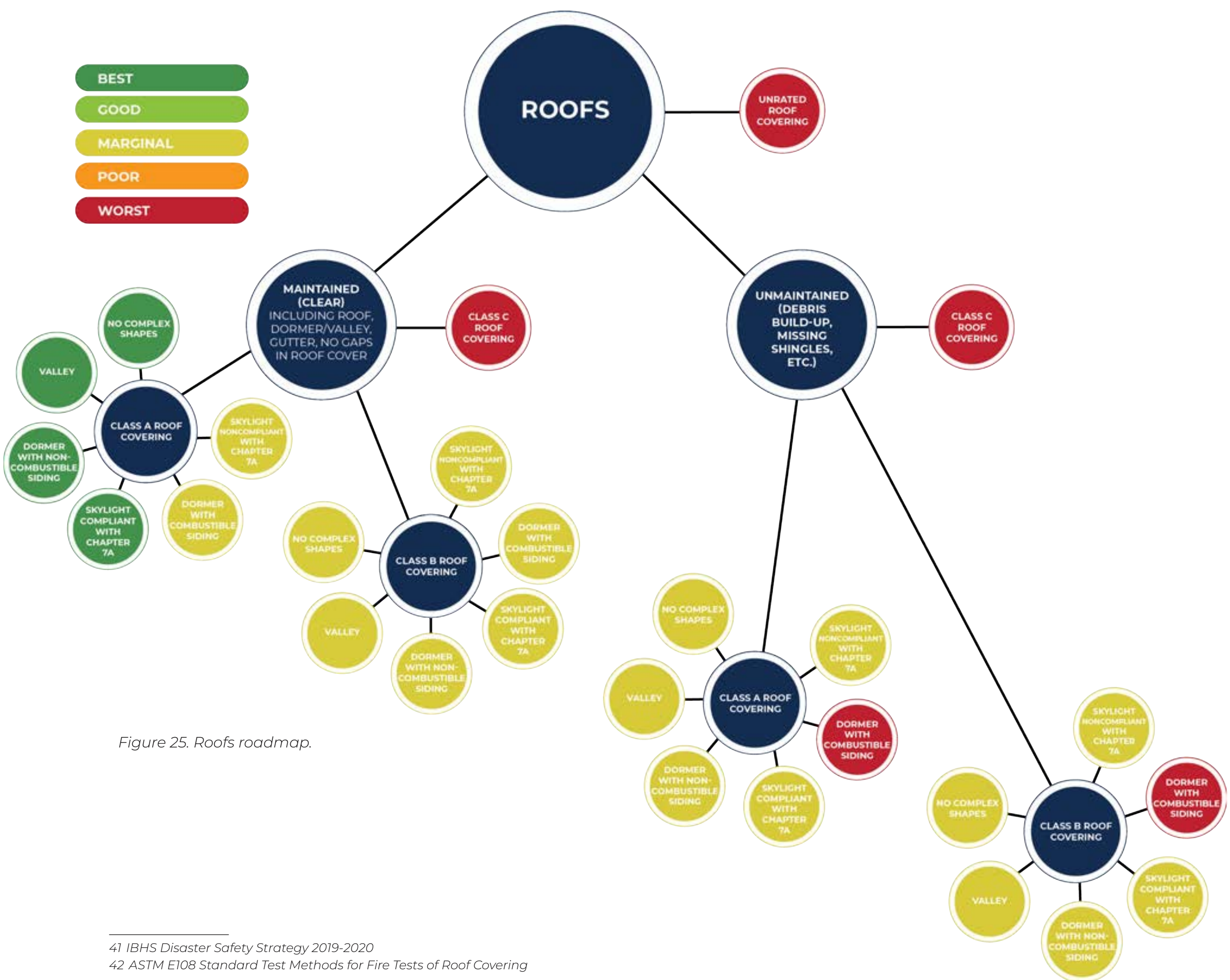


Figure 25. Roofs roadmap.

41 *IBHS Disaster Safety Strategy 2019-2020*
42 *ASTM E108 Standard Test Methods for Fire Tests of Roof Covering*

naturally over time and from events such as impacts and earthquakes. Cracks and crevices between tile are vulnerable to debris and ember accumulation.[43] Homes with a bird stop barrier on tiles at the roof edge are less vulnerable than those with open ends of tiles exposed.[31]

Vegetative debris accumulation is the one of the most critical vulnerabilities for a roof, second only to having an unrated roof covering. Overhanging vegetation can drop debris directly on a roof, while the wind can carry debris to a roof, which accumulates in corners and crevices (Figure 26). These areas such as gutters, roof valleys, and next to dormers, are the same as those where embers can accumulate and result in ignition of those fuels causing direct flame contact on the roof. A properly maintained, Class A roof is the only option to achieve the best risk category for roofs.

Figure 26. Vegetative debris (pine needles) accumulated in a gutter (top, Source: National Fire Protection Association®) and on a roof next to a dormer feature (bottom).

A simple roof shape is preferred over a complex shape because there are fewer locations for debris and embers to accumulate. Based on anecdotal evidence, valleys are slightly less vulnerable than other complex roof features such as dormers and other more vertical surfaces. Roof-mounted equipment such as HVAC, photovoltaic (PV) panels, and skylights add complexity to roof shape and provide places where debris can accumulate. Chapter 7A specifies glazing and framing requirements for skylights. As with wall windows, they should be multi-pane with at least one layer being tempered glass to reduce risk. Plastic glazing introduces a vulnerability as it can easily melt and create an opening for embers and flames to enter a home.

In the design of new construction homes, a metal roof covering is preferred. At a minimum, a Class A–rated product such as asphalt shingles should be used. Roof shape should be simple, minimizing the features that create potential for debris or ember accumulation.

There are retrofit options available to enhance the wildfire resistance of the roof for existing homes. For buildings with combustible roof coverings, such as wood shingles, one of the highest priority retrofits should be to replace it with a Class A covering. Combustible siding on dormers should be replaced with a noncombustible material (see Wall section). Installing metal drip edges where gutters are attached to a roof can provide some additional protection at this vulnerable location. Homeowners or occupants should have a plan to regularly remove debris that accumulates on the roof and in gutters.

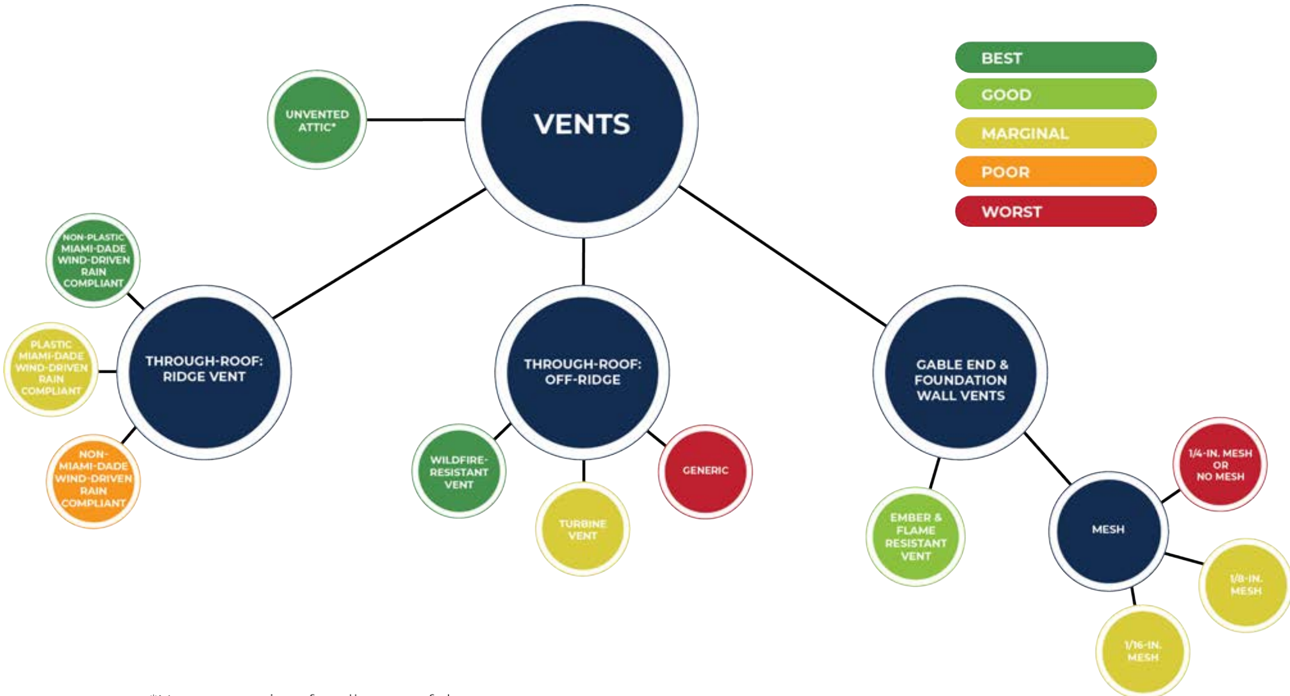
43 *Manzello, S.L., Hayashi, Y., Yoneki T., Yamamoto, Y. (2010). Quantifying the vulnerabilities of ceramic tile roofing assemblies to ignition during a firebrand attack. Fire Safety Journal. 45(1): 35-43*

VENTS

Vents provide a place for windborne debris and embers to collect or enter a home. The roadmap for vents (Figure 27) considers details such as:

- Whether the attic is vented
- The type of vents
- The size of mesh used in vents

Homes with an unvented attic are the least vulnerable to wildfire,[17, 44] but unvented attics are not appropriate for certain areas of the United States.[17] An IBHS experimental study showed there



*Not appropriate for all areas of the country

Figure 27. Vents roadmap.

were good ridge and off-ridge roof vents that performed well in wildfire experiments. However, there were a few key details that affected performance, including whether the vent was a wildfire-resistant vent or a Miami-Dade wind-driven rain compliant vent[38]. Many ridge vents are made of plastic, which can melt, and are not allowed in Chapter 7A, so plastic Miami-Dade compliant ridge vents should not be used in wildfire-prone areas. Many ridge vents also have an external baffle to prevent ember entry, but the baffle provides a place for debris to collect and are hard for a homeowner to see and therefore know when they need cleaning. Vents that are designed to resist flame intrusion[45] are available.

Other off-ridge vents tested in the IBHS experiments included turbine vents and generic vents. Turbine vents performed well[38] and will perform better as wind speeds increase, but maintenance is required. Generic off-ridge vents performed poorly in the experiments[38]. A study by Manzello et al.[46] found gable end vents to be vulnerable to ember entry. Wildfire-resistant gable end vents did not perform as well as ridge or wildfire-resistant off-ridge vents in the IBHS experiments[38] because

44 Quarles, S.L., TenWolde, A. (2005). Attic and Crawlspace Ventilation: Implications for Homes Located in the Urban-Wildland Interface
45 ASTM International (2014). ASTM E2886 / E2886M-14, Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement, ASTM International, West Conshohocken, PA, 14 pp.
46 Manzello, S.L., S.H. Park, S. Suzuki, J.R. Shields, Y. Hayashi (2011). Experimental Investigation of Structure Vulnerabilities to Firebrand Showers. Fire Safety Journal. 46(8): 568-578

gable vents provide a vertical face for ember entry. A 1/8-in. or finer mesh in the vents is considered the best option, while courser mesh is not recommended and no mesh at all is the riskiest scenario.

There have been several vent designs introduced into the market to resist flames in addition to embers. These use baffle designs, steel wool, or intumescent paint coatings. However, previous IBHS experiments have shown that coatings weather away quickly and may not offer the protection intended.[47]

For new construction, the feasibility of an unvented attic could be explored, but for most areas of the United States, the best option is a design that uses a metal Miami-Dade wind-driven rain compliant ridge vent or a wildfire-resistant off-ridge vent.

For existing homes, the first step to reduce risk should be to add 1/8-in. or finer mesh screens to existing attic vents, which is a low-cost DIY solution. For additional protection, a homeowner could change out plastic ridge, gable end, turbine, or generic vents and replace them with metal Miami-Dade wind-driven rain compliant ridge vents or wildfire-resistant off-ridge vents. However, the cost and complexity of this type of retrofit might make it impractical. The price and complexity for converting to an unvented attic would be even higher.

47 *Bahrani, B., V. Hemmati, A. Zhou, S.L. Quarles. (2018). Effects of Natural Weathering on the Fire Properties of Intumescent Fire-Retardant Coatings. Fire and Materials Journal. 42(4): 413-423*

EAVE OVERHANGS

The roadmap for eaves (Figure 28) considers:

- Whether there is an eave overhang, and if so, whether the eave overhang is closed or open
- The material used to construct the eave
- Ventilation details like those described in the Roof Vents section, such as the size of any screen mesh used

Homes with an unvented attic or no eave overhangs are the least vulnerable to wildfire[17,43] since they limit surfaces for direct flame contact and do not have openings for embers to enter. However, they may not be appropriate or even allowed in some areas, such as high snow-load climates or areas with high rainfall where concerns for wet siding are present.[17] Therefore, most homes will have a vented attic with inlet ventilation in the eave. The outlet ventilation options are discussed in the Roof Vents section.

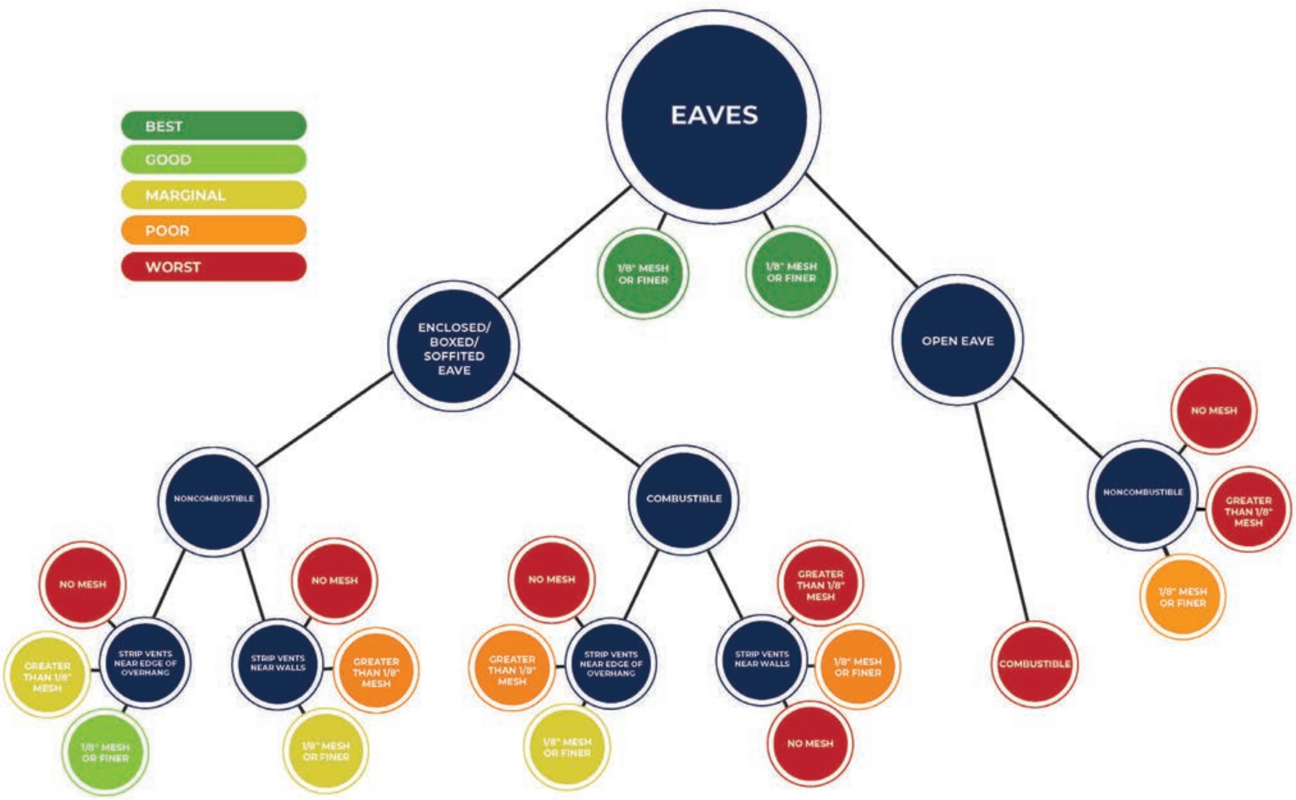


Figure 28. Eave overhang roadmap.

The IBHS Witch Creek Fire investigation[31] and a 2011 IBHS wildfire demonstration showed that eaves that are boxed, enclosed, or soffited and made of noncombustible materials are preferred over those with combustible materials, or worse, open eaves. Open eaves are especially vulnerable to flame contact because rafter tails are exposed and embers can collect where blocking and rafter tails intersect.[31] Also, their wall-mounted attic vents provide a vertical face for ember entry.[38] In soffited eaves, experts agreed strip vents located near the edge of the overhang are preferred over those near the walls to reduce the likelihood of ember entry. A minimum of 1/4-in. mesh in vents is required by the International Code Council's International Wildfire-Urban Interface Code (ICC IWUIC)[48] and the National Fire Protection Association (NFPA) Standard 1144.[49] However,

48 *International Code Council (2015). International Wildland-Urban Interface Code. Washington, DC*

49 *National Fire Protection Association (2018). Standard for Reducing Structure Ignition Hazards for Wildland Fire. Quincy, MA*

after post-event investigations in the 2007 Witch Creek[31] and 2012 Waldo Canyon[32] fires, IBHS has recommended covering vents with 1/8-in. or finer mesh, and Chapter 7A of the California Building Code requires vents to be covered with 1/16-in. to 1/8-in. noncombustible mesh. Larger mesh sizes increase the vulnerability to ember entry and vents with no mesh are the most vulnerable. An experimental study on the wildfire ember resistance of vents showed that an open eave with 1/4-in. mesh in its vents performed worse in resisting ember entry into the attic when compared to a soffited eave with 1/8-in. mesh.[38]

For new construction, the feasibility of an unvented attic or no eave design could be explored but would require careful attention to code and likely the assistance of a building science specialist during the design process. A design that includes a soffited eave with noncombustible material, strip vents near the edge of the overhang, and 1/8-in. or finer noncombustible mesh is the preferred solution for all climates.

For existing homes, depending on the current state of the building, there are several retrofits that could be completed with varying levels of complexity, effort, and cost. For homes with open eaves, the first thing to do is to enclose the eave with a noncombustible material. This is easier, more practical and cost-effective when compared to converting a vented attic to an unvented one. While making that change, the vents should be installed so that they are near the edge of the overhang and include 1/8-in. or finer noncombustible mesh. For homes that already have a soffited eave, the first step should be to replace combustible materials with noncombustible materials, followed by changes to the vent location and mesh.

RECOMMENDATIONS

The following sections summarize existing conditions that are unacceptable and must be addressed immediately, along with those that must be addressed as soon as time and resources permit. Recommendations for new builds and existing homes are also discussed, along with limitations. In many instances, an individual homeowner can only do so much, and their vulnerability is affected by the choices of their neighbors. Community-wide approaches are the best option to protect homes from wildfires, especially when homes are closely spaced.

CRITICAL BUILDING CONDITIONS AND COMPONENTS

The following conditions are considered to be unacceptable, and all must be addressed before any significant progress can be made in reducing wildfire risk. Where home spacing is very close, an individual owner will be limited to what they can do up to their property line.

REQUIRED MINIMUM UPGRADES

The following tasks must be completed as soon as time and resources allow, to continue reducing the wildfire risk to the extent possible. Where home spacing is very close, an individual owner will be limited to what they can do up to their property line.

Fuel management

- Remove double fence runs to prevent debris accumulation between them and share a single fence run with neighbors.
- Meticulously maintain defensible space if:
  - » Building is less than 5 ft from large fuels on neighboring properties (shed, fence, wood pile, vehicle)
  - » Walls have combustible siding
  - » Building is a complex shape with reentrant corners with openings or open bay windows
- Regularly clear debris on the roof, and in gutters and vents.
- Replace combustible mulch with a noncombustible material in the 0–5 ft zone around the home.
- Enclose low-elevation decks with 1/8-in. mesh screens or solid noncombustible walls to prevent debris accumulation in a space that is difficult to clean.
- Shelter large fuels such as hot tubs, grill supplies (charcoal, lighter fluid, propane tanks), and patio furniture off decks and away from the home when a wildfire is threatening.
- Move cars and recreational vehicles 30 ft away from the home when wildfire is threatening.

Fences

Replace the first 5-ft section of a combustible fence that attaches to the home with a noncombustible section.

NEW BUILDS

When designing and building a new home, there are many choices that can be implemented to reduce the wildfire risk. Additionally, community planning at the county, city, or even homeowners' association level, that restricts the use of combustible materials, spreads homes out, and requires maintenance can further help to reduce the risk of a wildfire igniting a home and spreading to others. These options are described in the following sections.

Fuel Management

VEGETATIVE

- Regularly clean up surface fuels (windblown debris, leaves, and pine needles).
- Plant only low-flammability vegetation with adequate horizontal and vertical distance in all three zones of defensible space.
- Do not plant vegetation aligned with the corner line of the home in the 5–30 ft zone.
- Do not plant anything in the 0–5 ft zone. Use only hard surface or rock mulch in this zone.

STRUCTURAL

- Do not place sheds larger than 25 sq ft within 30 ft of the home.
- Do not place accessory structures (sheds, gazebo) aligned with the corner line of the home within 30 ft of the home.
- Share fences between neighbors to avoid accumulation of surface fuels between them.
- Shelter deck accessories (hot tub, wicker furniture, charcoal, lighter fluid, propane tanks, lumbers, etc.) when wildfire is threatening.
- Move cars 30 ft away from the home when wildfire is threatening.
- Design parking areas for recreational vehicles (RV, boats, campers) in the community at least 100 ft away from the closest structure.

Fences

Use noncombustible or ignition-resistant materials for fences.

Decks

- Use metal substructure.
- Use noncombustible walking surfaces (lightweight concrete, tile, or metal), if available or treat underdeck areas in the same manner as the 0–5 ft defensible space zone.
- If noncombustible walking surfaces are not available, use high-density deck boards such as plastic composites, ipe wood, or a similar tropical hardwood.
- When a wildfire is threatening, shelter deck accessories (hot tub, wicker furniture, charcoal, lighter fluid, propane tanks, lumbers, etc.) when wildfire is threatening.

Building Shape

- Avoid complex shapes with reentrant corners and open bay windows.

OR

- Use only noncombustible siding in reentrant corners and enclose all bay windows.

Walls

- Use noncombustible material through all layers of the wall for at least 6-in. above the ground.
- Use noncombustible siding products.
- Use only Chapter 7A compliant windows, vents, and doors.

Roofs

- Avoid complex roof designs that create areas for debris and ember accumulation.
- Use only a Class A roof covering, preferably metal.
- Use only Chapter 7A compliant skylights.

Vents

- Explore feasibility of unvented attic.
- If venting is necessary, use metal Miami-Dade wind-driven rain compliant ridge vents or wildfire-resistant off-ridge vents.

Eave Overhangs

- Explore feasibility of an unvented attic or no-eave design.
- If venting and eaves are necessary, create a soffited eave with all of the following:
  - » Noncombustible material
  - » Strip vents near overhang edge
  - » 1/8-in. or finer noncombustible mesh

A research paper published by Headwaters Economics highlighted ways to build homes that are more wildfire-resistant by focusing on the roof, walls, deck, and near-home landscaping. The study showed that while some wildfire-resistant components would be costlier, others were actually cheaper.[39]

EXISTING HOMES

The choices for retrofitting existing homes to reduce wildfire risk are fewer than for new designs, and some can be costly or time-consuming. However, there are some steps that can be taken. These actions are outlined in the following sections.

Fuel Management

VEGETATIVE

- Regularly clean up surface fuels (windblown debris, leaves and pine needles).
- Maintain adequate horizontal and vertical spacing in all three zones of defensible space.
- Remove high-flammability shrubs aligned with the corner line of the home in the 5–30 ft zone.
- Remove plants from the 0–5 ft zone. Use only hard surface or rock mulch in this zone.

STRUCTURAL

- Move structures larger than 25 sq ft at least 30 ft from the home. For smaller structures, do not align them with the corner line of the home.
- Remove one layer of a double-layer fence.
- Shelter deck accessories (such as a hot tub, wicker furniture, charcoal, lighter fluid, propane tanks, or lumber) when wildfire is threatening.
- Move cars 30 ft away from the home when wildfire is threatening.
- Relocate recreational vehicles (RV, boats, campers) at least 30 ft away from the home when wildfire is threatening. Maintain defensible space around them.

Fences

- Replace the first 5 ft of softwood or plastic privacy fences attached to the home with a noncombustible fence.
- Consider adding a 6-in. vertical clearance from the ground if it does not inhibit the functionality of the fence (pet containment).
- Regularly clean up accumulated windblown debris from the base of the fence.

Decks

- Install a vertical 1/8-in. mesh screening around low (less than 4 ft high) decks.
- Treat underdeck areas in the same manner as the 0–5 ft zone of defensible space.
- When wildfire is threatening, shelter deck accessories (such as a hot tub, wicker furniture, charcoal, lighter fluid, propane tanks, or lumber).

Building Shape

- Replace wall claddings in corners with noncombustible materials.
- Replace any windows or doors in the corner that do not comply with Chapter 7A with those that do comply.
- Remove decks in the corner.
- Remove combustible landscaping materials in the corner.
- Enclose bay windows.

Walls

- Replace combustible siding with noncombustible siding.
- Replace windows that do not comply with Chapter 7A with those that do, or at least ensure all windows use tempered glass.
- Replace vents and doors that do not comply with Chapter 7A with those that do.

Roofs

- Replace Class C or unrated roof covers with a Class A roof, preferably metal.

- Regularly remove debris from roof and gutters.
- Replace combustible siding on dormers with noncombustible siding.
- Replace skylights that do not comply with Chapter 7A with those that do comply.

Vents

- Add 1/8-in. or finer noncombustible mesh on existing attic vents.
- Replace plastic ridge, gable end, turbine, or generic through-roof vents with metal Miami-Dade wind-driven rain compliant ridge vents or wildfire-resistant off-ridge vents.

Eave Overhangs

Enclose open eaves with, or replace existing eaves with

- Noncombustible material
- Strip vents positioned near overhang edge
- 1/8-in. or finer noncombustible mesh

LIMITATIONS

Despite the best science and roadmaps presented here, none of the recommendations will result in a fireproof house. There are still details about how wildfire impacts homes and communities that are not well understood (see Knowledge Gaps section). A community-wide approach to wildfire mitigation in suburban areas is essential to reduce the likelihood of fires entering and then causing home-to-home fire spread. In addition, products evaluated in testing labs may not capture real-world factors, such as impacts of supply chain, full-size construction, and natural aging of components. Although IBHS testing has indicated that Class A asphalt shingle products might not always provide the expected level of protection given real-world exposure, it is the best guidance currently available.

KNOWLEDGE GAPS

In developing the adaptation roadmaps, there were many cases where decisions could be made based on knowledge gained from previous events and experimental testing. In other cases, expert and engineering judgment provided the best guidance due to the scarcity of objective data.

A multidisciplinary research and implementation approach is needed to successfully adapt communities to the threat of wildland fires. Only recently has this approach been applied to wildfires and the components of the fire behavior triangle (Figure 1). Science continues to make significant strides and the roadmaps presented here represent the current state of knowledge. Yet, gaps remain in our understanding of fire dynamics, fire weather at the meso- and microscales, climate, the built environment and, maybe most importantly, human behavior and mitigation activities. Continuing to advance all these elements through multidisciplinary research is vital to being able to model the hazard and the potential outcomes at all scales so that suitable and cost-effective mitigation measures can be developed.

PHYSICAL SCIENCE

The ability to adequately model and determine where wildland fires might occur, and spread is directly tied to understanding key physical science components, including fire dynamics and weather. Additionally, the influence of the changing climate on wildfires has certainly gained attention in the scientific community. While patterns of severe drought and heat waves are becoming well understood, climate attribution studies for wildfires are still in their early stages.[50,51] The physical science research questions that need to be explored are linked to fire dynamics, weather, and climate:

FIRE DYNAMICS AND SPREAD

- What are the details of fire behavior at small, local scales?
- How does convective heat transfer from fire to available fuels? How does this vary between fuel types (vegetative vs. structural)? Can this be measured?
- How does fire spread through complex terrain?
- What are the aerodynamic properties of embers generated from different fuels? How far can they travel ahead of the fire front?
- What is the relationship between ember flux and probability of ignition? Does it vary by receiving fuel conditions?

50 Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam, 2006: Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity, Science, 313, 940-943. doi: 10.1126/science.1128834

51 Dennison, P.E., S.E. Brewer, J.D. Arnold, and M.A. Moritz, 2014: Large wildfire trends in the United States: 1984-2011, Geo. Phys. Res. Lett., 41, 2928-2933. https://doi.org/10.1002/2014GL059576

WEATHER

- What weather conditions support wildland fires?
- How common are events like those observed in the Carr Fire (2017), where plume dynamics resembled a structure more commonly associated with a tornadic thunderstorm?
- How do wildfire plume dynamics match or differ from thunderstorm updraft dynamics?
- How do wildfire plumes interact with the ambient environmental winds producing extreme events?
- How do intense fires alter their own environmental conditions? Where are the boundaries?
- How common are fire whirl features? How do they influence ember transport and fire spread?
- What in-situ observations are needed to help validate model results and their underlying assumptions? How can these be collected?

CLIMATE

- How does climate change impact forest ecosystems? How does changing these ecosystems influence fire behavior?
- What climate change scenarios would result in an increased risk of fire and fire spread? What scenarios would result in a decreased risk and inhibit fire spread?

THE BUILT ENVIRONMENT

Knowledge gaps regarding the built environment range from the community level down to the materials used in individual homes, and the type and arrangement of vegetation. One of the primary questions that research activities are working to answer is:

What combination of mitigation actions (large and small) substantially increase the chance of a home's survival?

Although experimental research can help provide insights into these combinations, other gaps remain in the ability of standardized testing to represent real-world conditions and predict performance.

The roadmaps presented here are focused on individual components of a single structure, but the fuel management roadmap shows that mitigation must be done at the community scale, since the majority of suburban neighborhoods have homes spaced closer than 30 ft. Recently, IBHS participated with several other organizations to conduct full-scale burn experiments on acquired single-family residential structures.[52] Measurements from these experiments suggest that structures spaced 10 ft apart may be highly susceptible to rapid fire spread as all three ignition mechanisms can act on an adjacent structure. At 50 ft of separation, the exposure was reduced. Little is known about the area in between these distances leading to the following question:

- What is the critical structural spacing that either increases or reduces a home's risk of igniting if a neighboring structure is burning? How does the size of the burning structure factor in?
- For existing communities that have homes closely spaced together, what are the best mitigation actions to counter the negative effect of structure spacing?

For other hazards such as hurricanes, strong building codes are used to protect lives and it has been shown repeatedly that strong building codes and strong enforcement can effectively reduce damages from a hurricane.[53,54] WUI codes have been developed and applied to reduce vulnerabilities. However, a recent IBHS survey of WUI codes indicated that the adoption and enforcement of WUI codes is sporadic and highly localized.[55]

52 Regan J., Bryant J., Weinschenk C. Analysis of the Coordination of Suppression and Ventilation in Single-Family Homes. UL Firefighter Safety Research Institute. March 2020
53 http://www.floridabuilding.org/fbc/publications/PrevattUF_FBC_2017_2018_FinalReport-Irma.pdf
54 https://www.fema.gov/media-library-data/20130726-1712-25045-3843/hurricane_s_impact_on_florida_s_building_codes___standards.pdf
55 https://ibhs.org/wildfire/wildfire-building-codes-and-standards/

Scientific research must fill in many of the gaps discussed here to help discern how effective WUI codes can be and how they can be modified to use the most effective methods to keep fire from spreading into and through the built environment.

SOCIAL SCIENCE

Perhaps the most important element in closing research gaps is centered on human behavior. Humans cause over 80% of the wildland fires we see today, while 30 years ago natural ignition mechanisms (i.e., lightning or sparks from rock slides) were the dominant source.[10,11] Population and associated infrastructure growth have introduced more sources of ignition. The result has been a change in the frequency of large fires, especially in the coastal zones of the western United States and east of the Appalachian Mountains.[11,56] The research questions that need to be explored regarding human influences on fire frequency include:

- What human behaviors cause fires? Are these human behaviors occurring more frequently? Or is it driven by population growth into regions where fire is prevalent?
- How are human ignitions altering annual occurrence probabilities? How are suppression activities altering these?

The establishment of the Joint Fire Science Program in 1998 helped spur research into human perceptions of wildland fire.[57] Early social science research efforts focused on the perception of fuel management and the ecological impact of management practices, but more recent research has moved into understanding the perception of risk and understanding the sociological and psychological barriers that lead to action or inaction regarding mitigation measures. A common belief is that people do not take mitigation actions because they do not understand the risk to their life and property. Research has shown that this is not the case and the problem is far more complex.[56,58] Recent work of Meldrum et al. (2015) explored in more detail how beliefs related to attributes of a person's home compared to those of wildfire experts. This study highlighted why the roadmaps presented here are so critical—homeowners significantly underestimated the importance of the local property-level topography, and roofing and siding materials, while their beliefs about the importance of vegetation and attached decks were closer to those of wildfire experts.[57] The principal question to answer is:

Why do people underestimate the wildfire risk of their home, especially for some components over others while understanding the risk of the surrounding lands?

The translation of science into action depends on human behavior. Without action, the best guidance is useless. Action or inaction in adopting risk reduction behaviors is influenced by several factors:

- Personal beliefs
- Psychological factors
- Situational characteristics (such as local ecological conditions, residency status, and the condition of adjacent properties)

Current research suggests that psychological factors are more influential than others.[59,60] An awareness of the risk is certainly necessary, but that alone is not enough to promote widespread action. Factors that influence mitigation are the perceived effectiveness of risk reduction activities and the attitudes of others (i.e., family members, friends, neighbors, or social groups) toward mitigation activities. Fortunately, at the community scale, both formal and informal outreach between government agencies and groups such as homeowners' associations have shown positive

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56 Abatzoglou J.T., J.K. Balch, B.A.Bradley, and C.A. Kolden, 2018: Human-related ignitions concurrent with high winds promote large wildfires across the USA. International Journal of Wildland Fire, 27, 377–386. doi:10.1071/ WF17149

57 McCaffrey, S., J. Toman, M. Stidham, B. Shindler, 2012: Social science research related to wildfire management: an overview of recent findings and future research needs, International Journal of Wildland Fire, 22, 15-24, https://doi.org/10.1071/WF11115

58 Meldrum, J.R., P.A. Champ, H. Brenkert-Smith, T. Warziniack, C.M. Barth and L.C. Falk, 2015: Understanding gaps between the risk perceptions of wildland-urban interface (WUI) residents and wildfire professionals, Risk Analysis, doi: 10.1111/risa.12370

59 Absher, J.D.; and J.J. Vaske, J.J., 2006: An analysis of homeowner and agency wildland fire mitigation strategies. In J. G. Pedan, and R. M. Schuster eds., Proceedings of the 2005 northeastern recreation research symposium. GTR NE-341. Newtown Square, PA: USDA Forest Service, Northeastern Research Station. 231-236

60 Vaske, J.J., J.D. Absher, and K. Lyons,2016: Homeowners' Wildland Fire Beliefs and Behaviors: Results from Seven Colorado Wildland-Urban Interface Counties. USDA-Forest Service, Pacific Southwest Research Station, 37 pp.

outcomes in building trust between stakeholders.[61,62] However, beliefs of others are balanced with a homeowner's personal beliefs about their property. The tradeoffs between preparedness and amenities, personal privacy, neighbors' properties and other factors, along with their perception of their ability to complete mitigation tasks, all influence the decision. Many of the maintenance activities described in the roadmaps are a near-continual process, which has been shown to be a barrier to entry for many people because they feel they cannot complete the work.[57,58] The use of social science to explore human behavior regarding how people respond and take mitigation actions to wildfires is relatively new but is growing quickly. Additional research inquiries for understanding human perception of risk and motivating factors for mitigating the risk include:

- Why has wildfire awareness not translated into action?
- How can a sense of hope be restored to motivate homeowners and communities to act?
- How do people respond to wildfires? How do they approach mitigation? What kinds of programs and incentives could provide motivation?

Research has identified the communication gaps that are still present, but also where messaging and outreach can have success. While communication efforts are often focused through mass media, more effective channels have been found. These have included more personalized and local efforts such as one-on-one consultation with fire experts, townhalls, small workshops, tours, and demonstrations. These activities were more effective at changing beliefs and behaviors.[55,63] The ability to exactly communicate a home's current risk, and the steps to take to reduce that risk and why, is critical to bridging the gaps between awareness and action. Also important is the ability to demonstrate both positive and negative outcomes and why they occurred. The Suburban Wildfire Adaptation Roadmaps make a leap forward in doing this using established science concepts, but their development has also shown that more work is needed.

61 Sturtevant V, M.A. Moote, P. Jakes, and A.S. Cheng, 2005: Social science to improve fuels management: a synthesis of research on collaboration. USDA Forest Service, North Central Research Station, General Technical Report NC-GTR-257. (St Paul, MN)

62 Toman EL, B. Shindler, J.D. Absher, and S. McCaffrey, 2008b: Post-fire communications: The influence of site visits on local support. Journal of Forestry, 106, 25–30

63 Toman E., B. Shindler, and M. Brunson, 2006: Fire and fuel management communication strategies: citizen evaluations of agency outreach activities. Society & Natural Resources, 19, 321–336. doi:10.1080/ 08941920500519206

APPENDIX A

LIGHT COMMERCIAL CONSTRUCTION ROADMAPS

LIGHT COMMERCIAL CONSTRUCTION ROADMAPS

In modern suburban settings, businesses and services are frequently in close proximity to homes to provide convenient services to residents. Light commercial structures include:

- Franchises (e.g., quick-service restaurants)
- Hotels
- Convenience stores
- Gas stations
- Pharmacies
- Retail stores
- Professional offices
- Schools and other municipal buildings
- Mixed use strip malls
- Multifamily housing

Wildfire mitigation requires a constant collaboration and effort by property owners and tenants to keep their properties wildfire ready. Selecting the proper materials for your building is just the beginning. Ongoing maintenence is also a key component in reducing your property's risk.

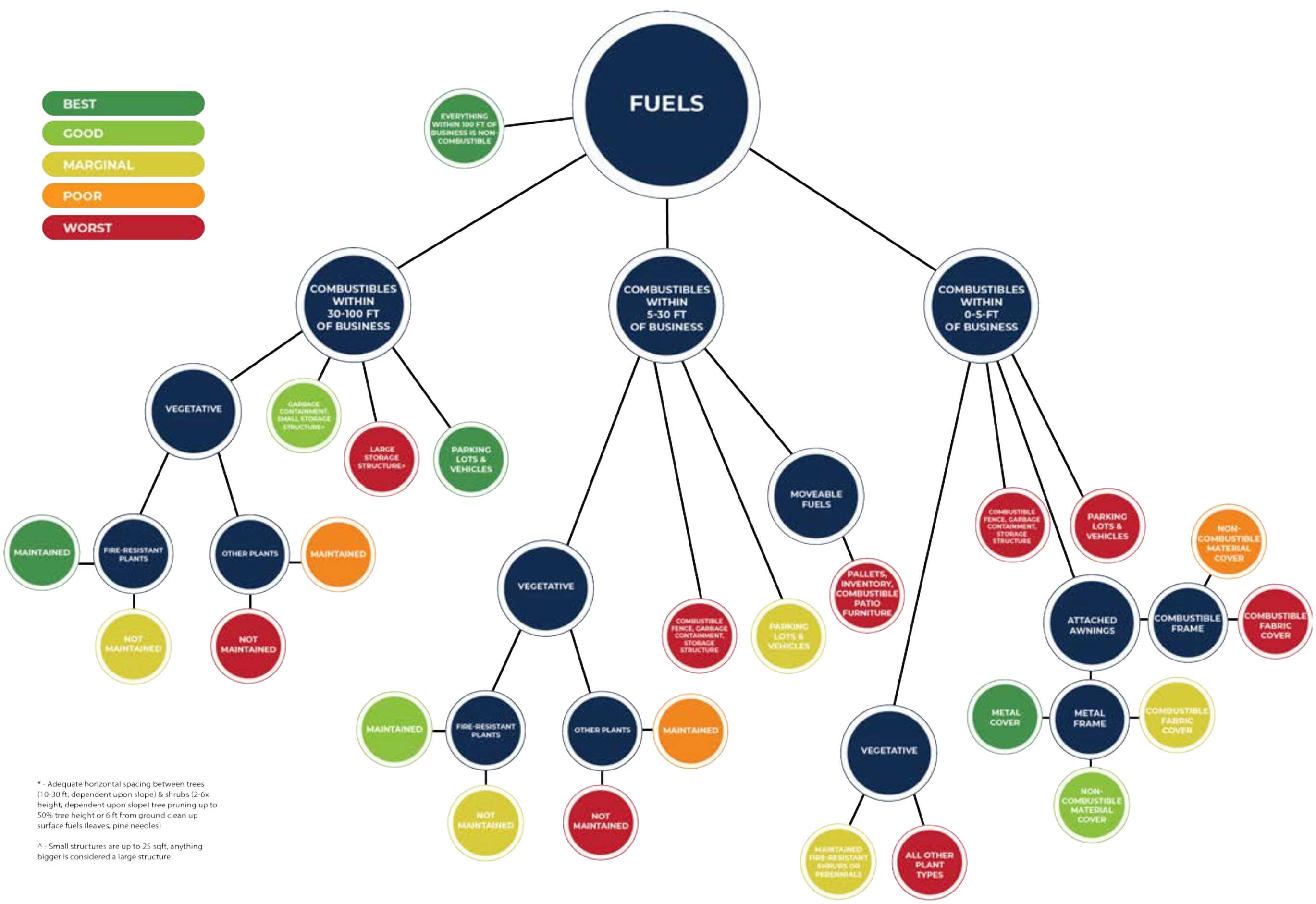
The following roadmaps evaluate key components of light commercial structures which are similar to their residential counterparts, and the surrounding vegetation and location. The roadmaps provide guidance on the spectrum of best to most risky practices for elements of light commercial structures. Although light commercial structures and their surroundings have a lot of unique variations, this report highlights the most common elements.

FUEL MANAGEMENT

The roadmap for fuel management focuses on three zones surrounding a building:

- 0–5 ft noncombustible ignition zone (defensible space)
- 5–30 ft zone
- 30–100 ft zone

Businesses or organizations with vegetation in the 0–5 ft ignition zone will need to remove those plants and/or trees to establish a noncombustible zone. This zone is an extremely important area to focus on. A routine maintenance plan for the building is necessary to keep fire or embers from igniting materials and spreading fire to your building. This roadmap considers combustible inventory or storage, garbage containment, outdoor seating, and other unique scenarios to the business.

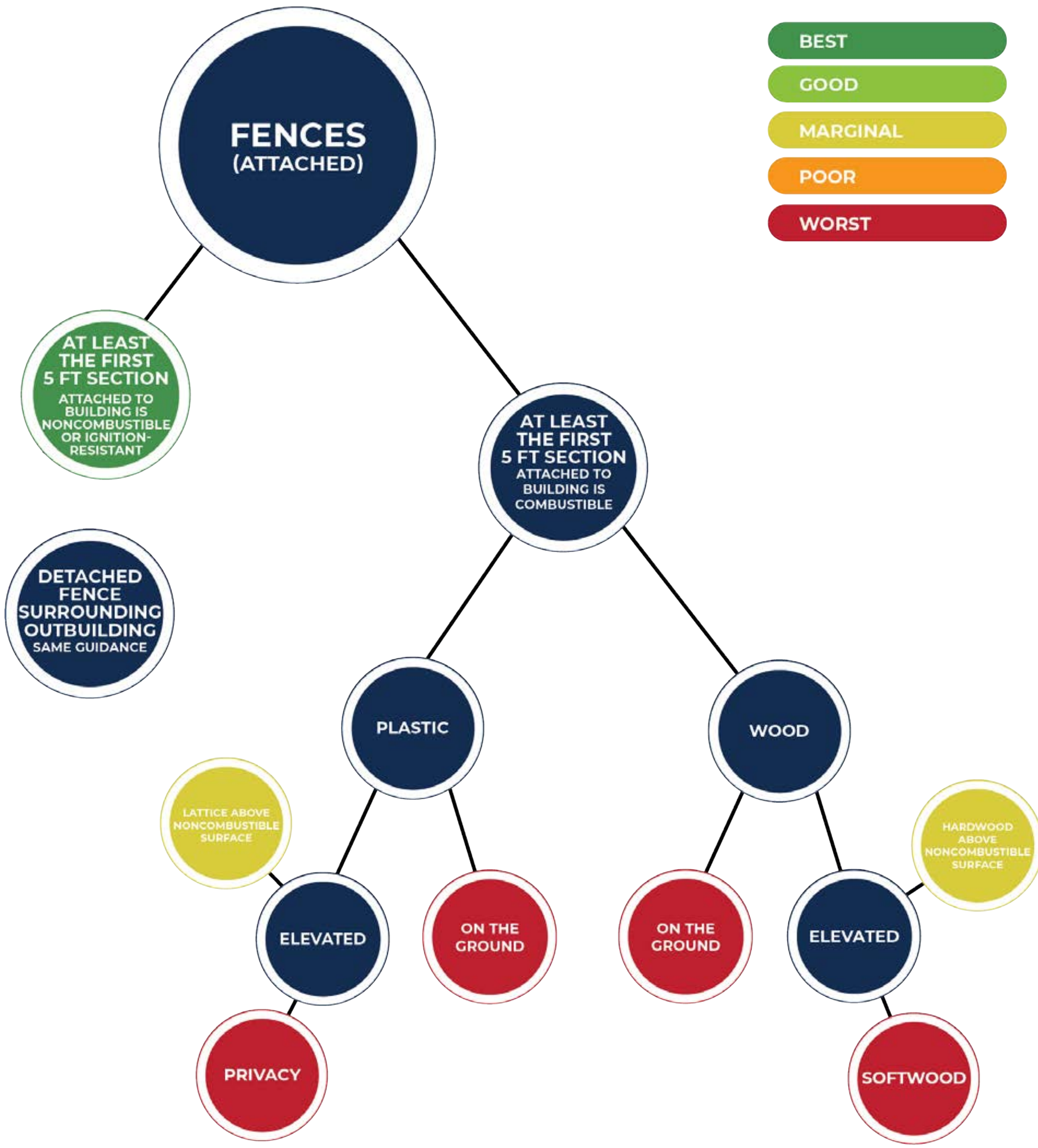


* - Adequate horizontal spacing between trees (10-30 ft, dependent upon slope) & shrubs (2-6x height, dependent upon slope) tree pruning up to 50% tree height or 6 ft from ground clean up surface fuels (leaves, pine needles)

^ - Small structures are up to 25 sqft, anything bigger is considered a large structure

FENCES

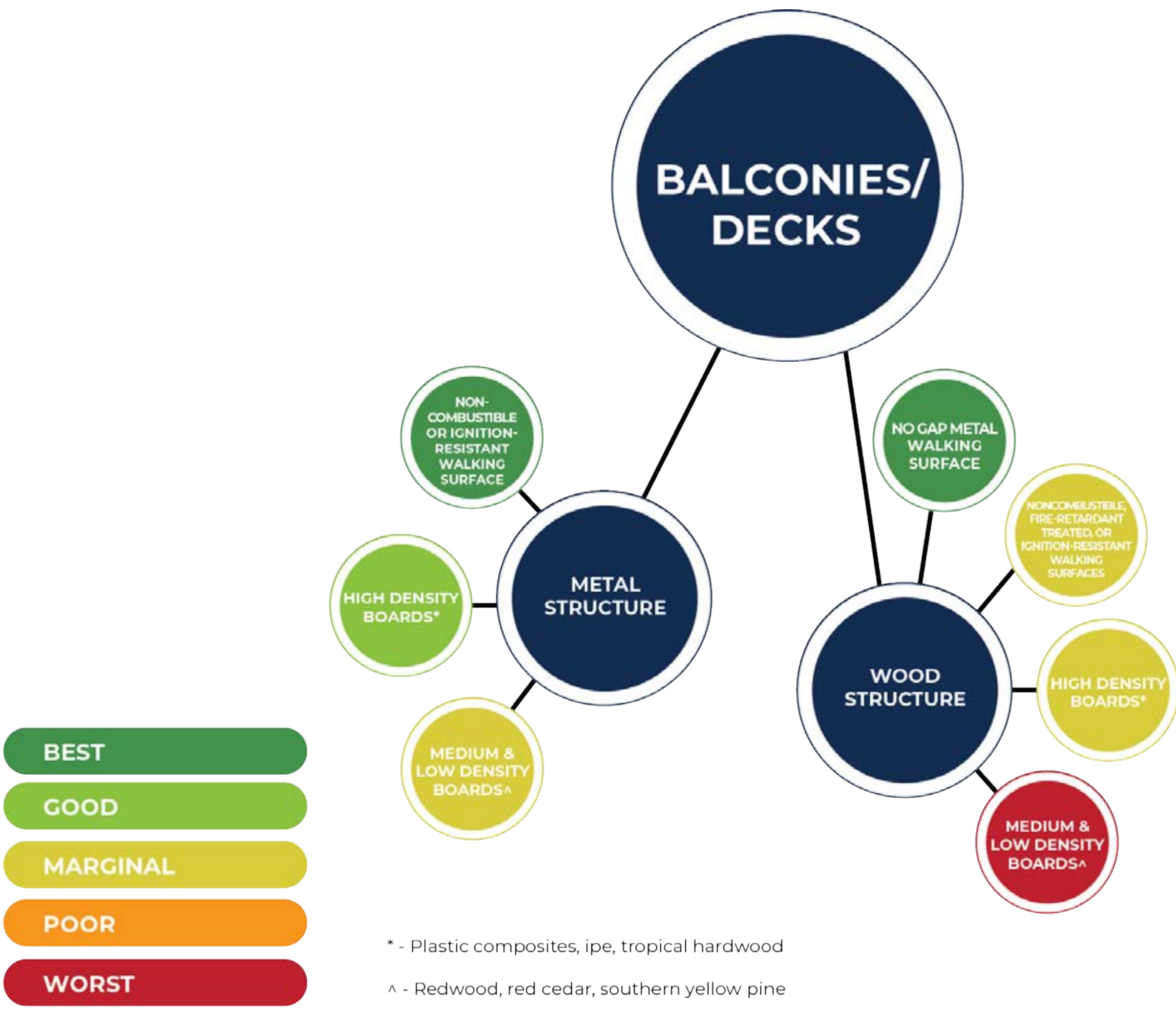
The roadmap for fences only addresses the 5 ft section of the fence that is in contact with the building. The focus of the wildfire vulnerability is based on design and material of this 5' portion. The best option to reduce the risk caused by fences is to use a noncombustible or an ignition-resistant material (such as metal, concrete, stone, or masonry) for at least the first 5 ft of the attached fence to help stop fire from spreading from the fence to your building.



BALCONIES AND DECKS

The roadmap for balconies and decks focuses on the vulnerability based on design and material of the balcony or deck. For existing decks less than 4 ft from the ground, a vertical 1/8-in. mesh screening should be installed around the outer perimeter of the deck to limit debris accumulation and ember intrusion. For existing balconies or decks higher than 4 ft, a defensible space should be maintained in the area underneath the deck to minimize ignition potential.

Our new research in 2021 identified an affordable retrofit option for the deck walking surface. The research showed that the vulnerability of decks to underdeck flame can be reduced by limiting the oxygen supply for the fire if it ignites the supporting structure. This can be achieved by using a metal decking system specifically engineered to be installed with no gap between the boards. Flame always tends to stretch up vertically and by blocking its pathway, the amount of available oxygen for the burning joists is reduced and the potential risk of a burning deck against a building structure is minimized.

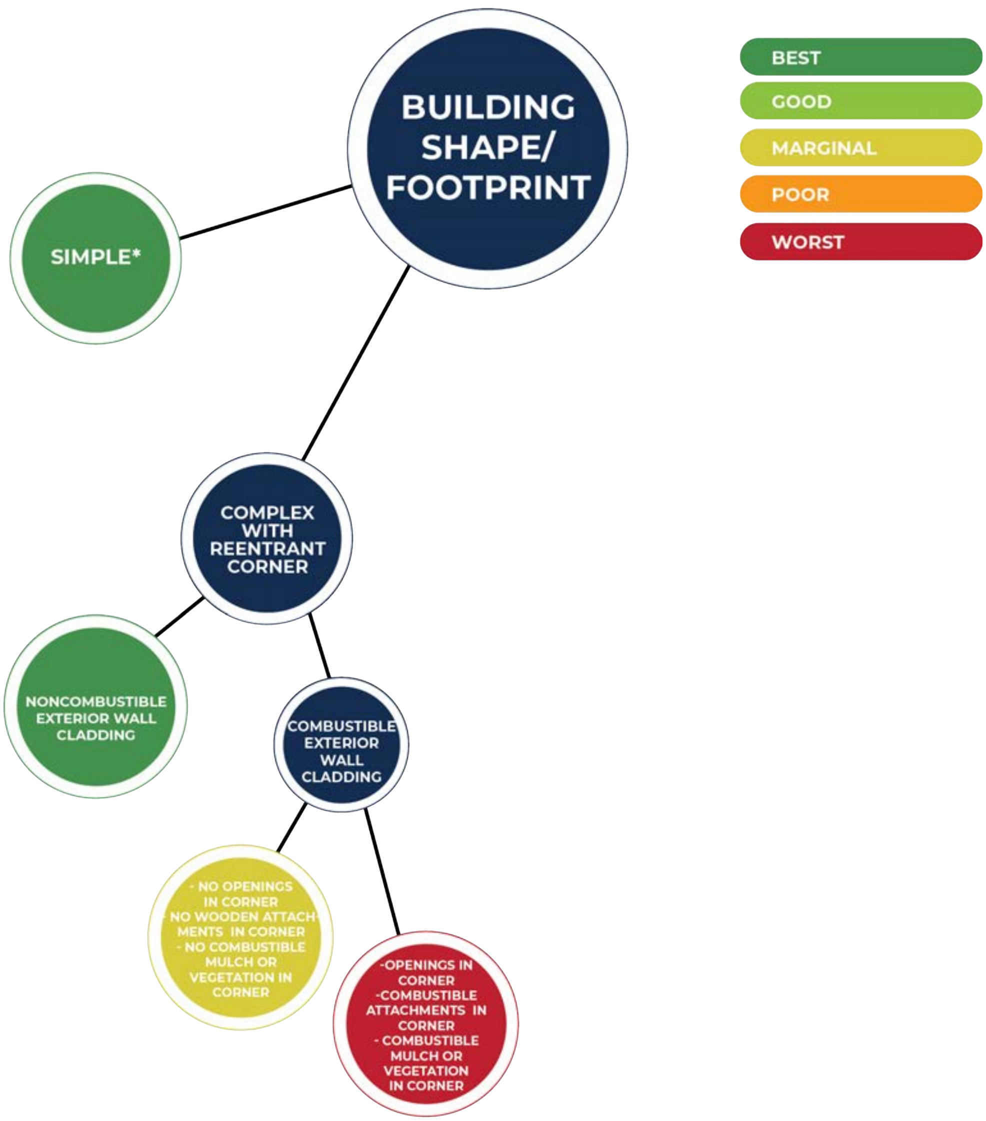


* - Plastic composites, ipe, tropical hardwood

^ - Redwood, red cedar, southern yellow pine

BUILDING SHAPE/FOOTPRINT

The roadmap framework for building shape is fairly simple and ultimately comes down to the shape itself, along with the materials that are attached or adjacent when there is a complex shape. Simple building shapes, such as squares, rectangles or circles, do not have reentrant corners. This type of corner is a common location for embers to accumulate and ignite fuel on or near the structure. A complex shape with no combustibles in reentrant corner locations can be a good option.



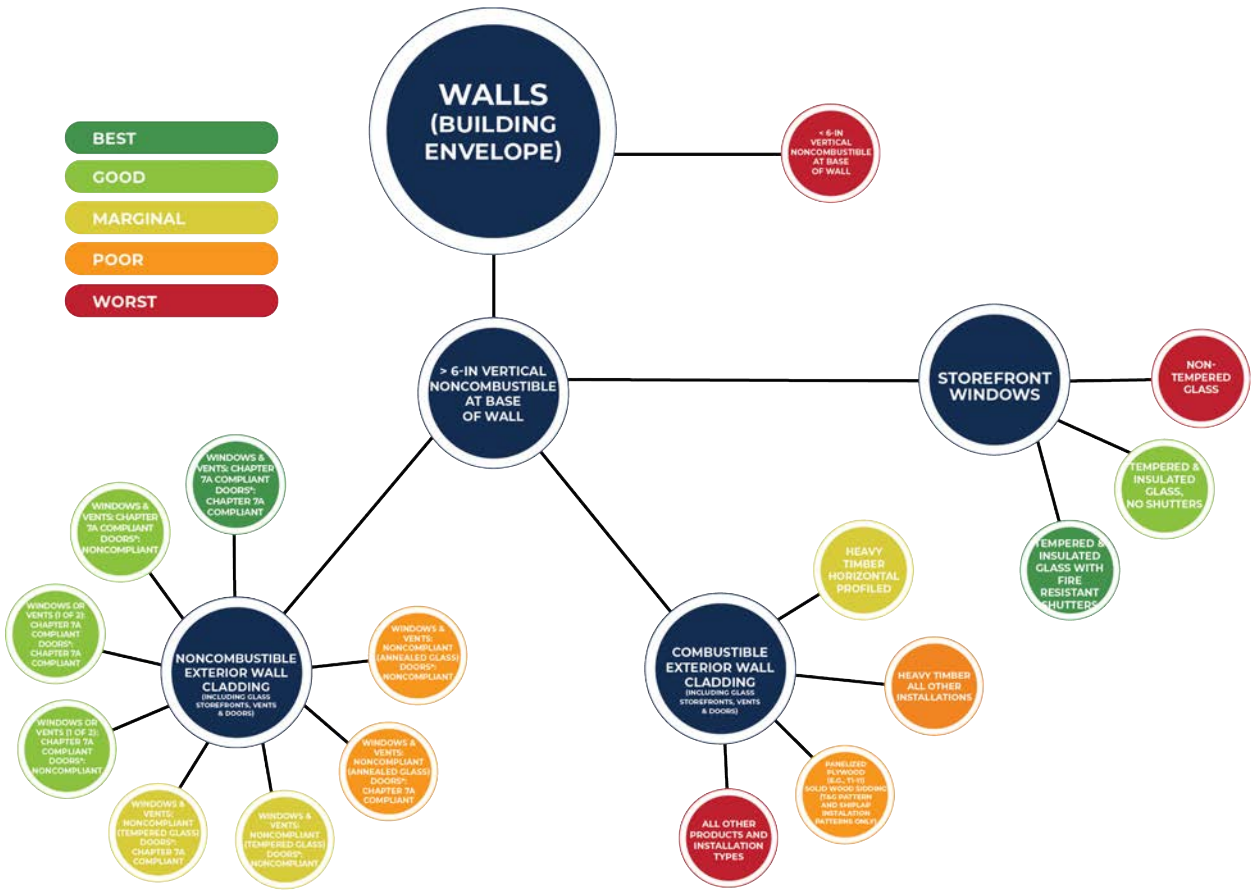
*SQUARE, RECTANGLE, CIRCLE, ETC.

WALLS

For this report, walls include the following components:

- Base sheathing material and cladding (siding)
- Openings such as windows and personnel doors

The roadmap for walls first evaluates whether there is a 6-in. vertical noncombustible zone between the exterior wall and the ground, including cladding, sheathing, and framing. If this zone does not exist, the walls are considered to be high risk no matter what other features are present. This 6-in. vertical noncombustible zone has the highest importance because even if noncombustible siding is used, combustible sheathing is still commonly used behind the cladding. This combustible sheathing is vulnerable to ignition sources, such as burning mulch or embers that accumulate at the base of the wall, posing a high risk to the structure.



* - Pedestrian & rollup doors

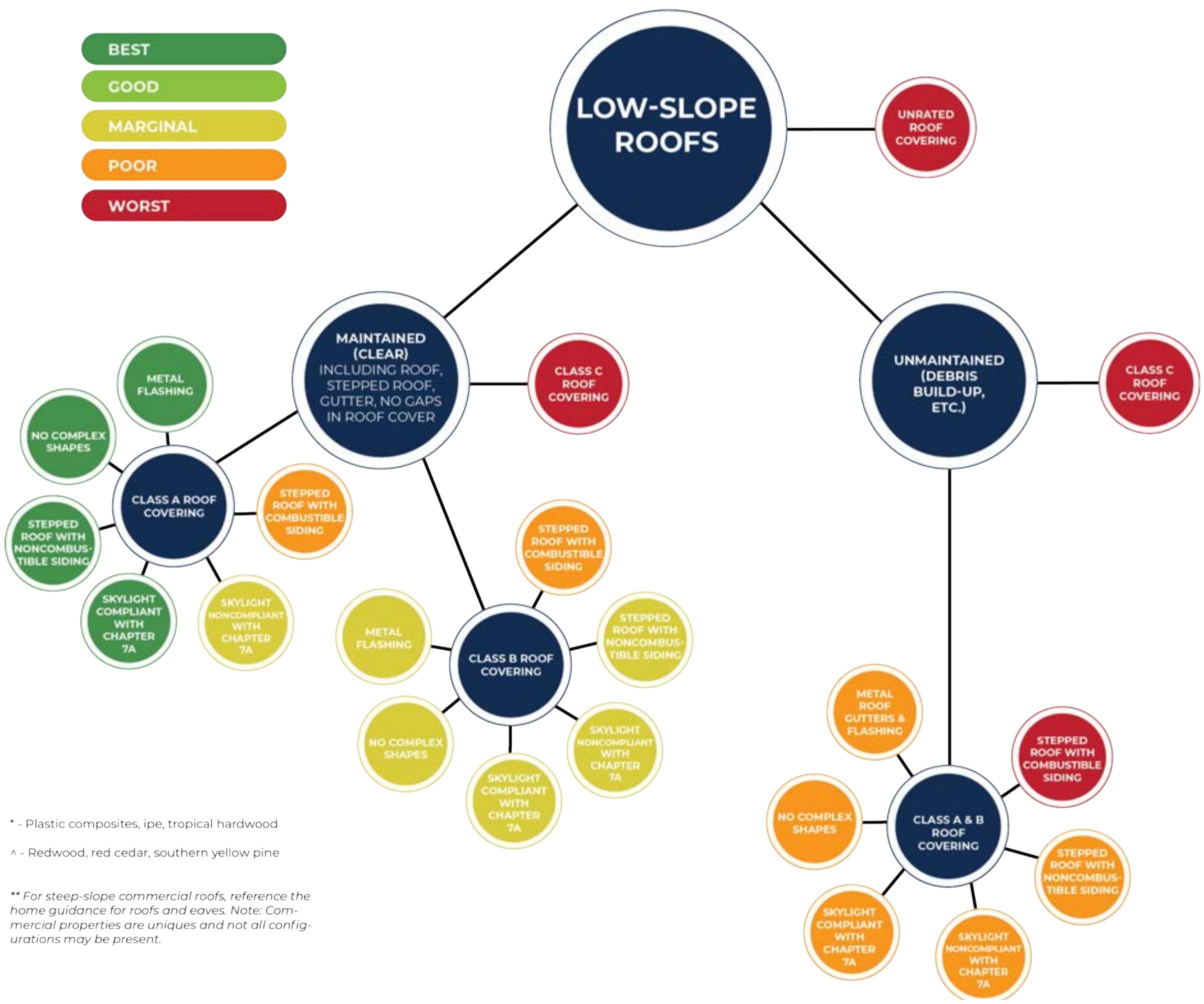
LOW-SLOPE ROOFS

A low-sloped roof has minimal to no pitch and is a large, complex part of a building. Based on the geometry of a low-sloped roof, embers can accumulate against corners or roof mounted equipment and even fly through roof vents creating vulnerabilities to an ember attack. Low- and steep-slope roofs are rated from Class A to Class C based on their fire resistance, with Class A providing the most protection from fire.

In addition to wildfire-resistant building materials on the roof, constant maintenence is required to remove debris to lower the wildfire risk to a building.

With a stepped roof, follow the guidance of the 6” noncombustible space from the bottom of the wall to the ground level of the roof. Chapter 7A of the California Building Code specifies glazing and framing requirements for skylights. As with wall windows, they should be multi-pane with at least one layer being tempered glass.

NOTE: If you have a steep-slope roof defer to the Residential Steep-Slope and Eaves sections. This may not cover every commercial variation.



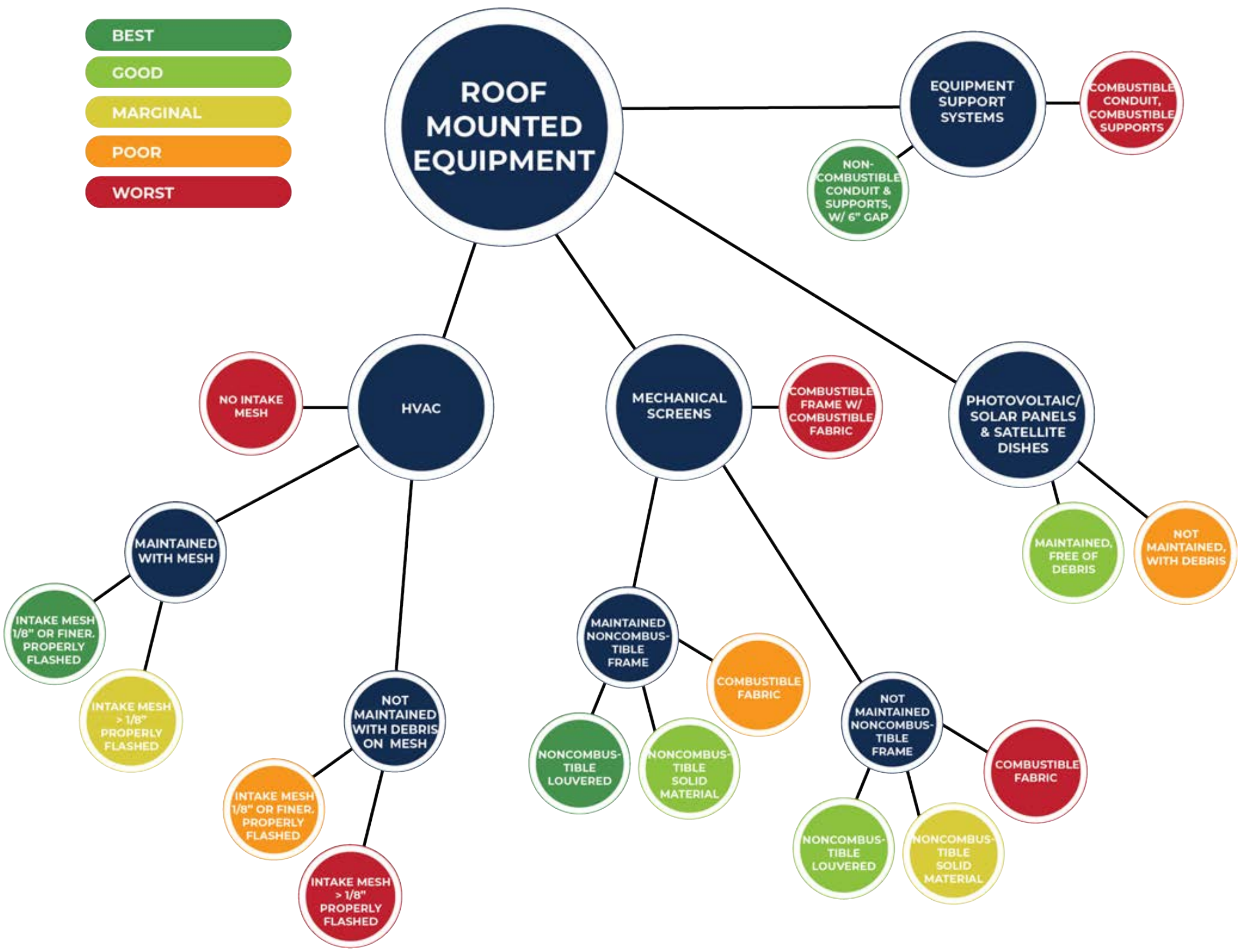
* - Plastic composites, ipe, tropical hardwood

^ - Redwood, red cedar, southern yellow pine

*** For steep-slope commercial roofs, reference the home guidance for roofs and eaves. Note: Commercial properties are uniques and not all configurations may be present.*

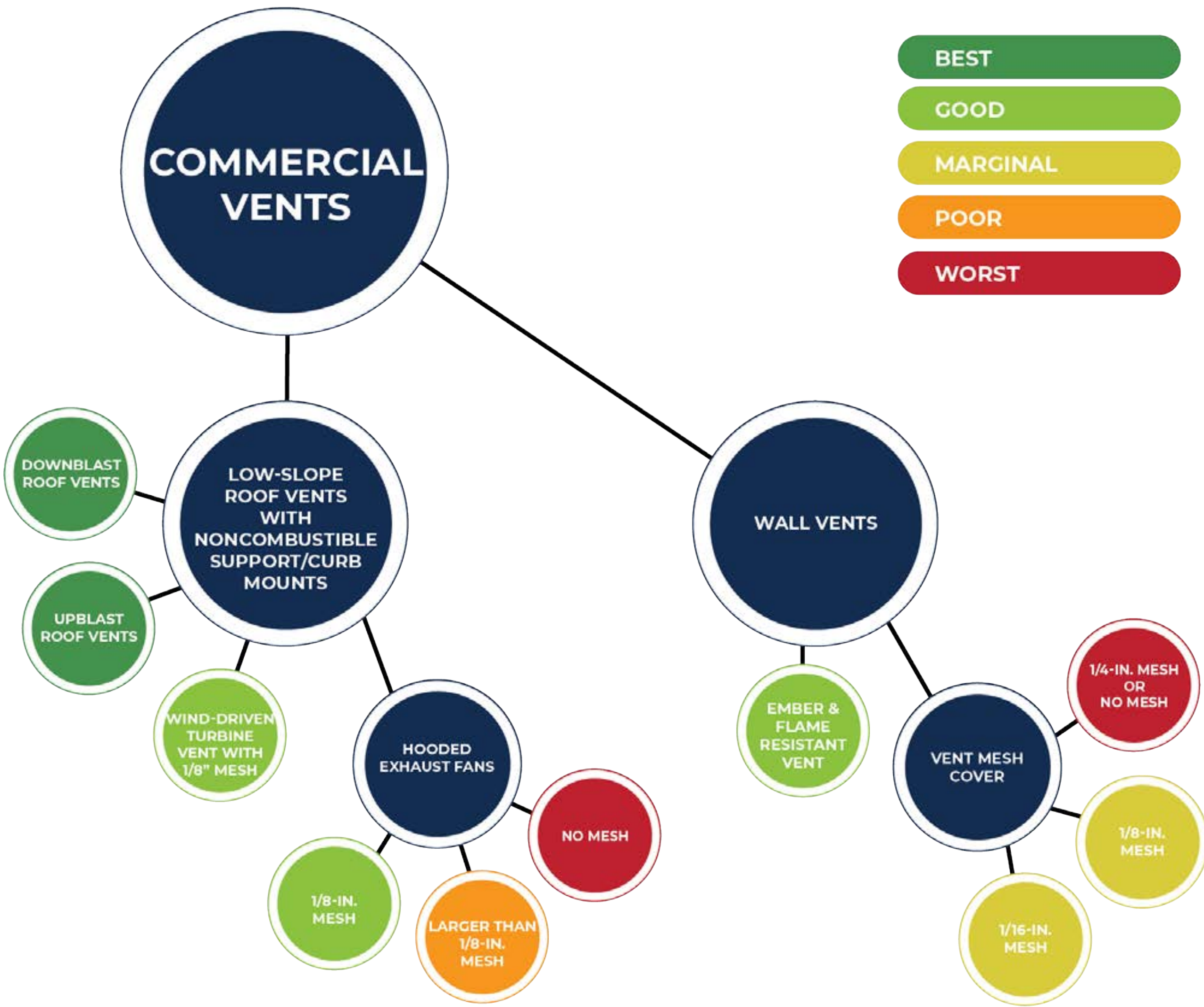
ROOF-MOUNTED EQUIPMENT

Roof-mounted equipment such as HVAC, photovoltaic (PV) panels, satellite dishes, and mechanical screens provide places where debris can accumulate. Impeccable maintenence is required to remove debris and reduce the wildfire risk to a building. Another important factor is to ensure the roof-mounted equipment is supported with noncombustible materials. Embers can accumulate next to combustible supports and ignite them.



COMMERCIAL VENTS

Flying embers can enter buildings through vents in the roof and walls. There have been several vent designs introduced into the market to resist flames in addition to embers. These use baffle designs, steel wool, or intumescent paint coatings.



SUBURBAN WILDFIRE ADAPTATION ROADMAPS

A Path To Coexisting With Wildfires

IBHS RESEARCH