

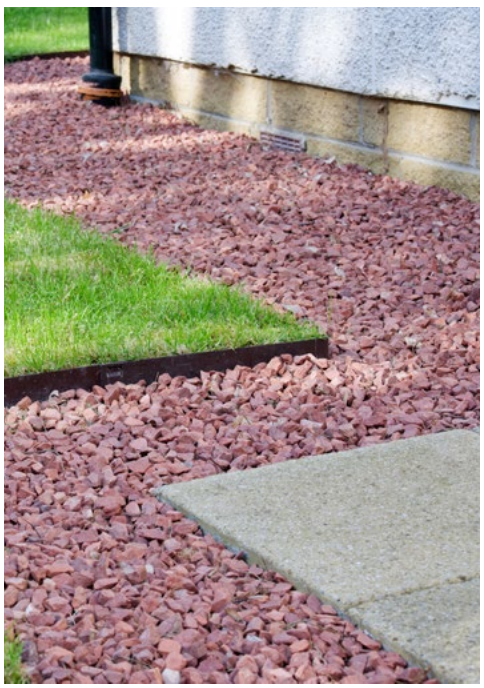


Retrofitting a Home for Wildfire Resistance

Costs and Considerations

Spring 2024

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HEADWATERS ECONOMICS

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Published Online:
https://headwaterseconomics.org/natural-hazards/retrofitting-home-wildfire-resistance/

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Acknowledgments
This report was made possible by generous support from the State of California's Department of Forestry and Fire Protection, CAL FIRE, and the USDA Forest Service. We would like also to thank the following people for their contributions to this research: Chief Steve Hawks with Insurance Institute for Business & Home Safety, Megan Haughey and Heidi Rogers of Studio Limen Architects, and Katherine Shearman of Shearman Builders. Additionally, we received valuable feedback from external reviewers Daniel Gorham with UL Fire Safety Research Institute, Yana Valachovic with University of California Cooperative Extension, and team members of the California Wildfire Mitigation Program.

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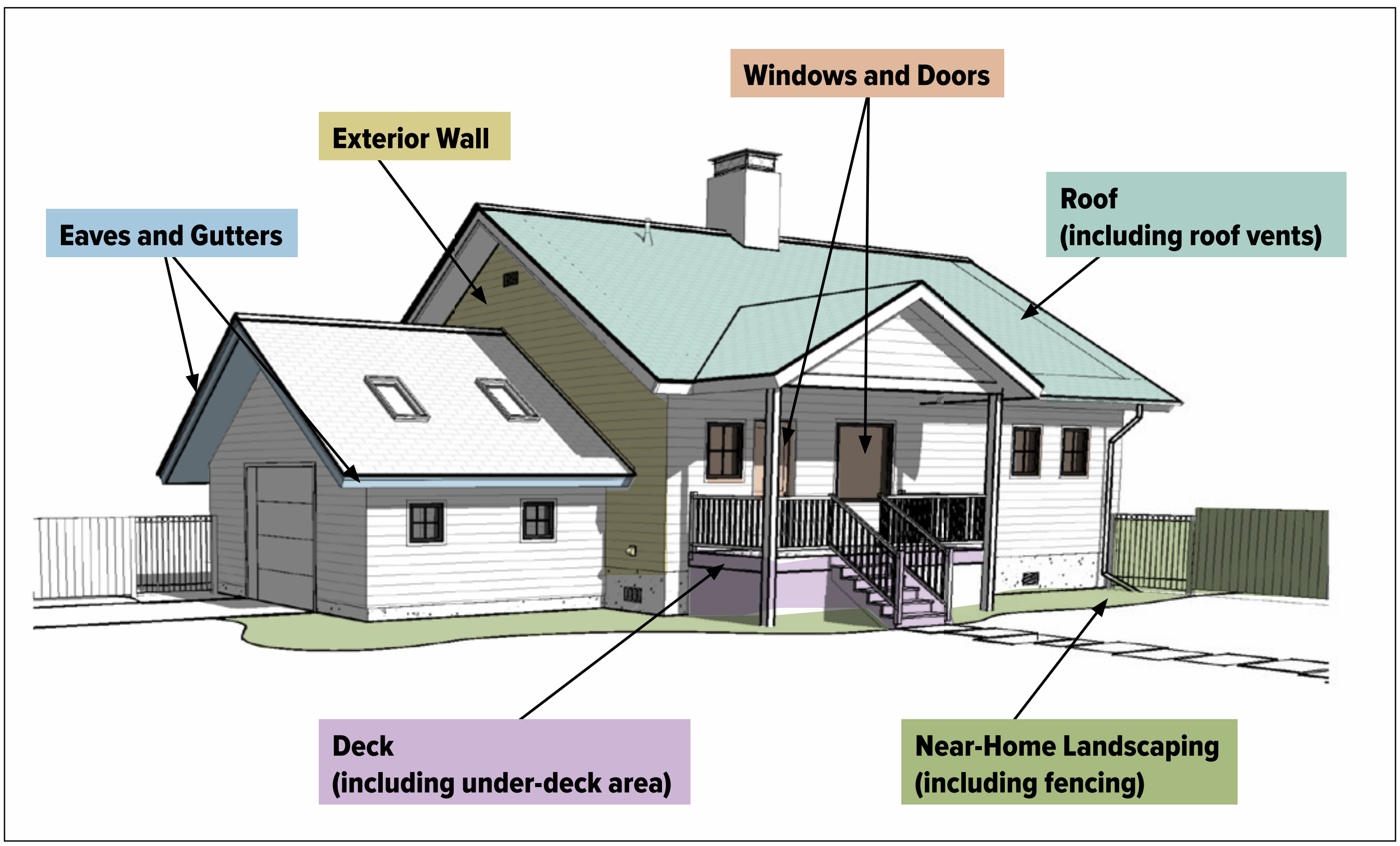


Executive Summary

Wildfires in the American West have grown in duration, severity, and frequency. Decades of construction on wildfire-prone lands that have largely disregarded wildfire-resistant building techniques have left communities vulnerable. It is essential to retrofit the existing housing stock in wildfire-prone areas to an upgraded wildfire-resistant construction standard to reduce overall community wildfire risk. But how much would it cost to retrofit homes for a safer, fire-adapted future?

This report identifies the costs for retrofitting existing structures to meet the construction requirements specified by California's Building Code Chapter 7A: Materials and Construction Methods for Exterior Wildfire Exposure and the best available science for ignition-resistant construction. The results can inform the California Wildfire Mitigation Program and other efforts to fund structural improvement ("home hardening") programs that will increase wildfire resilience at the home, neighborhood, and community scales.

The authors analyzed building materials, demolition and construction costs, and contractor overhead using a national database for standard construction costs and consulting with California-based building contractors and subject matter experts. Mitigation measures for broader property management at the parcel level, while critical in reducing wildfire risk to the primary structure, were beyond the scope of this project. These measures include defensible space, modification of sheds, outlying buildings, and other potential vulnerabilities.

Construction costs were calculated as a per-unit value and are explicit to the exterior components of the home. The report offers detailed estimates for upgrading a home's exterior walls, roof, deck, windows and doors, eaves, gutters, and near-home landscaping (also known as the noncombustible zone). Suggested retrofits were based primarily on northern California and Bay Area housing trends, general homeowner material and design preferences, and structure and property characteristics.

Given the heterogenous composition, design, and building materials of home construction, it is difficult to assign a cost for retrofitting a single structure or group of structures. This research is therefore intended to provide a range of scenarios and baseline cost estimates for upgrading various components of a home for improved wildfire resistance.

Analysis from this report demonstrates that some of the most effective strategies to reduce structure vulnerability to wildfire can be done affordably. Risk-reduction strategies such as removing flammable materials from decks, clearing gutter systems, and removing vegetation and debris from the roof are critical maintenance tasks with little to no cost to the homeowner. Outcomes from this analysis suggest that for a typical 2,000-square-foot home in California, retrofitting costs can be as low as $2,000 for minimal retrofits to upwards of $100,000 if all retrofits to the highest level of protection are needed.

However, a full retrofit is likely not necessary in most cases, and selective, targeted replacement of particular components may reduce risk effectively and more affordably. For example, replacement of exterior vents with flame- and ember-resistant vents, installing metal flashing at all deck-to-wall intersections, maintaining clean gutters and installing metal gutter guards, and replacing bark mulch with noncombustible gravel mulch go a long way in reducing home vulnerability to wind-blown embers during a wildfire and cost between $10,000 and $15,000.

Homes must be built to be stronger, smarter, and more durable in light of the increasing pace and scale of wildfire risks. Retrofitting houses to an upgraded standard can be an effective mechanism to reduce community vulnerability to wildfire, and ideally would be paired with policy reforms. As development accelerates in wildfire-prone areas, communities must have greater access to funding and technical support from state and federal governments for home hardening.

1. Introduction

Wildfires in the American West have grown in duration, severity, and frequency. Increasing wildfire risks underscore the need to create ignition-resistant communities. Community wildfire risk reduction has traditionally focused on reducing hazardous fuels on wildlands and in the natural environment. However, complementary mitigation of the built environment – including homes, neighborhoods, and infrastructure – is critical in reducing overall exposure and potential damage to communities.

Regulatory measures such as zoning and building codes provide construction requirements intended to impart wildfire resistance for new developments and significant remodels. However, given the extent and scale of wildfire risk, it is essential to also *retrofit the existing housing stock* in wildfire-prone areas to reduce parcel and community-level wildfire risk.

In 2019 California established a wildfire resilience initiative to support, fund, and provide technical assistance to communities to retrofit homes for wildfire resistance in high-risk areas. Known as the California Wildfire Mitigation Program (CWMP), this initiative encourages Californians to implement cost-effective measures to improve the fire resistance of homes, businesses, public buildings, and public spaces.

The question that arises is: How much does it cost to modify a structure to resist wildfire? Relatedly, what are the most cost-effective retrofitting strategies?

This report identifies the costs for retrofitting existing structures to meet the construction requirements specified by California's Building Code Chapter 7A: Materials and Construction Methods for Exterior Wildfire Exposure[1] and the best available science for ignition-resistant construction. More specifically, this report identifies the costs for retrofitting exterior components of the home including exterior walls, roof, eaves and gutters, windows and doors, deck, and near-home landscaping. Costs for broader property management, defensible space, and modification of sheds, outlying buildings, and other potential vulnerabilities at the parcel level were beyond the scope of this project, and while critical to reducing overall risk to the home, are not included in the findings. This report is intended to inform CWMP and other efforts to fund structural improvement ("home hardening") programs that will increase wildfire resilience at the home, neighborhood, and community scales.

California has the advantage of a proactive statewide building code and other property-level vegetation regulations focusing on wildfire. Applicable to all new construction in State Responsibility Areas (SRAs) and the highest fire hazard severity zones in Local Responsibility Areas (LRAs), California's Building Code Chapter 7A is intended to reduce the vulnerability of homes to wildfire. Requirements divide the home or building into components (e.g., roof, exterior wall, eaves, vents, and decks) and provide prescription and performance options for compliance. This report is organized in a similar fashion.

This report also relies heavily on the National Institute of Standards and Technology's Technical Note 2205[2] published in 2022. Titled *WUI Structure/Parcel/Community Fire Hazard Mitigation Methodology*, this 77-page document considers the spatial relationships between fuels, exposures, and hardening at the structure and parcel levels. Importantly, it notes that effective mitigation depends on two factors: 1) lowering exposure (i.e., reducing, removing, or relocating fuels), and 2) increasing resistance to wildfire (i.e., home hardening).[3] This report addresses the latter approach.

In this study we determined the cost of modifying the exterior of California homes to better resist wildfire by analyzing building materials, demolition and construction costs, and contractor overhead using a national database for standard construction costs and consulting with California-based building contractors and subject matter experts. Construction costs were calculated as a per-unit value. Suggested retrofits were based primarily on northern California and Bay Area housing trends, general homeowner material and design preferences, and structure and property characteristics.

Structure of this report

A short review of the state of the knowledge regarding the cost of retrofitting homes to improve their resistance to wildfire opens this report in Section 2. Section 3 explains the methodology of how home-retrofitting costs were determined in this analysis. Results of the research (i.e., the costs) are offered in Section 4, which is divided into subsections according to specific home components: exterior walls, roofs, eaves and gutters, decks, windows and doors, and near-home landscaping. Section 5 provides a discussion of the research findings and potential implications for wildfire retrofitting within a broader context. Section 6 offers conclusions and a vision for moving toward safer, more wildfire-resistant communities. The appendices provide more details about building costs.

California Wildfire Mitigation Program

The California Wildfire Mitigation Program (CWMP) provides grants, financial assistance, and incentives to property owners to retrofit their home and property to reduce their vulnerability to wildfire. The initiative targets socially vulnerable communities and provides direct financial assistance to low- and moderate-income households to retrofit homes with ignition-resistant materials such as clay roofs, metal gutters, and tempered-glass windows to meet or exceed the requirements of California Building Code Chapter 7A.

The program includes a significant outreach program to educate all California community officials, homeowners, and local organizations about effective wildfire resilience measures to homes, businesses, public buildings, and public spaces.

CWMP is overseen by California Governor's Office of Emergency Services (Cal OES) and the Department of Forestry and Fire Protection (CAL FIRE), both of which provide personnel and equipment to the program through a joint powers agreement.

In its pilot phase, CWMP has prioritized six counties (San Diego, Shasta, Lake, El Dorado, Tuolumne, and Siskiyou) for funding after analyzing the state at the parcel and census-tract level for high wildfire risk overlapping social vulnerability. Homeowners in pilot-phase communities can apply online to receive a home assessment and funding. The resilience program is funded by the state and the Federal Emergency Management Agency (FEMA).

In addition to tapping CWMP, California counties have independently secured FEMA Building Resilient Infrastructure and Communities (BRIC) grants to assist homeowners in retrofitting and hardening their homes and properties. In 2022, three counties (Mendocino, Napa, Santa Cruz), one city (Auburn), and one tribe (Karuk) received more than $125 million in BRIC grants to strengthen community wildfire resilience, including home hardening, creating more effective defensible space, reducing hazardous fuels, and improving infrastructure.

2. Literature Review

A growing body of scientific work has focused on the cost and considerations of retrofitting homes to improve their wildfire resilience. Research suggests that retrofitting is a valuable strategy from several perspectives.

A home and its immediate surroundings are critical determinants of survivability during a wildfire.[4] Modifications to a structure (including the building materials and design), landscaping, and vegetation management within 100 feet of the structure (also known as the "home ignition zone") are essential for reducing risk.

The National Institute of Standards and Technology (NIST) developed a Hazard Mitigation Methodology[5] that outlined a detailed structure-hardening strategy to resist ignitions from ember and fire (radiant heat and flame) exposures. It identified 50 potential structure ignition vulnerabilities and explains how each component (e.g., roofs, doors, decks) may be adapted to improve wildfire resilience.

Penman et al. (2017) quantified the cost of retrofits of a small number of households in New South Wales, Australia. Costs ranged from $8,527 to $46,856 with an average of $24,596.[6] Kalhor and Valentin (2018) derived a cost estimate framework for optimal retrofits for 389 residential properties in Santa Fe, NM, to mitigate vulnerability to wildfires. The cost-effectiveness of various retrofit measures (e.g., removing grass and shrubs, reroofing, capping vents) were evaluated to optimally reduce high- and very-high-vulnerability homes to a moderate vulnerability. Overall, 95% of optimal retrofit costs for homes were less than $10,000, and 81% were less than $4,000.[7] Indeed, an earlier analysis of home hazard assessments in New Mexico indicated that 20% of average home hazards could be reduced by undertaking easy mitigation steps such as mowing grass and cleaning gutters.[8] A 2018 Montana study affirmed that key mitigations could be implemented by most builders and homeowners.[9]

At a national level, costs are more daunting.[10] Retrofitting nearly 1 million vulnerable roofs in wildfire-prone regions in the United States was estimated to cost at least $6 billion in a 2022 study by Headwaters Economics,[11] emphasizing the need for federal help in building more wildfire-resilient communities.

The contribution of housing units to the pattern of fire spread has not been well researched. In a 2007 study,[12] Spyratos et al. developed a fire-spread model that included housing and vegetation data. Results indicated that housing density and flammability of homes affected fire size probability distributions. The authors concluded that "fire proofing houses and their immediate surroundings within the WUI would not only reduce the houses' flammability and increase the security of the inhabitants, but also reduce fire risk for the entire landscape."

A later study by Alexandre et al. (2016) affirmed that "specific locations in the landscape have a higher fire risk, and certain development patterns can exacerbate that risk." Factors related to topography and spatial arrangement of buildings were more apparent in regression models than vegetation-related factors.[13] In a more recent study by Knapp et al. (2021), critical components of home survivability included structure-to-structure proximity, nearby vegetation, and structural features of the home including windows and siding.[14] An analysis of Colorado's Marshall Fire in 2021 also concluded that spacing between buildings likely played a role in structure-to-structure fire spread.[15]

However, Syphard and Keeley (2019) analyzed building inspectors' reports for home risk reduction strategies to investigate determinants of structure survival from wildfire. Their research indicated that structural characteristics explained more of a difference between survived and destroyed structures than defensible space distance.[16]

In a white paper published by the Insurance Institute for Business & Home Safety (IBHS) in 2023,[17] recent structure (urban) conflagrations exhibited similar characteristics as large conflagrations of the past. Common traits include preceding drought conditions, high winds, and densely situated flammable structures with fuel continuity between structures. According to the authors' analysis of urban conflagrations, including the Marshall Fire in 2022, the built environment – specifically where high-density construction built with little to no fire-resistant materials are ignited under volatile weather conditions – is where the catastrophes unfold. The link that must be broken to avoid catastrophe is fire spread between structures.

Within the context of urban conflagrations and structure-to-structure ignitions, this report addresses an important gap in identifying the economic costs for critical home hardening and structural mitigation efforts. Research findings draw from the existing body of work while concomitantly contributing new insights regarding estimated costs and related considerations for improving wildfire resilience of existing structures.

3. Methodology

Data Gathering and Analysis

Analyzing the costs of retrofitting is more nuanced than analyzing new building construction due to the multifaceted considerations and potential legacy issues of existing assemblies. For instance, retrofitting a roof can be complicated by issues that only become identified during demolition, such as fungal decay or other moisture-related damage that may require the roofing underlayment and other associated building materials to be replaced. In any retrofitting scenario, unforeseen conditions may require professional contracting services and replacement of building materials beyond the costs included in this report.

An important consideration in any discussion of reducing home ignitions is the *form* of fire or heat to which a home might be exposed. Different types of exposures require different mitigation strategies. Homes burn down in three ways[18]:

- Wind-blown embers traveling ahead of a wildfire can land on combustible material and ignite spot fires. Direct and indirect ember ignition scenarios are the most common cause of ignitions.
- Radiant heat from a nearby fire can ignite combustible materials. The effect of radiant heat depends upon the duration of the exposure, distance, and the intensity of the heat.
- Direct flame contact occurs when flames spread to touch a building or combustible material.

Building codes that focus on construction in wildfire-prone areas, such as Chapter 7A in the California Building Code, rely on prescriptive and performance compliance options, usually specified by component. Performance options rely on a standard test method that is referenced in the building code. For example, Chapter 7A requires that an installed roof covering have a Class A fire rating and references ASTM E108 (and UL 790) as the standard test method that a manufacturer would use to determine whether their product complies with this provision of the code. Performance-based options are provided for all exterior-use components on a building (e.g., siding, windows, and deck boards). Prescriptive options are also provided for components such as vents. For example, a window manufacturer need only provide a product containing a dual-pane insulated glazing unit with one of the two panes of glass being tempered. Chapter 7A does not restrict framing material. Materials and design details used in this report are based on the more restrictive compliance options. Examples include use of a noncombustible material (ASTM E136), an ignition-resistant material (ASTM E2768), and a fire-rated wall assembly (ASTM E119). Other "best practices" identified by, for example, the Insurance Institute for Business & Home Safety (IBHS) and the National Institute of Standards and Technology (NIST) were also used in this analysis. These materials, assemblies, and best practices have been grouped into the general "wildfire-resistant" category.

DEFINITIONS

Many of the terms used to describe favorable performance are used interchangeably, even though they may have different technical definitions. Different wildfire codes may have discrepancies but are generally based on traditional laboratory tests that determine the response of a material or assembly to fire.

Wildfire-Resistant
A general term used in this report to describe a material and design feature that can reduce the vulnerability of a building to ignite, either from wind-blown embers or other wildfire exposures.

Fire-Resistant
Property of an assembly that resists the spread of fire from the fire-exposed to a non-exposed side of an assembly.

Ignition-Resistant
Property of a material that resists ignition of sustained flaming combustion. Materials designated ignition-resistant have passed a standard test that evaluates flame spread on the material.

Noncombustible
Material of which no part will ignite or burn when subjected to fire or heat, even after exposure to moisture or the effects of age. Materials designated noncombustible have passed a standard test.

Standards for exterior components are based on the expectation that vegetation around structures has also been mitigated. Vegetation management for an extended distance from structures ("defensible space") is required in many places. California's Building Code, Section 701A.5 explains Vegetation Management Compliance requirements and should be consulted for structures in California. A full discussion of defensible space was beyond the scope of this report.

A three-part methodological approach guided the analysis and data collection for this research:

- **Building materials and components:** Existing literature, including California's Building Code Chapter 7A (Materials and Construction Methods for Exterior Wildfire Exposure) and primarily the NIST Technical Note 2205 (Appendix tables A and D) provided baseline building material considerations and design elements for wildfire construction retrofit.
- **Retrofitting application:** Working in partnership with architects and California-based building contractors, the selection of building materials, components, and costs were calibrated for accuracy and retrofitting applicability. The architects, building contractors, and authors closely vetted the building materials and assessed whether the proposed retrofitting mitigation measures complied with building code requirements and weather and climate mitigation needs.
- **Data collection:** Building material costs, including construction costs for material, labor, demolition, and contractor overhead, were provided by RSMeans, a national database for the construction industry. A locator multiplier was factored into the analysis to reflect regional markets in northern California (Redding/Bay Area). Data for southern California generally varied within 10% of reported data for northern California. Variability in market trends, material supply, contractor expenses, and a myriad of other factors influence location costs for building materials. Results provided in this report provide a baseline range of estimated costs and reflect the precision of the data sources used in the study. Costs for products not available in RSMeans were procured from local California-based suppliers, construction industry experts, or the manufacturer directly. Estimated average labor and overhead expenses were acquired from analogous cost indices from RSMeans. Some building material costs are conservative estimates for California due to location, availability, and industry trends that are not accurately captured in RSMeans.

Assumptions and Parameters

Due to the specific nature of retrofitting strategies construction costs for retrofitting were calculated as a per-unit value. For instance, costs to replace individual windows, including glass and frame, were calculated and reported separately from costs to replace the entire exterior wall. In structuring the analysis in this way, the intent was to recognize the discrete and diverse needs of retrofitting improvements and present the information as a menu of different options and considerations.

To contextualize common examples of retrofitting scenarios and to illustrate the range of potential costs, a description of a retrofit strategy was included for each component (i.e., exterior wall, roof, under-eave area, deck, windows and doors, and landscaping). The example of a suggested retrofit for each component was based on California housing trends, common structural design and building preferences, and structure and property characteristics. For each component, a decision tree illustrates the process of building material selection and helps refine the range of retrofitting options. The decision trees are not comprehensive but include the most common and suggested priorities for retrofitting individual components of the home. For a complete list of retrofitting building materials, related costs, and underlying assumptions, see Appendix A.

For this report, a 2,000-square-foot, two-story, single-family residential structure was assumed as a "model home" and used for descriptive analysis of retrofitting costs. The footprint of the representative home was 1,000 square feet (25 feet by 40 feet). The prototypical home was located on a 15- to 20-degree slope with wildland vegetation adjacent to the rear of the home. The home featured a daylight basement and an attached deck measuring 100 square feet. A neighborhood commonly characterized as suburban density was assumed, implying neighboring structures were within 30 feet of the home.

This study focused on exterior building products, specific to exterior walls, roofs, decks, eaves and gutters, deck, windows and doors, and near-home landscaping. With the exception of the structural support system for the deck, the cost of framing, whether wood or steel, was not included in the study. Steel studs do not contribute to fire resistance once ignition occurs, nor does a steel framing system affect the vulnerability of a home or building to initial ignition from embers, radiant heat, or direct flame contact. Similarly, this study did not consider alternative wall systems such as straw bale, insulated concrete form, concrete masonry unit (CMU) block walls, and cross-laminated timber. Once the fire moves into the occupied space of the home, many combustible materials—furniture, walking surfaces and floor coverings, and other interior contents—will contribute to fire growth and ultimate heat release from the home. While critical in reducing overall vulnerability to the home, management and maintenance costs for defensible space and the larger property were not included in this report.

Building Material Cost Data

Cost estimates for individual building materials for this report were provided through RSMeans, a national database of construction costs for residential, commercial, and industrial developments. Cost estimates include building material, demolition, labor, equipment, and contractor overhead costs such as transportation and storage fees. RSMeans is updated quarterly and averages construction cost indices from more than 970 locations and uses the latest negotiated labor costs for average wages in 30 major cities. The data used in this study were captured and analyzed from the RSMeans database during the summer and fall of 2023. They include national averages as well as cost indices to compare regional variability across the country.

Rather than generalize a single value range for all of California, a locality multiplier within RSMeans was used for building materials in northern California and complemented by cost estimates from building contractors and suppliers located within the Bay Area. Costs for southern California were not explicitly included in this study and tend to vary within 10% of the costs reported for northern California.[19] For improved accuracy, building material costs for specific locations should be calibrated and confirmed with local suppliers and contractors.

Several important assumptions were made in building material selection and corresponding calculations for potential retrofitting. The estimated costs for some building materials were not available in RSMeans. In these cases, pricing was acquired by working directly with California-based building contractors and industry subject matter experts to estimate potential material costs, including raw material, labor, demolition, and overhead and profit rates.

Best judgment and local guidance were provided by California-based partners including structural engineers, design firms, California Building Industry Association (CBIA), and CAL FIRE. Architectural and construction expertise and cost estimates were provided by Studio Limen in Bozeman, Montana, and Shearman Builders in Alameda County, California.

While using a national database like RSMeans provided consistency for this study, it also had limitations. The costs reported in this study reflect the level of precision provided by the data sources used in the analysis and accuracy may vary depending on location-specific circumstances, market forces, and other cost contingencies. The values included in the database were averages, and even with the locality multiplier it was difficult to reliably capture market adjustments specific to community conditions. Nuances in supply and demand, contractor availability, market fluctuations, managerial efficiency, competition, or local building or union requirements were not included in RSMeans and therefore were not factored into this analysis.

During any home improvement or retrofitting scenario, underlying degradation of structural components may be exposed and require additional remediation work. For example, removing roof covering may expose a portion of degraded roofing underlayment that needs repair and replacement. Costs for unforeseen conditions are not included in this report and may increase expenses for new materials and professional contractor services.

4. Results

The costs of retrofitting homes in California vary widely depending on condition, materials, and site. Results of this study are divided into subsections related to home components: exterior walls, roof, eaves and gutters, deck, windows and doors, and near-home landscaping (i.e., the 5-foot noncombustible zone around the home). Within each subsection a range of potential mitigation strategies and costs is available: some building materials and retrofitting options provide adequate wildfire resistance ("Good") with an intended focus on resistance to ember ignition. Other premium building materials and assembly selections provide higher levels of wildfire resistance ("Better" and "Best"). The latter two categories incorporate more fire-resistant building materials and assemblies to reduce vulnerability to extended radiant heat and flame contact exposures, thus increasing the overall costs for these components. Discussions of each component are further refined to address the type of exposure likely to occur: wind-blown embers, radiant heat, or direct flame contact.[20] Decision-tree diagrams provide a tool for conceptualizing which costs may be incurred for each component and for specific risk-reduction strategies based on the existing structure. Corresponding costs for suggested building materials and retrofitting options are provided on a per-unit basis and include expenses for demolition, new material, labor, dumping fees (if applicable), and contractor overhead and profit.

Some of the most effective strategies for reducing a structure's vulnerability to wildfire are relatively affordable maintenance measures that can be performed by the homeowner. Important maintenance and mitigation activities to reduce home vulnerability to wildfire include:

- cleaning the roof (including the valleys) of accumulated vegetative debris such as pine needles;
- routinely clearing combustible debris from gutters;
- removing combustible materials from the deck and under-deck area and relocating firewood at least 30 feet from the home;
- maintaining a 5-foot noncombustible zone around the home and under all attached decks; and,
- ensuring broader vegetation management beyond the noncombustible zone and similarly mitigating other outlying buildings, campers, and structures on the property.

Other effective and affordable improvements that can reduce ignition potential include:

- replacing all exterior vents with flame- and ember-resistant vents per building code requirements for airflow ventilation needs;
- installing a minimum 6-inch vertical metal flashing (or noncombustible cladding) on deck-to-wall and roof-to-wall intersections;
- enclosing the under-deck area with metal mesh screening to minimize debris accumulation and ember intrusion;
- replacing the first (i.e., near-home) deck board that is parallel to the side of the home with a metal grate or metal deck board (for applicable decks) or replacing the bottom 6 to 12 inches of exterior siding with noncombustible material;
- installing a noncombustible (metal) gutter guard;
- replacing bark or other combustible mulch within 5 feet of the home with pea gravel or another noncombustible material; and
- ensuring that fencing within 10 feet of the home is noncombustible.
- Components with large surface areas such as roofs, decks, and siding are more expensive to mitigate due to the quantity of material needed and associated labor costs for demolition and installation. Yet the large surface area exposed to potential ignition sources makes retrofitting these components particularly important. In some cases, retrofitting exterior components may not require complete replacement. For example, replacing the first 6 to 12 inches of siding with a noncombustible material can reduce ignition potential from an ember exposure without having to replace all the siding on all exterior walls.

More extensive modifications that improve wildfire resistance will range in costs depending on the dimensions, location, and unique characteristics of the home and property. These improvements include:

- replacing non-fire-retardant-treated wood shake/shingle-covered roofs with a Class A roof covering such as asphalt fiberglass composition shingles, tile, or standing seam metal;
- converting all open-eave designs to enclosed (boxed-in) eave designs and installing flame- and ember-resistant vents;
- replacing deck boards with a more ember- and/or flame-resistant option;
- replacing single-pane windows with dual-paned, tempered glass windows; and
- modifying or replacing skylights and exterior pedestrian and garage doors as needed.

The estimated cost to completely retrofit a two-story, 2,000-square-foot, single-family home (1,000-square-foot footprint measuring approximately 40 feet by 25 feet) for adequate wildfire resistance ranged from $23,000 to $40,000. A “Better” scenario using slightly better retrofit materials ranged from $40,000 to $60,000. The “Best” retrofit scenario using premium building materials and assemblies ranged from $60,000 to more than $100,000. (See Appendix A for a cost breakdown.) However, as noted above, many effective and affordable retrofits and mitigation tasks can be undertaken by homeowners at a much lower cost. Every home is unique in site characteristics, property conditions, and structure materials and design, which influences the applicability of different retrofitting strategies. While some homes may require the complete suite of recommended retrofitting measures for improved wildfire resistance and thus cost more, many homes may only need slight modifications and structural improvements to reduce risk, which can be more affordable.

Exterior Walls

Ongoing Maintenance and Management Measures:
• Remove accumulated vegetation and debris from roof, including roof valley • Remove accumulated vegetation and debris from gutters • Remove flammable materials from on top of and under deck area • Maintain a noncombustible zone (0-5' around the home) • Manage vegetation and similarly mitigate outlying buildings, campers, and structures on the property

Exterior Walls							
			Scenario Range			Reduces Exposure to	
Retrofitting Material & Cost	Cost/ Unit	Unit	Good	Better	Best	Embers	Radiant/ Direct Flame
Flashing at wall-to-deck intersections	$4.14	LF	X	X	X	X	
Noncombustible flame- and ember- resistant vents in foundation	$229.32	Ea	X	X	X	X	
Noncombustible material to replace first 6-12" vertical siding	$6.67	SF		X	X	X	X
Noncombustible flame- and ember-resistant vents in gable ends	$420.80	Ea		X	X	X	
Noncombustible exterior wall siding (fiber-cement material)	$6.67	SF			X	X	X
Fire-rated panelized gypsum product	$1.24	SF			X		X
Fire-rate caulk (i.e. Vent perimeter, >1/8" gaps in siding, etc.)	$4.38	LF	X	X	X	X	
Metal dryer vents	$68.70	Ea			X	X	
Metal intake air vents	$106.11	Ea			X	X	

Description and Assumptions

If the claddings on the exterior walls of the home (siding material and trim) are combustible, then one or more of the walls may require retrofitting depending on the expected exposure. For example, a wood or wood-based or vinyl siding could be replaced with a noncombustible option such as fiber-cement siding or three-coat stucco to increase overall wildfire resistance of the exterior wall. For horizontal lap cladding, resistance to an ember exposure can be mitigated by removing the bottom course of combustible cladding and installing noncombustible cladding (e.g., fiber cement siding). Installing metal flashing over the combustible cladding is additionally an option and requires inserting the flashing behind the siding with a kerf cut insertion. (Figure 1). Mitigation of a vertically applied cladding system (e.g., plywood T1-11 panels or a vertical board and batten product) using the flashing option will be more complicated, but termination of the upper leg could be accomplished by making an upward angle kerf cut in the siding near the base of the wall and inserting the metal flashing into the cut. Replacing the bottom portion of the siding with a noncombustible option will result in a nonuniform appearance. When addressing the cladding, additional retrofitting considerations should include the under-eave area including the soffit, vents, and potential penetrations into the attic space (see Eaves and Gutters).

In some cases, only part of the exterior may need to be replaced, such as the side of the home adjacent to and facing a nearby home, shed, or outbuilding. In this case, full replacement of siding for all sides of the home may not be needed if exposure from adjacent structures is limited to a single side of the home, a near-home noncombustible zone is developed and maintained (minimizing the chance of an ember ignition), and surrounding fuels have been mitigated (minimizing the chance of an extended radiant heat exposure from vegetative fuels or a storage shed).

In a high-density development where home-to-home spacing is less than 30 feet and radiant heat could be a major exposure, a complete retrofit of all exterior walls (siding and other components on the wall) may be necessary.[21]

A fire-rated gypsum wallboard (5/8-inch Type X) can be installed under combustible or noncombustible claddings to improve fire resistance. However, this option addresses only fire penetration through the wall assembly; where combustible siding is used, it will not reduce vulnerability from vertical and lateral spread should the siding ignite. Vulnerability of windows, vents, and the under-eave area is not addressed with this strategy. Some cladding products approved for use in wildfire-prone areas of California already require an additional fire-resistant material

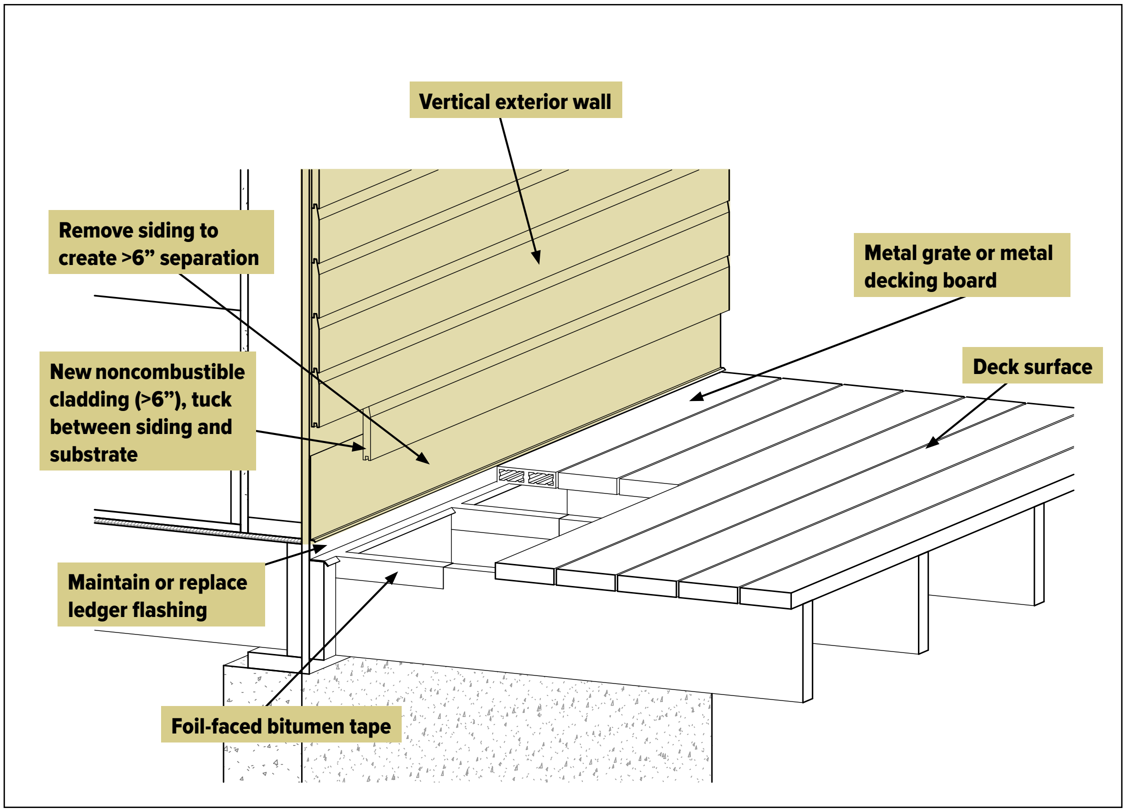


Figure 1: Improvements for enhanced wildfire resistance at wall-to-deck intersections. Importantly, a noncombustible zone (0-5') around the home is critical including the under-deck area.

(e.g., a Type X gypsum product) in the wall assembly. Installation of wallboard must comply with manufacturer's specifications to minimize degradation from water. A fiberglass-gypsum sheathing product could be used instead of a paper-faced gypsum wallboard but would likely cost more.

Vents can be vulnerable to wind-blown embers. Exterior wall vents include gable end vents, foundation vents for crawl spaces, and make up air vents into rooms with gas appliances such as a hot water heater or furnace (see "Eaves and Gutters" and "Roofs" sections for other applicable vents). If the roof is being replaced, exhaust (outlet) vents can be relocated from the gable end to a ridge or off-ridge location. Alternatively, replacing the gable end vent with an approved, flame- and ember-resistant vent is another retrofit option although costs can vary due to the high location and contractor safety considerations for replacing gable vents. In this case, applying a fire-rated caulk (e.g., an intumescent caulk) around the perimeter of the vent will help protect the area at the vent-to-exterior wall intersection from embers and flame. Installation instructions for flame- and ember-resistant vents specify use of caulk. As with roof vents, building codes provide minimum ventilation requirements for crawl spaces. When upgrading to flame- and ember-resistant vents, therefore, it is important to consult the local building code official as the number of vents may need to be increased or decreased to ensure adequate airflow.

Typical foundation vents covered with metal mesh screening can be replaced with flame- and ember-resistant vents; the quantity of vents may need to be increased to maintain code-required ventilation. Installing a plastic ground cover in the crawl space would considerably reduce the amount of required venting. Alternatively, creating a non-vented crawl space would eliminate the need for traditional vents in the exterior wall. The latter strategy is more difficult to implement in an existing home and was not priced for this report.

Combustible dryer vents should be replaced with noncombustible vents. Installing a corrosion-resistant metal dryer vent with a flap that remains closed when the dryer is not in use will reduce the vent's vulnerability. Fire caulk should be applied at the perimeter between vents and exterior wall locations to reduce the vulnerability of that area to flame exposures. Dryer lint should be removed from ducts regularly.

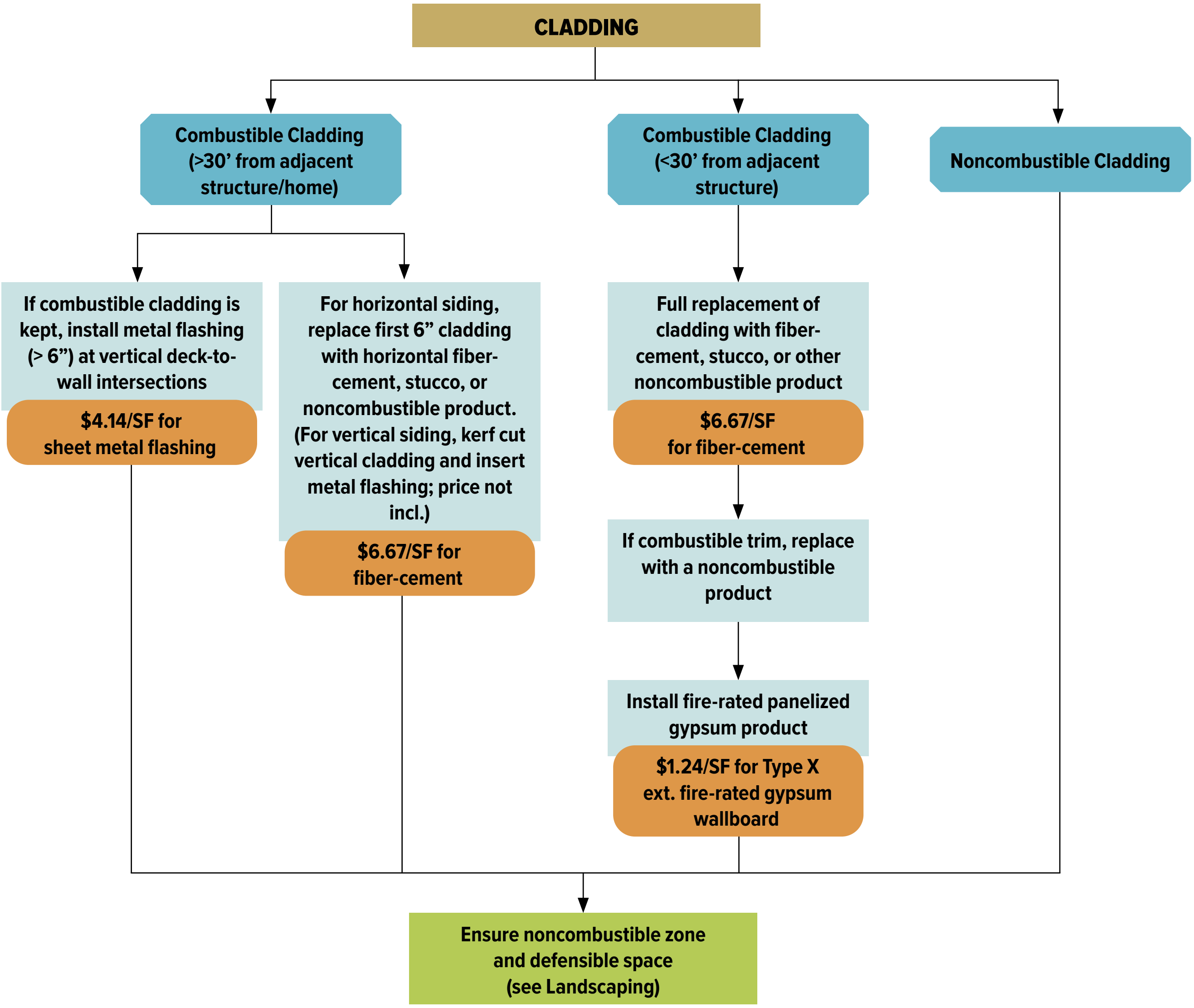
Example Retrofitting Costs

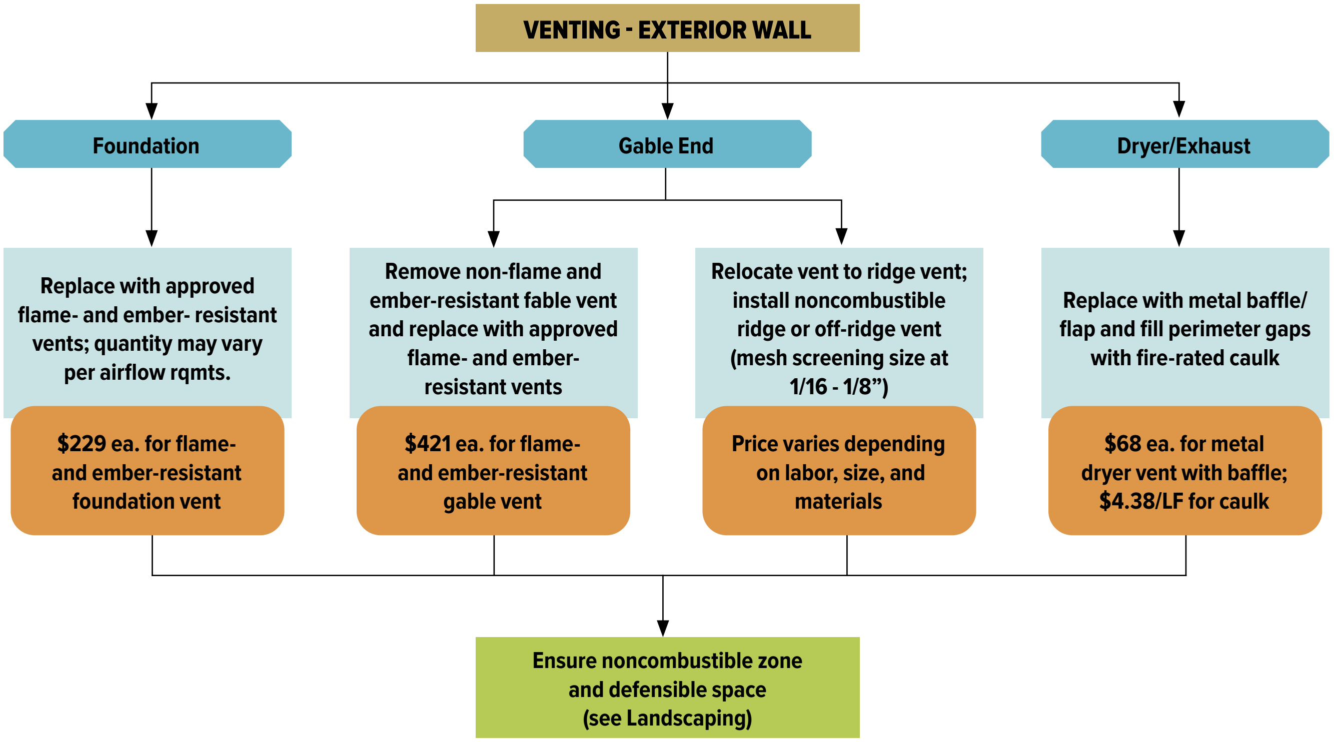
The cost of retrofitting the exterior walls of a home to improve wildfire resilience are variable, depending on materials. Cladding materials meeting Chapter 7A requirements include noncombustible fiber-cement siding and stucco, heavy timber and log, and materials rated as being ignition resistant. Combustible materials that have been tested to provisions provided in ASTM E2707 and complying with acceptance criteria specified in Chapter 7A can also be used, but analysis for this report has only focused on noncombustible options. A weather barrier (e.g., house wrap or building paper) and metal flashing at deck-to-wall locations are also required.

For the purposes of this report, retrofitting the exterior wall included replacing the combustible siding with fiber-cement siding and applying a synthetic house wrap product and gypsum wallboard in the wall assembly. Replacement with a fiber-cement product (without the gypsum wallboard) would comply with Chapter 7A provisions. Alternatively, a three-coat stucco application over a wire mesh on wood frame and sheathing system would be wildfire-resistant but is not priced out in this report.

A six-inch vertical metal flashing was installed at the deck-to-wall intersection. The cost for fiber-cement lap siding with a woodgrain texture was around $7 per square foot. The synthetic house wrap, gypsum wallboard, and metal flashing added costs per square foot. Retrofitting one side of a home measuring 480 square feet with noncombustible siding, synthetic house wrap, and gypsum wallboard cost around $4,000. Including gypsum wallboard is not required by Chapter 7A building code and would reduce the price if not used. For horizontal combustible cladding, a more affordable retrofitting strategy is installing metal flashing over the bottom course and costs around $4.14 per square foot. Flame- and ember-resistant vents for the gable end, including demolition and installation, average $420 per vent with a minimum of two gable vents needed for one home.

Decision-Tree Diagram




VENTING - EXTERIOR WALL
Foundation
Gable End
Dryer/Exhaust
Replace with approved flame- and ember- resistant vents; quantity may vary per airflow rqmts.
Remove non-flame and ember-resistant fable vent and replace with approved flame- and ember-resistant vents
Relocate vent to ridge vent; install noncombustible ridge or off-ridge vent (mesh screening size at 1/16 - 1/8”)
Replace with metal baffle/ flap and fill perimeter gaps with fire-rated caulk
$229 ea. for flame- and ember-resistant foundation vent
$421 ea. for flame- and ember-resistant gable vent
Price varies depending on labor, size, and materials
$68 ea. for metal dryer vent with baffle; $4.38/LF for caulk
Ensure noncombustible zone and defensible space (see Landscaping)

Roof

Ongoing Maintenance and Management Measures:
• Remove accumulated vegetation and debris from roof, including roof valley • Remove accumulated vegetation and debris from gutters • Remove flammable materials from on top of and under deck area • Maintain a noncombustible zone (0-5’ around the home) • Manage vegetation and similarly mitigate outlying buildings, campers, and structures on the property

Roof							
			Scenario Range			Reduces Exposure to	
Retrofitting Material & Cost	Cost/ Unit	Unit	Good	Better	Best	Embers	Radiant/ Direct Flame
Class A roof covering, e.g., asphalt fiberglass composition shingles, incl. fire-resistant synthetic underlayment	$6.29	SF	X	X		X	X
Synthetic underlayment for Class A roof	$1.33	SF	X	X			X
Class A roof covering, e.g., standing metal seams, incl. fire-resistant synthetic underlayment	$18.68	SF			X	X	X
Metal flashing for all roof-to-wall intersections (e.g., dormers, chimney, etc.)	$1.02	LF	X			X	X
Noncombustible siding material for wall-to-roof intersections (does not include shingle or fascia replacement)	$5.20	SF		X	X	X	X
Protective baffle if keeping plastic ridge vents	$2.93	SF	X			X	
Noncombustible flame- and ember-resistant ridge vents, incl. baffle	$33.77	LF		X	X	X	
Noncombustible flame- and ember-resistant off-ridge vent	$126.00	SF		X	X	X	
Metal drip edge	$2.93	LF	X	X	X	X	X
Flat tempered-glass skylight	$1,434.88	Ea			X	X	X
Birdstop material (e.g., for tile roof coverings)	$20.26	SF	X	X	X	X	

Description and Assumptions

Many vulnerabilities on the roof warrant retrofitting to improve wildfire resistance. Due to its large surface area, the roof can be one of the more extensive and expensive retrofits for a home, yet also one of the most critical considerations to reduce vulnerability. For example, the highest priority for a home with a roof of non-fire-retardant-treated wood shake or shingle covering would be roof replacement.

Chapter 7A requires a Class A roof (the highest fire rating) as “stand alone” or “by assembly.” Examples of the former include asphalt fiberglass composition shingles, flat/barrel-shaped tile, and standing seam steel roofing panels. Roof coverings that meet Class A rating “by assembly,” such as fire-retardant-treated wood shingles or shakes, must have an underlying material or a special installation technique to meet the acceptance criteria. Given the popularity and affordability of asphalt fiberglass composition roof coverings, most roof coverings are Class A.

Replacing a roof covering involves replacement of the underlayment, which is installed to manage moisture. This underlayment is either a more traditional asphaltic/fiber roofing felt or a synthetic product. Hardware related to ventilation is also usually replaced. When replacing the roof covering with standing seam steel roofing panels, installing both a fire-resistant underlayment and a synthetic underlayment is recommended.

Roof valleys can be vulnerable and require special consideration. For an asphalt fiberglass composition roof covering, there are two basic options: interweaving the shingles or incorporating corrosion-resistant metal flashing in the valley and terminating the roof covering at the valley. When choosing the metal flashing option, an asphalt fiberglass composition shingle roll roofing product (i.e., a mineral-surfaced nonperforated cap sheet) must be installed under the flashing. Chapter 7A provides direction regarding the installation of flashing and accompanying underlying mineral-surfaced cap sheet, stating that where installed, “*the flashing shall be not less than 0.019-inch No. 26 gage* *galvanized sheet corrosion-resistant metal installed over not less than one layer of min 72-lb mineral-surfaced nonperforated cap sheet complying with ASTM D3909, at least 36-inch wide running the full length of the valley. (705A.3 Roof valleys).*" If the asphalt fiberglass composition shingles are installed by interweaving the shingles, then there is no need to install the cap sheet material in the valley.

The costs for a roof replacement depend on the complexity of the roof (i.e., the number of roof-to-other-material intersections). For example, simple roofs with no dormers or multiple roof-to-wall intersections will be easier and less labor intensive to retrofit than a roof with more complex design features. Removing the roof covering may reveal damaged and/or decayed sheathing. Unforeseen conditions such as water damage, fungal decay, insect damage, fastener corrosion, and certain materials such as asbestos-containing products may require removal and remediation of the impacted area before a new roof covering can be applied. These ancillary outcomes and associated costs for repair were not accounted for in this study.

Installing a corrosion-resistant metal drip edge at the roof edge can reduce ignition vulnerability at that location. This angle flashing protects the exposed materials (typically wood or wood-based) at the edge of the roof such as the sheathing and fascia from embers and flame, and also water (usually from rain). A noncombustible gutter and gutter cover device are recommended for improved wildfire-resistance (see section on "Eaves and Vents").

Ridge vents can be another point of entry for embers and flames into the attic space. Roof vents are important for air circulation to remove excess moisture and, depending on roof covering, may help moderate temperature in the attic. Roof vents should be installed for roofs covered in either asphalt fiberglass composition shingles or standing seam steel roofing panels. Exiting air vents can be located on the roof ridge, on the slope of the roof ("off-ridge"), or on the exterior wall (i.e., gable end vents), though not all roof and attic spaces have vents.

Most building codes provide minimum ventilation requirements for attics and crawl spaces, typically expressed in terms of net free ventilation area (NFVA) per square foot of horizontal floor (crawl space) or ceiling (attic) area. For example, in California's Chapter 7A the venting requirement for a crawl space is 1 ft^2 of vent area per 150 ft^2 of floor area. The NFVA for flame- and ember-resistant vents is less than that of traditional 1/4- or 1/8-inch mesh screening, commonly used as vent covers. As a result, when replacing traditional vent openings with flame- and ember-resistant vents, the vent opening may need to be increased, or the number of vents increased, to comply with ventilation requirements.

Plastic roof vents should be replaced with ridge or off-ridge noncombustible flame- and ember-resistant vents. Ridge vents with an external baffle have been shown to resist the entry of embers, so are considered a good design feature. Plastic ridge vents are vulnerable if vegetative debris that can accumulate at the entrance of the vent is ignited by embers, resulting in direct flame exposure to the plastic components. If full replacement of a plastic ridge vent with a noncombustible metal ridge vent is not an option, installing a metal angle flashing, with the vertical leg covering the exposed surface of the baffle and the horizontal leg terminating under the roof covering, over the plastic ridge vent would reduce vulnerability to flames from ember-ignited debris while maintaining resistance to ember entry from the external baffle. In a similar fashion, a ridge vent lacking an external baffle can be modified by installing angle flashing (i.e., an inverted metal drip edge) at the inlet to the vent.

Replacing combustible off-ridge vents with flame- and ember-resistant vents would require removal of some portion of the roof covering surrounding the vent. Depending on the age and type of roof covering, it may be difficult to match roof covering and color. According to California's Chapter 7A, vents that are installed on a sloped roof, such as a dormer vent, are required to be covered with a noncombustible, corrosion-resistant mesh screen with openings at least 1/16-inch and no larger than 1/8-inch.

Because of the size of gable end vents and their location on a vertical surface, they are vulnerable to ember entry. This vent can be relocated to a ridge or off-ridge location. This would require removal of the gable vent and re-cladding over the opening, then cutting into the ridge line and inserting a new flame- and ember-resistant ridge vent (see "Exterior Wall").

Common construction for a skylight includes a lumber frame clad with metal flashing (the base framing) with the skylight sash mounted on top with attachment to the upper edge of the frame. The skylight sash is typically either glass (flat-type) or plastic (dome-type). It is recommended to replace a plastic, dome-type skylight with a glass, flat-type skylight. In many cases, a similar-sized glass type (typically dual-pane with outer pane tempered glass and inner pane laminated glass) can be found. The plastic sash can be detached by removing screws that connect the sash to the base frame. The glass sash can be installed and attached with a similar procedure.

At roof-to-wall intersections such as at a dormer, chimney chase, or on a home with a split-level design where the siding is a combustible horizontal lap siding product, the siding can be replaced with a noncombustible option (Figure 2).

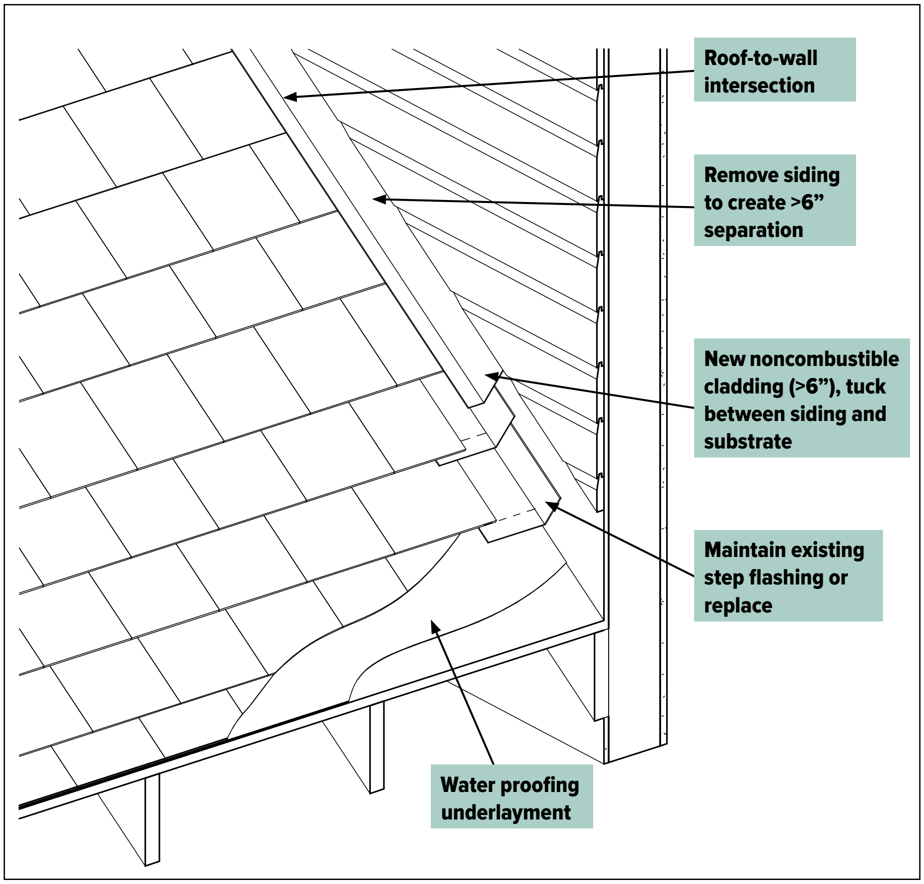


Figure 2: Structural improvements for wildfire risk reduction at roof-to-wall intersections (e.g., chimney or dormers)

Roof

The under-eave area above the roof line in these areas should also be evaluated and hardened if needed. Given the vulnerability of open-eave construction, modifications may be warranted (see under-eave retrofitting strategies elsewhere in this report). If a 5-foot noncombustible zone around the home has not been developed or maintained and a combustible cladding is used, then modifications to the under-eave are recommended.

Alternatively, if replacing combustible horizontal lap siding at roof-to-wall intersections is not possible, installing a 6-inch vertical metal flashing at the base of the exterior wall will increase wildfire resistance to a direct-ember-ignition scenario. If this option is chosen, then a portion of the roof immediately adjacent to the intersection will have to be removed and reinstalled to integrate the new step flashing in such a way as to avoid water entry. The vertical leg of the flashing will also need to terminate behind the siding to avoid water-related degradation. Similarly, installing metal flashing for vertically oriented siding at roof-to-wall intersections will increase wildfire resistance by reducing the likelihood of a direct ember ignition, although this may require custom cutting the siding and flashing to integrate flashing with the existing siding. Fire-retardant coatings, including intumescent types, were not included in this report because research indicates they have a relatively short effective service life.

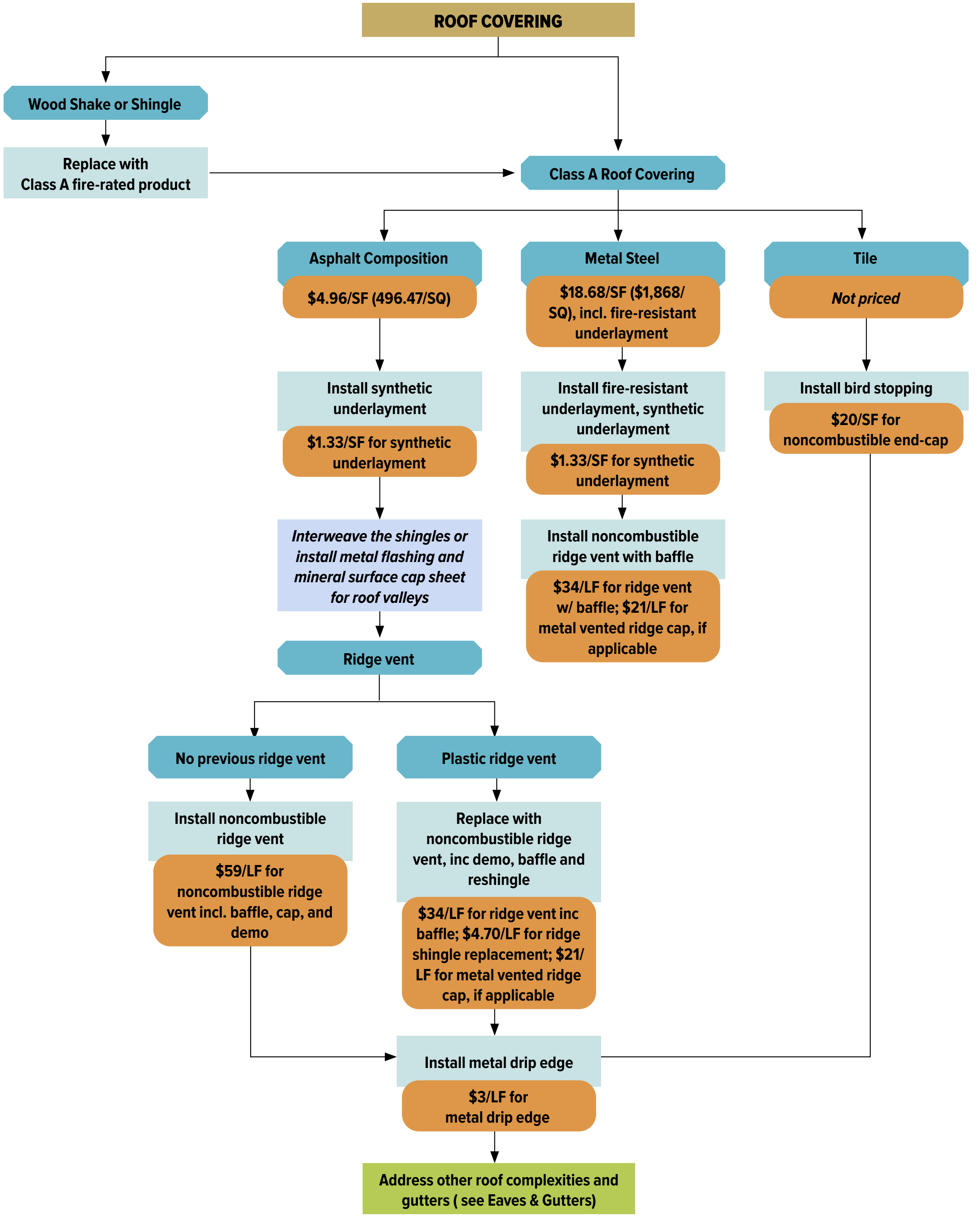
If the roof is covered with a tile or metal product and there are gaps between the roof covering and roof deck, then noncombustible end caps (i.e., a "bird-stopping" product) should be installed to block these gaps. Note that gaps can also occur at ridges and where hip tiles intersect with the roof. Bird-stopping is required by Chapter 7A, which specifies the installation of noncombustible material in these gaps to minimize ember entry. Materials that can be used to plug these open areas include a mineral wool insulation material, a mortar mix, and fine mesh screening. Some manufacturers of barrel-shaped and flat-tile roof coverings offer a bird-stop product.

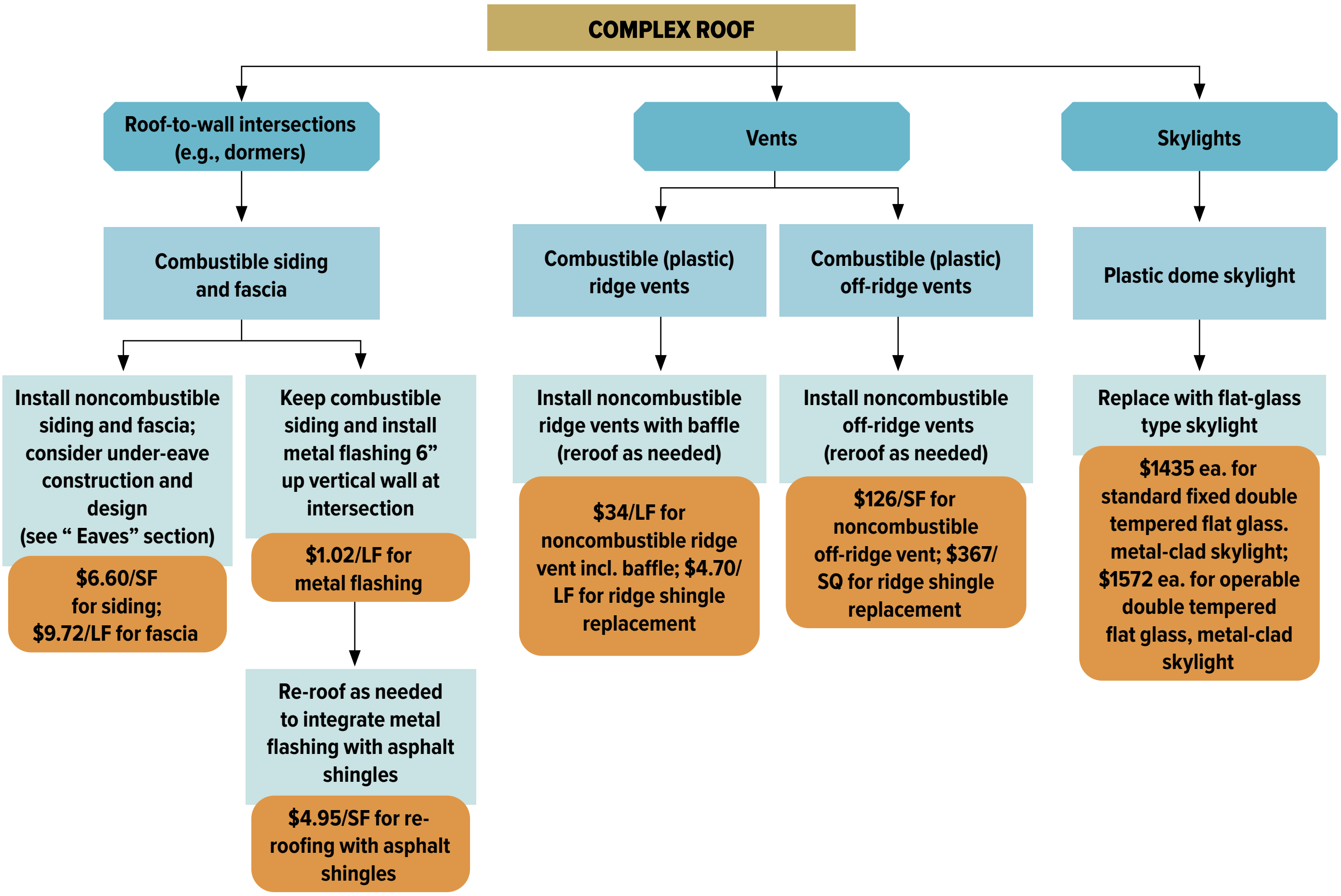
Example Retrofitting Costs

The cost of retrofitting a simple, 1,000-square-foot, wood-shake roof with an asphalt fiberglass composition shingle product, including a synthetic underlayment, was around $6,300. Installing an edge-of-roof metal drip edge and an approved flame- and ember-resistant ridge vent will add costs. Alternative noncombustible roof covering options such as steel roofing panels or tile will cost more than asphalt fiberglass composition shingles. Addressing potential decay of wood or wood-based components in the roofing assembly and other unforeseen degradation that is revealed with removal of the roof covering will add costs for remediation and repair.

Replacing a plastic dome skylight with a standard fixed flat-glass skylight measuring 22-by-46-inches costs around $1,435 for each unit including labor and demolition costs.

Decision-Tree Diagram




COMPLEX ROOF
Roof-to-wall intersections (e.g., dormers)
Vents
Skylights
Combustible siding and fascia
Combustible (plastic) ridge vents
Combustible (plastic) off-ridge vents
Plastic dome skylight
Install noncombustible siding and fascia; consider under-eave construction and design (see " Eaves" section)
$6.60/SF for siding; $9.72/LF for fascia
Keep combustible siding and install metal flashing 6" up vertical wall at intersection
$1.02/LF for metal flashing
Re-roof as needed to integrate metal flashing with asphalt shingles
$4.95/SF for re-roofing with asphalt shingles
Install noncombustible ridge vents with baffle (reroof as needed)
$34/LF for noncombustible ridge vent incl. baffle; $4.70/ LF for ridge shingle replacement
Install noncombustible off-ridge vents (reroof as needed)
$126/SF for noncombustible off-ridge vent; $367/ SQ for ridge shingle replacement
Replace with flat-glass type skylight
$1435 ea. for standard fixed double tempered flat glass. metal-clad skylight; $1572 ea. for operable double tempered flat glass, metal-clad skylight

Eaves and Gutters

Maintenance and Management Measures:							
• Remove accumulated vegetation and debris from roof, including roof valley • Remove accumulated vegetation and debris from gutters • Remove flammable materials from on top of and under deck area • Maintain a noncombustible zone (0-5' around the home) • Manage vegetation and similarly mitigate outlying buildings, campers, and structures on the property							
Eaves & Gutters							
			Scenario Range			**Reduces Exposure to**	
Retrofitting Material & Cost	**Cost/ Unit**	**Unit**	**Good**	**Better**	**Best**	**Embers**	**Radiant/ Direct Flame**
For open eave design: circular noncombustible flame- and ember-resistant vents	$53.02	Ea	X			X	X
For open eave design: fire-rated caulk for gaps between blocking and adjacent members	$4.38	LF	X			X	
For open eave design: noncombustible soffit material to enclose eave (framing and assembly costs not incl.)	$3.92	SF		X		X	X
Noncombustible flame- and ember-resistant vents in eaves	$105.05	Ea		X		X	X
For enclosed eave with combustible soffit: replace with noncombustible soffit (incl. demolition)	$4.51	SF			X	X	X
For enclosed eave with noncombustible soffit: noncombustible flame- and ember-resistant vents (incl. demolition)	$106.24	Ea			X	X	X
Metal gutter guard	$4.48	LF	X	X	X	X	X
Metal drip edge	$2.93	LF	X	X	X	X	X
Metal gutter systems	$18.78	LF		X	X	X	X

Description and Assumptions

When considering the vulnerability of the under-eave area to flames and wind-blown embers, the primary consideration is whether it is enclosed ("boxed-in") or open. An open eave is more vulnerable to flames and embers than an enclosed eave due to the greater heat-trapping potential between the exposed rafters and resulting impact on ignition potential. Once ignited, the under-eave area will experience rapid lateral flame spread to adjacent rafter bays. In addition, vents in the open-eave blocking are vulnerable to the entry of embers, and gaps between blocking and adjacent materials (rafters, top plate, and roof sheathing) can trap embers, potentially resulting in ignitions in those areas. Maintaining a noncombustible zone around the home is critical in reducing ignition vulnerability of homes with an open-eave design. This is particularly true where combustible siding is installed.

A retrofit strategy for an open eave design would be to enclose with a noncombustible soffit material, such as a fiber-cement product, and install flame- and ember-resistant vents. While this may be the more expensive option, enclosing an eave can greatly improve wildfire resistance.

Options for enclosing an eave include installing horizontal noncombustible soffit panels from the exterior wall to the roof edge (typically attaching to the fascia board) or by attaching noncombustible panels to the bottom edge of the rafters (Figure 3). Regardless of the size or shape of the soffit panels, the use of flame- and ember-resistant vents is important in reducing ember penetration into the interior of the structure.

A more affordable approach for an open-eave design is applying a fire-resistant caulk at all the gaps around the between-rafter blocking and replacing traditional ¼-inch-mesh under-eave vents with a flame- and ember-resistant alternative. As noted above, a developed and maintained noncombustible zone reduces the ignition potential of the siding, particularly for open-eave construction. If it is not possible to create and maintain a noncombustible zone, then the under-eave area should be enclosed.[22]

For eaves that are already enclosed with combustible soffit material, replace the soffit with noncombustible materials such as a fiber-cement product. Stucco is a more expensive option. Replace traditional soffit venting with a flame- and ember-resistant option. The building code provides performance-based methods whereby combustible claddings can be used in the under-eave area. These options were not directly evaluated here.

When there is a maintained noncombustible zone for 5 feet around the home and also a 6-inch vertical noncombustible area at the base of the exterior wall (this would typically be the concrete foundation), converting an open eave to a soffited eave is less critical. Note that vents installed in a soffited eave are less vulnerable to ember entry. Also, if the existing cladding is combustible, it is important that vegetation and other combustibles within 30 feet of the home be maintained in such a way that, if ignitions occur in this area, the radiant heat and/or flame impingement exposure to the exterior wall is minimal.

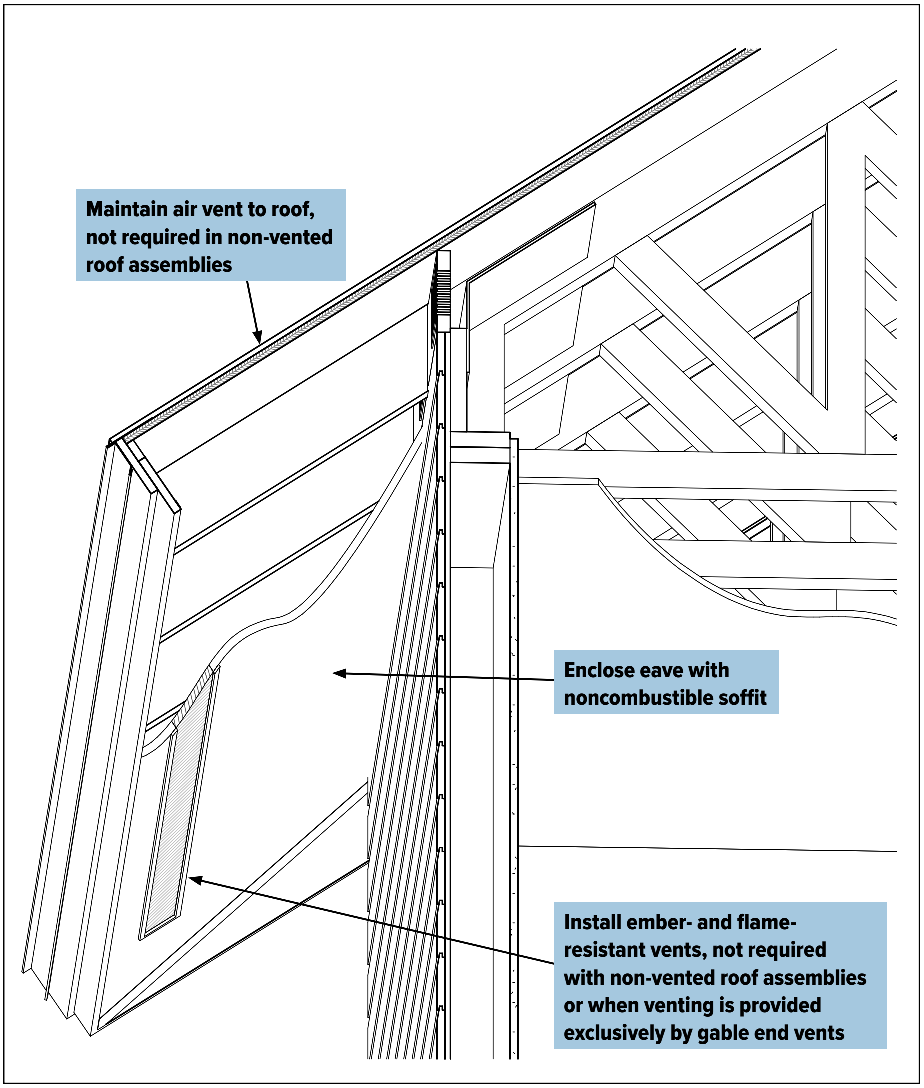


Figure 3: Enclosing an open eave via attaching noncombustible soffit panels to bottom of rafters and installing a single linear ember- and flame-resistant vent. A maintained noncombustible zone is essential to complement structural improvements to eaves, exterior walls, and other exterior home components.

Regarding wildfire, the most important consideration with gutters is the accumulation of vegetative debris, regardless of the gutter material. Installing a metal gutter cover can minimize accumulation of leaves, pine needles, and other combustible materials in gutters, which when ignited can expose the roof edge (roof sheathing and fascia). Similarly, plastic gutters can detach and fall to the ground and ignite surrounding combustible materials if the accumulated vegetative debris is ignited.

A noncombustible gutter system (i.e., metal gutter and noncombustible gutter cover) can increase a structure's wildfire resistance because it would minimize the accumulation of vegetative debris in the gutter, reducing the amount of fuel that could be ignited by wind-blown embers. This system also protects the roof edge material as any ignited debris would be on top of the gutter cover device.

If the metal gutter does not have an integrated drip edge whereby the horizontal leg slips under the roof covering but rather is attached directly to the fascia, a separate metal drip edge should be installed at the roof edge (Figure 4). Note that no gutter cover device has been proven to completely eliminate the collection of vegetative debris on top of the device and/or roof, so removal of debris will still be needed.

Labor costs for all of the recommended retrofit strategies noted for eaves and gutters will increase with the height and complexity of the home and roof design. The cost of safety items such as ladders, scaffolding, and fall protection that would be incorporated into contractor costs will increase with the scope of the project and were not considered here.

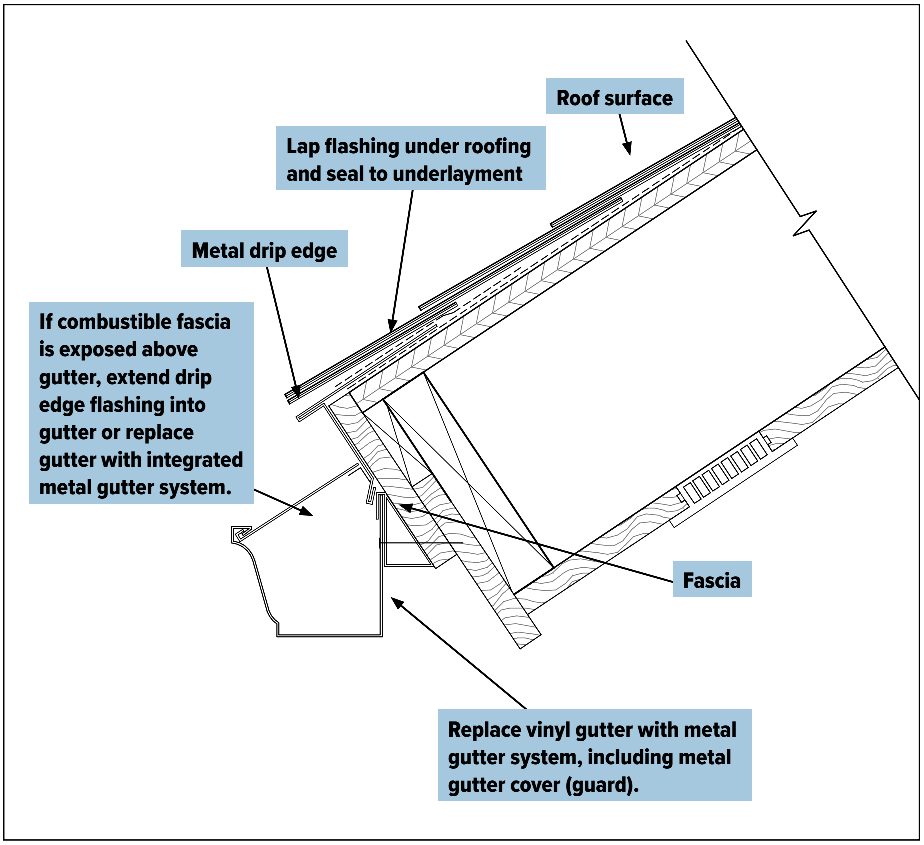


Figure 4: Replacing vinyl gutter system with metal gutter system, including integrated drip edge and cover/gutter guard.

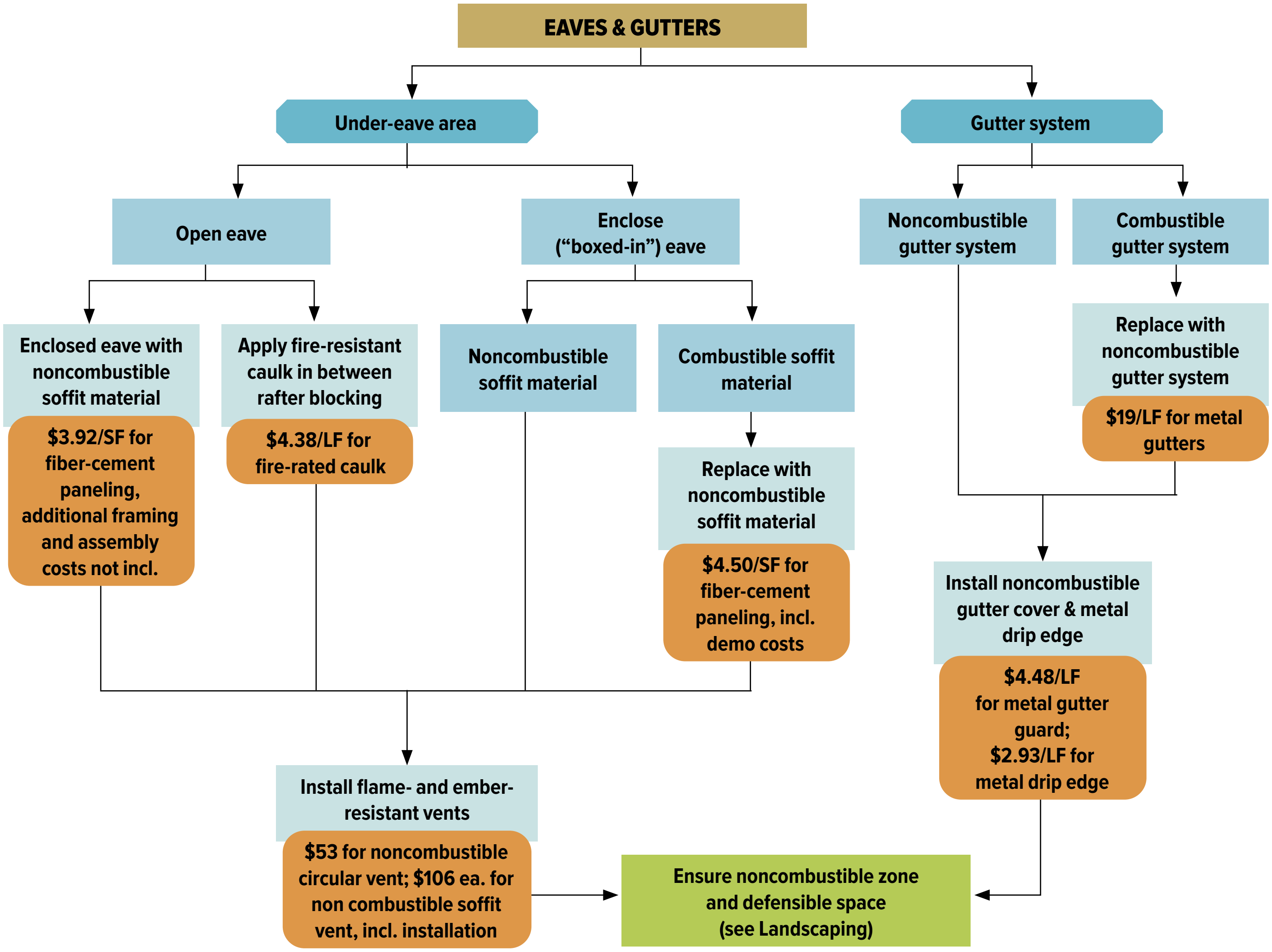
Example Retrofitting Costs

Retrofitting a home with flame- and ember-resistant vents can be done relatively affordably and can improve wildfire resistance. For instance, a single flame and ember-resistant vent for an enclosed eave costs around $106 including material, labor, and installation. The cost would be much lower if the retrofit was done by the homeowner. Approved flame- and ember-resistant vents are readily available in lumber yards and home improvement stores.

Replacing combustible soffit material with noncombustible soffit material should also include installing flame- and ember-resistant vents. Estimated costs for replacing 40 feet of soffit material and installing appropriate wildfire-resistant vents for one side of a home having an 18-inch eave overhang was around $4,000.

Installing a metal gutter system will vary with the length of the system. Replacing a 40-foot vinyl gutter along one side of a home with a metal gutter system including a gutter guard costs around $930. Installing a metal drip edge is additionally recommended and would increase the costs by $100 to $200 for each side of the roof requiring a drip edge.

Decision-Tree Diagram



Deck

Ongoing Maintenance and Management Measures:							
• Remove accumulated vegetation and debris from roof, including roof valley • Remove accumulated vegetation and debris from gutters • Remove flammable materials from on top of and under deck area • Maintain a noncombustible zone (0-5' around the home) • Manage vegetation and similarly mitigate outlying buildings, campers, and structures on the property							
Deck							
			Scenario Range			**Reduces Exposure to**	
Retrofitting Material & Cost	**Cost/ Unit**	**Unit**	**Good**	**Better**	**Best**	**Embers**	**Radiant/ Direct Flame**
Metal grate to replace first deck board that's parallel to the home	$104.13	LF	X			X	X
Metal flashing to deck-to-wall intersection	$2.74	LF	X	X		X	X
Higher-density material (e.g. bamboo) deck surface incl. fastners; substructure and foil-faced bitumen tape around joists and posts	$50.36	SF		X		X	X
Higher-density material for deck surface (e.g., plastic composite), does not incl. structural support	$7.93	LF		X		X	X
Noncombustible deck surface (e.g., concrete slab), demolition not included	$11.17	SF			X	X	X
Noncombustible deck surface and support system (metal surface and structural support)	$66.76	SF			X	X	X
Incl. excavation/footings	$255.84	Ea			X	X	X
Incl. metal framing	$116.95	Ea			X	X	X
Noncombustible (metal) stairway	$676.37	Ea			X	X	X
Noncombustible (metal) railing for stairs	$91.11	LF			X	X	X
Noncombustible mesh screen skirting for underdeck area	$27.03	SF	X	X	X	X	

Description and Assumptions

A home that is threatened by wildfire will be exposed to wind-blown embers. As a result, strategies to enhance the deck's resistance to ember exposure are critical to the survival of a building.

Similar to the roof covering, decks are vulnerable to ignition during a wildfire as a result of their relatively large surface area. Embers can accumulate on the surface and in the gaps between deck boards if on top of a joist, or fall to the ground under the deck if not. They can also accumulate in, on top of, or adjacent to other items on the deck, such as deck furniture, firewood, and at the deck-to-wall intersection.

The underside of decks are also vulnerable to flame exposure if combustible materials stored under the deck ignite and/or if the deck overhangs a slope where downslope shrubs and trees ignite. Combustibles stored under the deck can be ignited by wind-blown embers.

Removal of combustible materials in the under-deck area and careful management of vegetation near the deck can minimize the chance of an under-deck exposure (Figure 5). Removal of vegetation and other combustible materials downslope of the deck – part of the creation and maintenance of effective defensible space on the property – will also reduce the ignition potential of the deck.

Top-of-deck fires, particularly ember ignitions that start in deck-board gaps, tend to be smaller fires (i.e., shorter flame height), but can sustain ignition while the fire spreads to the exterior wall of the home or building where the fire can grow, depending on materials used in the wall construction. Under-deck fires are more likely to become larger deck fires since they can grow more rapidly, resulting in radiant heat and flame exposure to the exterior wall, particularly in the under-deck area.

Combustible deck attachments and projections such as awnings, stairs, ramps, and patio covers and should be replaced, relocated, or removed. In this report, replacing stairs and rails with noncombustible options are included in the cost analysis.

Figure 5: The under-deck area should be considered in the noncombustible zone, including managed vegetation and removing combustible materials. (Photo: Shearman Builders)

Several options are available that can reduce the vulnerability of decks, ranging from replacing deck components (e.g., using noncombustible deck boards or higher-density deck boards that are resistant to ember ignition), to enclosing the under-deck area, to replacing the entire deck. For example, nearly all commonly used decking walking surface materials are combustible, with the exception of metal deck boards, concrete, and flagstone. Retrofitting options to improve wildfire resistance include addressing vulnerabilities at deck-to-wall intersections, steps and rails, and the structural support system.

Replacement of a full deck, including walking surface and structural support system, is costly because of materials and labor requirements. For the highest wildfire resistance, installing a steel structural support system with a noncombustible surface area is recommended. Cost considerations in retrofitting include demolition, excavation, and noncombustible decking material and associated assemblies for framing and footings. Alternatively, replacement of the walking surface with a noncombustible option while maintaining the existing wood-based structural support system may require a structural analysis by a licensed civil (structural) engineer. If the deck is being fully replaced, a portion of the exterior wall cladding may have to be removed and reinstalled, which will add to costs.

Alternative decking surface options for resistance to wind-blown embers include (exterior-rated) fire-retardant-treated lumber and some types of plastic composite deck boards.[23] Higher-density wood deck board products, such as many tropical hardwood products, are more resistant to ignition from embers than the lower-density softwood deck board products (e.g., redwood and cedar) that are more commonly used. Fire-retardant-treated (FRT) wood products can also be more resistant to ignition from embers.[24] If the joists are wood, a foil-faced bitumen product applied to the top surface of the joists and extending about halfway down each side of the joist will reduce the vulnerability of the deck to embers but, because of the bitumen component, would likely increase the vulnerability to flames. Minimizing the chance of flames *under* a deck built with combustible deck boards will reduce the chance that a burning deck will threaten the home. To accomplish this, development and maintenance of a noncombustible zone under and within 5 feet of the perimeter of the deck is critical.

If the deck is close to grade, then a patio upgrade could include replacing the decking surface with concrete and increasing the thickness of the monolithic slab. For decks on a slope with an extended overhang, a more comprehensive approach of replacing the structural support system may be required.

When deck boards are parallel to the home, a cost-effective strategy to reduce the potential of ember ignitions on top of the deck from burning to the house is to replace the first board near the home with a metal grate or metal deck board (Figure 6). This strategy creates a noncombustible zone adjacent to the home. The mitigation strategy for decks where the deck boards are perpendicular to the exterior wall is more complicated since it requires cutting the ends off each deck board, then adding a new under-deck support system to support the ends of the newly cut deck board and the noncombustible grate or deck board. This report does not include the costs for retrofitting deck boards installed at an angle other than parallel; the costs would be greater for other scenarios. These strategies must be combined with developing and maintaining a noncombustible zone around the home and underneath the

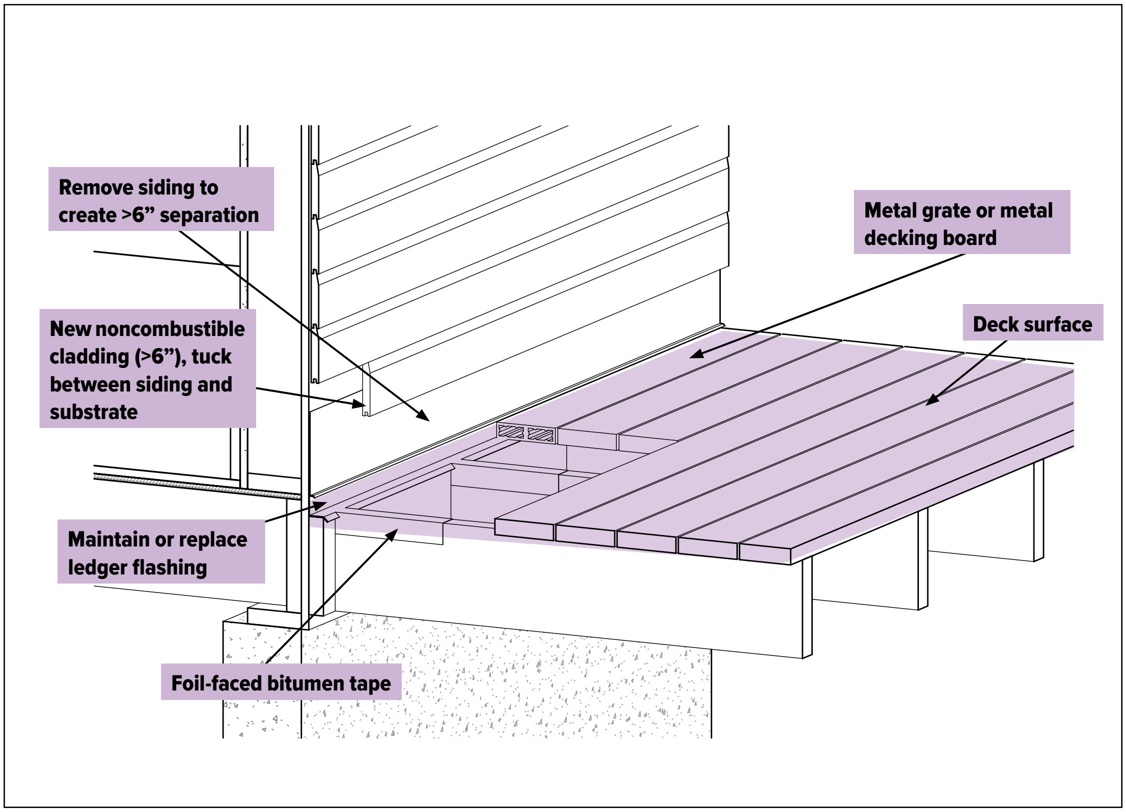


Figure 6: Structural improvements for wildfire resistance for decks, ensuring noncombustible zone extends below the deck area.

deck. Additionally, where a combustible siding product is installed, removing the bottom course and installing metal or noncombustible cladding would limit the chance of embers accumulated at the deck-to-wall intersection from igniting the siding. In this sense, metal cladding (siding material) is differentiated from metal flashing (water proofing material). A 6-inch metal vertical flashing at the deck-to-wall intersection should be installed to limit the chance of embers accumulated at the deck-to-wall intersection from igniting the siding.

Other combustible deck accessories such steps and rails should be upgraded to noncombustible materials such as metal if a deck is completely replaced.

When decks are within four feet of the ground, installation of a corrosion-resistant metal mesh screen with a minimum 1/8-inch mesh screening could be used to enclose the under-deck area. This will minimize the accumulation of vegetative debris in the under-deck area and, during a wildfire, minimize accumulation of embers in the same area. Enclosing the under-deck area with non-mesh materials such as fiber-cement is an alternative option, but is not advised as it requires appropriately installed foundation vents and increased awareness of the potential for water-related degradation (e.g., fungal decay of wood members and fastener corrosion) and other unforeseen damage to the under-deck area. Enclosing the deck horizontally (e.g., attachment of a fiber-cement panel to the bottom of joists) should not be done unless a solid-surface walking surface has been installed (i.e., deck boards are not used as the walking surface).

Example Retrofitting Costs

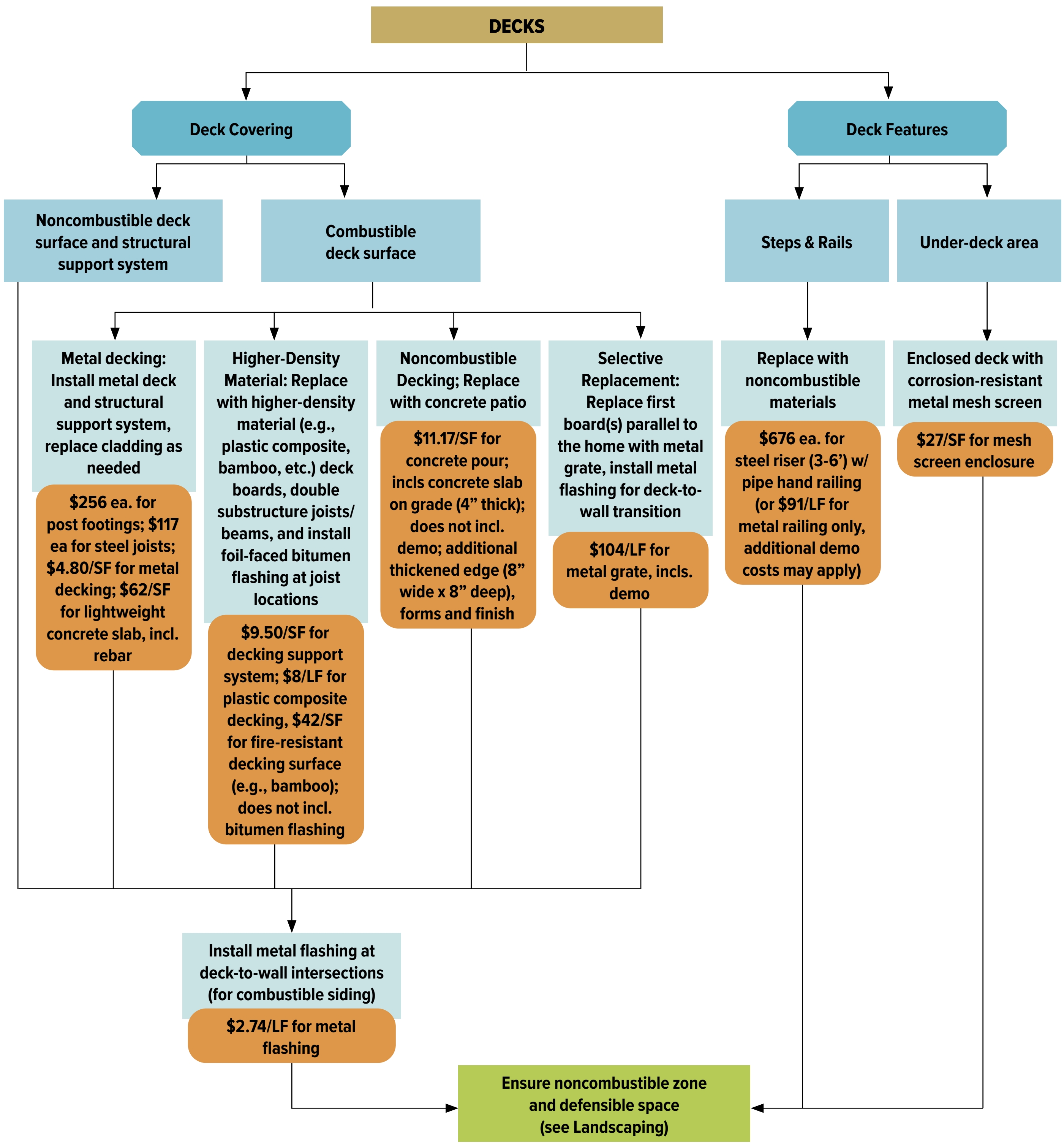
Retrofitting a wood deck can greatly vary with area of the decking surface, height from the ground, slope, and replacement building materials. As an example of estimated costs, a 10-by-10-foot deck retrofitted with a plastic composite deck board product (wood-grained, 1-by-6-inch, grooved edge) and foil-faced bitumen tape on the joists and metal flashing at deck-to-wall intersections costs around $2,500 to $3,000. Replacing a redwood or cedar decking surface with a higher-density material will increase the costs to around $5,000 for a 100-square-foot deck.

A larger retrofit and replacement of the deck with a noncombustible deck surface, such as concrete, will cost more than installing a plastic composite decking material. For instance, replacing a 100-square-foot wooden deck with a steel decking surface and a steel structural support system can cost more than $9,000 depending on costs for excavation, demolition, concrete slab width, piers, and slope of the property. A portion of the siding of the home will also likely have to be replaced for a full deck replacement and will add costs for labor, material, and installation.

One potential and more affordable option for decks with wood deck boards that run parallel to the home is replacing the first one to three decking boards that are adjacent to the home with a metal grate, as described above. Estimated costs for partial demolition of the deck and installation of a metal grate positioned adjacent and parallel to the exterior cladding are around $1,000 for 10 linear feet. It is additionally recommended that metal flashing is installed vertically at the deck-to-wall intersection. Again, if this approach is applied, it is critical for a noncombustible zone to be maintained in the under-deck area as embers will fall through the metal grate and the between deck board gaps and will accumulate in the under-deck are. An alternative retrofitting option is to replace the first one to two parallel horizontal boards (6 to 12 inches) of the exterior wall siding with a noncombustible option (see Exterior Walls). Additional mitigation steps include installing metal railing and noncombustible steps on the deck, which would increase the costs depending on quantity, material, and labor.

Installing noncombustible mesh screen skirting around the deck can minimize debris accumulation under the deck and is a relatively affordable option, although regular maintenance of the underdeck area is still needed to ensure a noncombustible zone is maintained. Mesh screening can be installed for around $27 per square foot and costs will vary with dimensions of the deck.

Decision-Tree Diagram



Windows and Doors

Maintenance and Management Measures:								
• Remove accumulated vegetation and debris from roof, including roof valley • Remove accumulated vegetation and debris from gutters • Remove flammable materials from on top of and under deck area • Maintain a noncombustible zone (0-5' around the home) • Manage vegetation and similarly mitigate outlying buildings, campers, and structures on the property								
Windows/Doors								
			Scenario Range			**Reduces Exposure to**	
Retrofitting Material & Cost	**Cost/Unit**	**Unit**	**Good**	**Better**	**Best**	**Embers**	**Radiant/ Direct Flame**
Protective shutters	$46.78	SF		X			X
Double-paned, tempered metal-clad glass windows (2' x 3'), does not incl. flashing and trim	$755.46	Ea		X		X	X
Fiberglass framed exterior pedestrian door	$1,517.14	Ea		X		X	X
Metal framed exterior pedestrian door	$1,246.87	Ea			X	X	X
Fiberglass framed exterior sliding door with tempered insulated glass	$9,819.00	Ea		X		X	X
Metal framed exterior sliding door with tempered insulated glass	$2,681.00	Ea			X	X	X
Metal kick plate for exterior pedestrian (wood) door	$120.41	Ea	X			X	
Fiberglass framed exterior garage door	$3,903.00			X		X	X
Metal framed exterior garage door	$2,358.00				X	X	X
Metal kick plate for exterior garage (wood) door	$265.61	Ea	X			X	
Weather stripping around exterior pedestrian and garage doors	$530.29	Ea	X	X	X	X	

Description and Assumptions

The two major components of a window are the glass and framing material. Experiments have largely demonstrated that glass is the most vulnerable component of a window, although studies have demonstrated that some types of vinyl-framed windows can be vulnerable.

The best opportunities to improve wildfire resistance in windows is to replace the glass. Glass is the most vulnerable component in a window because it can crack and break under prolonged exposure to heat. When the glass pane cracks and falls out, flames and embers can directly enter the interior of the home and burn from the inside out.

As noted in previous studies,[25] there is a wide range of building products and sizes for windows and doors, including different types of glass (e.g., annealed, tempered, and laminated) and framing material (e.g., vinyl, wood, aluminum, plastic- or aluminum-clad wood, and fiberglass). The vulnerability of windows to heat exposures will vary as a function of the size, glass, and framing material. For instance, an insulated glass unit in a vinyl-framed single- or double-hung window, without reinforcement in the horizontal meeting rail (i.e., interlock), can fail at a radiant heat exposure lower than that required to break the glass. In this case, the meeting rail member deforms and allows the insulated glass unit (IGU) to fall out of the frame or create a gap between the glass and frame, exposing the interior of the home to embers and flames. Most new vinyl-framed windows today have reinforced meeting rails because of building code requirements related to wind load resistance and securing the window locking mechanism. Vinyl-framed windows are also vulnerable to deformation, even if the IGU unit does not fall out, and might need to be replaced after a radiant heat exposure after a wildfire.

Tempered glass is three to four times more resistant to heat exposures than annealed glass and should therefore be the preferred glass for windows. In California, at least one pane of tempered glass is required in new homes built in designated wildfire-prone areas. Most building codes already require dual-paned windows for energy efficiency, which can further strengthen wildfire resistance, particularly if both panes are tempered. Changes in the energy code resulted in dual-pane windows being the norm.

Metal and plastic-clad wood windows are more wildfire resistant than non-clad wood-framed windows. A fine-meshed metal screen (with 1/16-inch openings) over the operable portion of a window will increase resistance to the entry of embers into the interior of the home if the window is left open. The screen will also reduce the vulnerability of the glass to radiant heat exposure.

Windows

Replacing windows can be costly, depending on the size, selected frame type, and number of windows needing replacement. Adding a storm window rather than replacing a window can be a more affordable option but the cost varies with location, climate, and window specifications. To provide continual protection, the storm window would have to remain in place year-round. Costs for the demolition and replacement of exterior and interior trim are not included in this report.

Windows with decayed wood frames or that are constructed with a wide sill that provide a ledge where embers can accumulate should be replaced with metal, metal-clad wood, or fiberglass-framed windows. In California, the building code will require a dual-pane insulated glass unit (IGU) with a minimum of one pane being tempered glass. The best choice would be an IGU with both panes tempered. In addition, the exterior trim should be replaced with a noncombustible product for the highest wildfire resistance, regardless of the exterior siding material.

An alternative retrofit option for windows would be the installation of a noncombustible protective shutter or cover that can be placed over vulnerable windows. Protective barriers can be temporarily or permanently installed, the cost varying with material, size, and quantity needed.[26] A noncombustible option would provide the best protection as would a permanent installation that was easily deployed. Protective barriers often are a more affordable alternative for wildfire retrofitting than complete window replacements, assuming the barriers could be deployed/installed when needed. The authors acknowledge the difficulty in assuring that installation of a barrier material would be installed when wildfire is threatening. This strategy is not priced in this report.

All window replacements and retrofits should be done by a professional contractor due to the complexity of most projects. Demolition of the window casement can expose additional degradation within the wall. Costs for window replacement are therefore broad.

Doors

There are generally four types of doors to consider for retrofitting a home for increased wildfire resistance: exterior pedestrian doors (side doors), porch or deck doors, front doors, and garage (vehicle access) doors. As with windows, the costs and considerations for retrofitting doors vary widely based on size, quantity, specifications, and material.

Doors are vulnerable to wildfire because embers can accumulate in and around the door and adjacent jamb (framing), or at the base of the door-to-horizontal surface, resulting in ignition of the door frame. Depending on the location of the door and presence of nearby combustibles, doors can also be vulnerable to flame and/or radiant heat exposures.

One strategy to improve wildfire resistance in doors is to apply weather stripping around the perimeter, between the door and jamb. Weather stripping will minimize the intrusion of embers into the home. It is important to remove debris, vegetation, and other combustible material that can accumulate at the base of the door. Modern homes will have weather stripping installed if for no other reason than for the comfort of the resident. Where they may not be installed is in garage doors.

Weather stripping has an energy-saving function but it is also applied around the perimeter of garage doors, including the bottom, to minimize the intrusion of embers into the garage through gaps between door and jamb (perimeter framing). In California, this is required by Chapter 7A when visible gaps exceed 1/8 inch (Section 708A.3.1).

Replacing a wood exterior door and garage door with a more fire-resistant door constructed of steel would reduce vulnerability to ignition. A metal kick plate can be installed to further minimize the potential of an ember ignition at the base of the door.

Example Retrofitting Costs

Retrofitting costs for windows and doors can vary greatly depending on size, location, design, and building materials. Cost estimates used in this report are based on replacement of a vinyl or wood frame window with a double-paned, tempered glass, metal-clad wood casement window measuring 2-by-3-feet. In addition to the new material costs, expenses included labor for demolition and removal of the original window, replacing interior and exterior trim, and sealing gaps around the window with flashing and caulking along the header and sill. Estimated costs for replacing one 2-by-3-foot window with a more wildfire-resistant window was around $755.50 per window. The costs for tape, flashing, and replacing and refinishing the interior and exterior trim add around $400 to $500 per window. For a typical short side of a home with two 2-by-3-foot windows, total costs would be between $2,200 and $2,500.

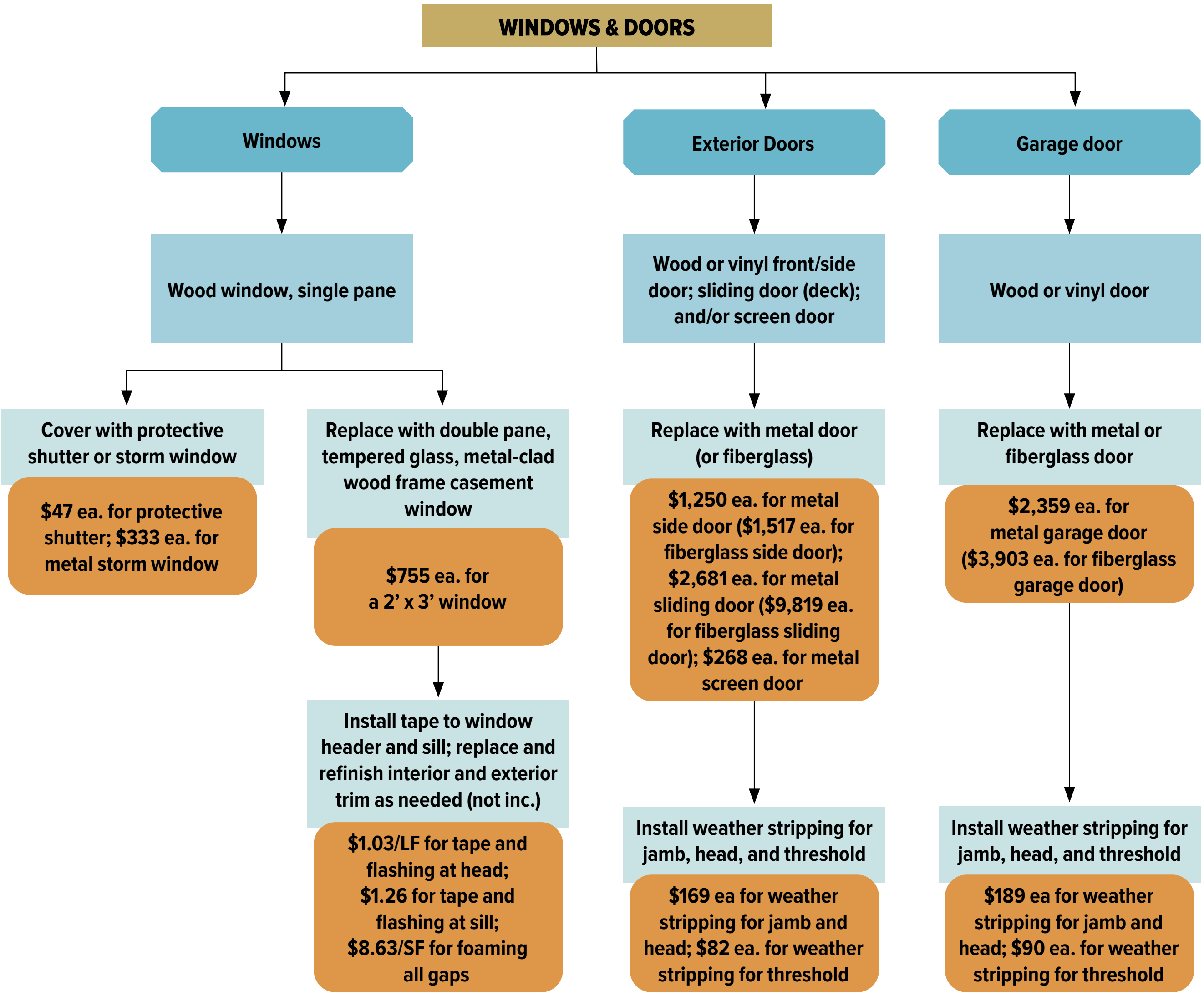
Similarly, retrofitting doors can vary in costs depending on a wide range of options for material, dimensions, and design. Replacing a front or side pedestrian door with a fiberglass door, including a metal kick plate and weather stripping around the door jamb, header, and threshold, costs between $2,000 and $2,500. While less common, a metal-clad front door is often more affordable than a fiberglass door; estimated costs are $1,600 to $2,000 for replacement and installation.

Replacing a vinyl-clad-wood sliding door used on a deck or patio with a more wildfire-resistant aluminum sliding door with 5/8" (total thickness) tempered insulated glass unit (measuring 8 feet by 6-feet-8-inches) costs around $3,000 while a fiberglass option would be more expensive.

Like most doors, a fiberglass garage door will cost more than a metal-clad garage door due to market trends, material costs, and homeowner preferences. An example of retrofitting costs for a garage door, including demolition of the original door and installing a 16-by-7-foot fiberglass garage door and weather stripping around the jamb, head, and threshold total approximately $4,300.

A more affordable opportunity for windows and pedestrian doors would be to install a protective barrier or shutter. Quotes from California contractors estimated the retrofitting costs for adding protective noncombustible shutters (manual crank for rolldown shutters, mounted on the top exterior portion of the frame) to four 2-by-4-foot windows and one 8-by-10-foot door totaled around $8,900.

Decision-Tree Diagram



Near-Home Landscaping

Maintenance and Management Measures:
• Remove accumulated vegetation and debris from roof, including roof valley • Remove accumulated vegetation and debris from gutters • Remove flammable materials from on top of and under deck area • Maintain a noncombustible zone (0-5' around the home) • Manage vegetation and similarly mitigate outlying buildings, campers, and structures on the property

Landscaping							
			Scenario Range			Reduces Exposure to	
Retrofitting Material & Cost	Cost/Unit	Unit	Good	Better	Best	Embers	Radiant/ Direct Flame
Pea gravel to replace bark mulch	$463.62	CY	X	X	X	X	X
10' of noncombustible fencing	$60.44	SF	X	X	X	X	X

Description and Assumptions

The local conditions surrounding the home – including the near-home landscaping, vegetation, and other combustible items – are critical in determining a home's vulnerability to wildfire.[27] A best practice for wildfire resistance is to maintain a 5-foot noncombustible zone around the home with a 6-inch vertical band of noncombustible material along the foundation at the ground level of the home. Very importantly, this noncombustible zone includes the area below all attached decks, bay windows, and other overhangs of the home. These areas must be routinely maintained to avoid the growth and accumulation of vegetation and other combustible materials such as wind-blown vegetative debris.

The noncombustible zone, also referred to as the "ember-resistant zone" or "Zone 0," protects the building from ignitions that can result from wind-blown embers that accumulate at the base of the exterior walls, and from exposure to radiant heat or direct flame contact that can occur when combustible materials near the building or under an attached deck ignite (Figure 7). The goal of landscaping and vegetation management in the adjacent 5-to-30-foot zone is to minimize the chance that any surface fire spreads to the house. Pruning trees and avoiding planting bushes under trees reduce the chance that fire burns into the upper parts of the tree. However, wind-blown embers may still be able to ignite individual islands of plants in the 5-to-30-foot zone, which is why the near-building noncombustible zone is critical.[28]

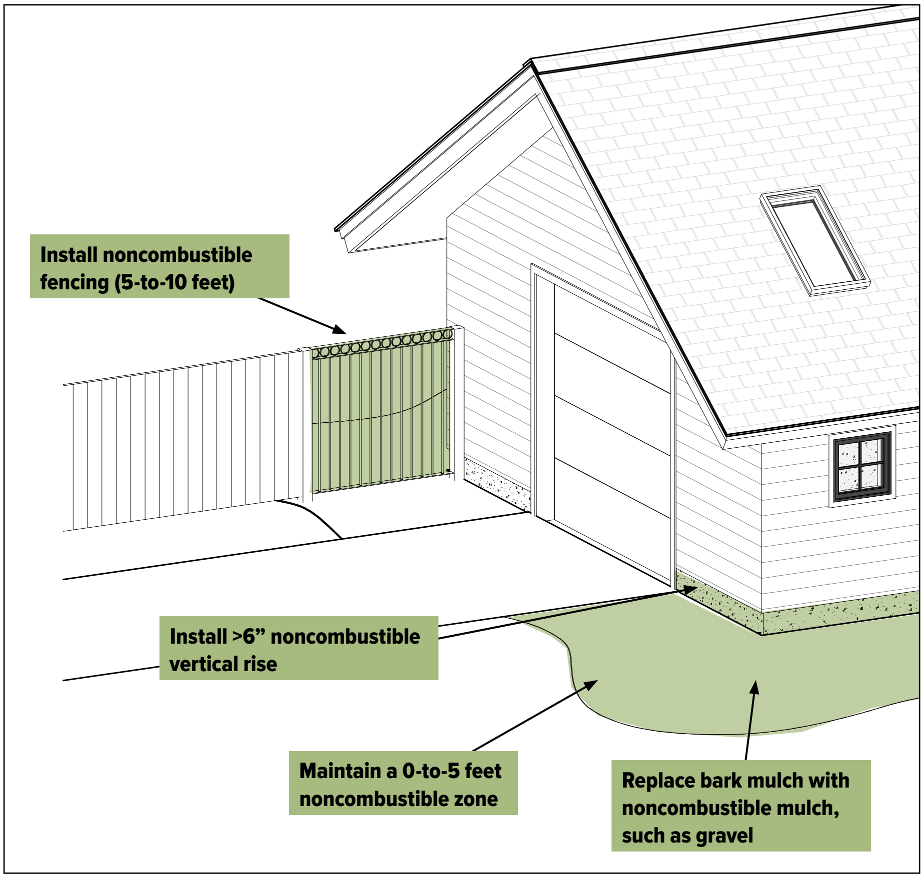


Figure 7: Maintaining a noncombustible zone (0-5') around the home is critical for reducing wildfire risk and complementing recommended structural improvements to the home itself.

It is important to maintain defensible space in the 30-to-100-foot zone

Landscaping

around the home to effectively complement home hardening efforts. If the property owner does not have 100-feet of defensible space, then targeted and selective retrofitting of vulnerable sides and components of the home should be considered. Sheds, outlying buildings, RVs and campers, firewood, and other combustible materials should be relocated at least 30 feet from the home. If it is not possible to accommodate a 30-foot separation distance from sheds and other outlying buildings, then mitigation measures similar to the primary structure should be applied.

Figure 8: Noncombustible fencing should extend 5 to 10 feet from the home (Photo: Shearman Builders)

Retrofitting the noncombustible zone around the home implies removing all combustible materials, including vegetation, combustible mulch, and other combustible items.[29] In conditions where trees are proximate to the home, the local fire department can provide guidance regarding pruning, trimming, and general vegetation management of the property. Bark mulch should be replaced with pea gravel, rock, or other noncombustible mulching material, and in most cases, a weed barrier or other component or material that limits weed growth. As of late 2023, California was developing regulations regarding the requirements for the 5-foot noncombustible zone.

Fences that are attached to the exterior wall of the home should be constructed with noncombustible material such as metal posts and rails. Noncombustible attached fencing (including gates and hardware) should extend 10 feet out from the home (Figure 8). Metal fencing, or other noncombustible material, will minimize the opportunity for a direct flame impingement to the exterior of the home. Note that combustible fencing installed parallel to the home can threaten the home if it is within 5 to 10 feet of the home. The National Institute of Standards and Technology (NIST) also reported that the layout, design, and combination of fence and mulch materials under or adjacent to the fence can greatly influence the spread of fire to the home.[30] The cost provided in this report applies to fencing perpendicular and parallel to the home.

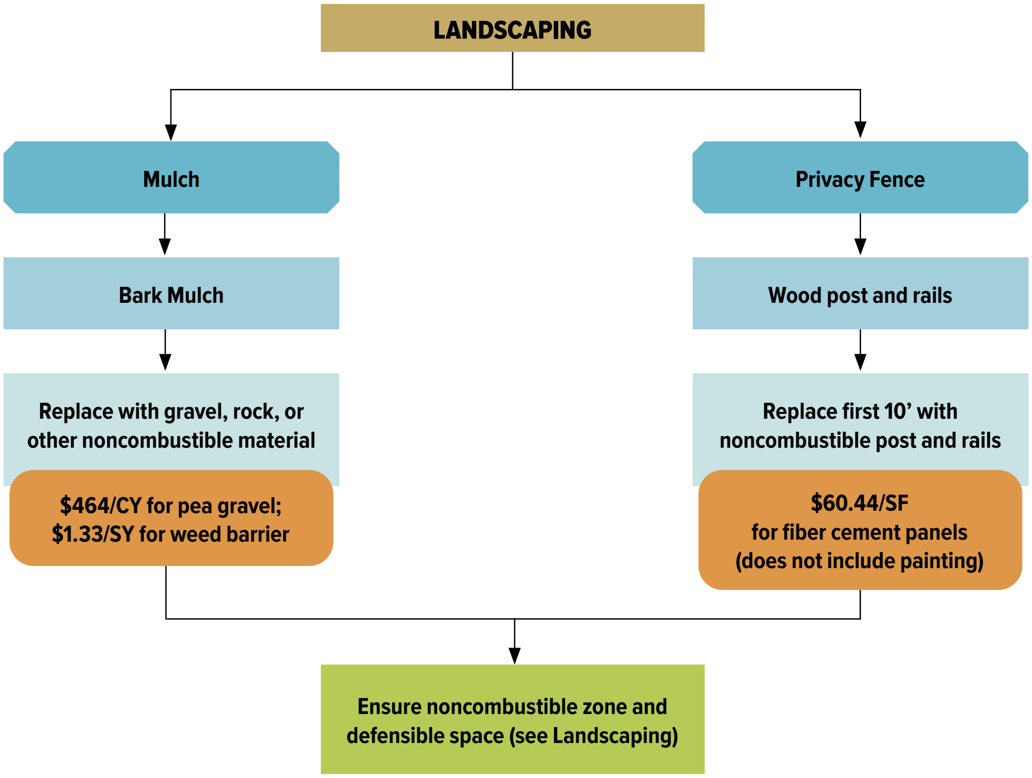
Example Retrofitting Costs

Retrofitting near-home landscaping within the noncombustible zone requires digging out the bark mulch, removing vegetation, applying a weed barrier (or other material that serves that purpose), and installing pea gravel or other decorative rock mulch product. Depending on site and property characteristics, the grade of the slope will have to be taken into consideration for near-home landscaping guidelines. Additional costs include dumping fees and labor costs for excavating, dumping, and reinstalling noncombustible mulch.

For example, a 5-foot noncombustible zone around a structure with a 1,000-square-foot footprint requires approximately 6 cubic yards of pea gravel spread to a depth of around 3 inches. Because the size of a deck can vary, an under-deck area was not included in this example. Total estimated costs, including labor and time for removal and dumping of previous mulch as well as contractor overhead and profit was $2,782. Additional pea gravel would be needed underneath the deck. If applicable, a weed barrier would be an additional cost of around $100 for the polypropylene product selected for this example.

Estimated costs for fencing included removing wooden rails and posts within the first 5 to 10 feet of the home and replacing them with noncombustible materials. For example, noncombustible fencing material can include metal panels, chain link, stone, concrete, and fiber cement paneling. In the latter scenario, replacing wooden plank fencing with fiber cement panels and steel posts costs around $60.44 per square foot. For a fence extending 5 to 10 feet from the home at a height of 8 feet, calculated for both sides of the home, costs are estimated at $9,670 including fees for demolition, removal, and dumping. Costs can be lower depending on materials, labor, and dimensions of the fence, for example using metal fencing material. These costs did not include replacement of a wooden gate, likely attached to one side of the house, with a noncombustible gate such as metal. A chain link gate can be purchased for about $150.

Decision-Tree Diagram



Landscaping

5. Discussion

In the past century, our nation has focused on responding to and suppressing wildfire. While largely successful with more than 95% of all wildfires contained and extinguished, reducing community wildfire risk effectively must concurrently address the built environment.[31] Today's increasing risks of wildfire and home loss require new multidisciplinary approaches that recognize the importance of fortifying structures and investing in resilience far in advance of a wildfire disaster.

Effectiveness of Retrofitting Homes

Decades of research indicate that the building materials and design of a home, as well as conditions surrounding the home,[32] are primarily responsible for structure ignition during a wildfire.[33]

Homes are being built in wildfire-prone areas at an unprecedented rate, accounting for more than 44 million homes in the wildland-urban interface (WUI).[34] In some areas, regulatory measures such as zoning and building codes require construction standards for wildfire resistance for new developments and significant remodels. Other regulatory measures such as public resource codes, fire codes, landscaping regulations, and subdivision standards can have requirements for vegetation management, adequate access and road widths, water supply, and development siting. However, much of the U.S. housing stock predates modern land use planning and was constructed with little thought to wildfire.[35] It is essential to retrofit the existing housing stock in wildfire-prone areas to an upgraded construction standard to reduce overall community wildfire risk. Retrofitting structures to mitigate the impacts of natural hazards has been identified by the Federal Emergency Management Agency (FEMA) as a critical strategy for adapting to increasing and evolving hazards.[36]

Moreover, given the increasing costs of wildfires—from wildfire prevention and hazardous fuels reduction, to suppression, to the costs of recovery and rebuilding—retrofitting houses to an upgraded standard may provide a cost-effective and sustainable mechanism to reduce community vulnerability to wildfire.[37]

To be cost-effective, retrofitting requires consideration of a number of site factors such as topography, slope, and neighborhood density – as well as building design and materials. The most effective risk-reduction strategies apply a holistic approach and consider the entire parcel, including broader property characteristics, defensible space, and the home itself. The variability of costs for retrofitting at the parcel-level therefore reflect site-specific conditions and potential vulnerabilities. For example, an isolated home at the top of a forested hill will require different strategies for wildfire resistance than a landscaped suburban home with neighbors within 20 feet on either side. Some wildfire-resistant home features (e.g., noncombustible decking materials, pea gravel mulch, etc.) have additional benefits such as a longer lifecycle and reduced maintenance.[38]

Adapting Communities

Home retrofits must be complemented with communitywide mitigation measures. A homeowner may incorporate every recommendation to make their house less vulnerable to ignitions, but one neighbor's inaction can still present a threat to nearby homes. This can be of particular concern for dense developments and when homes are closely spaced. Residents of neighborhoods and communities must adapt together to the new wildfire reality.

Creating fire-adapted communities requires a full-systems approach toward ignition-resistant structures coupled with vegetation management and fuels reduction in and around communities. Land use planning, building codes, wildland-urban interface codes, and other development standards can help reduce risk by requiring the use of ignition-resistant building materials and ember-resistant design features, thoughtful neighborhood design, and the management of vegetation surrounding structures.

Policies mandating broad compliance with wildfire-resistant construction and mitigation measures can reduce community vulnerability to wildfires because they compel mitigation measures across a neighborhood. Additionally, and in light of increasing uncertainty in the homeowner insurance market, regulatory measures and home-hardening programs can help stabilize the shared risk of policyholders and encourage coverage retainment.[39] However, exterior structural improvements alone will not guarantee home survivability. Community design, neighborhood layout, tree canopy, vegetation management, structural density, and housing patterns also affect home survivability.[40] Research asserts that formal management of the built environment, especially through land use planning, community development policies, and residential regulation, is key to creating resilient landscapes and fire-adapted communities.[41]

Cost of Retrofitting Homes

The costs for retrofitting a home to improved wildfire resistance depend on its unique suite of characteristics, conditions, and considerations. Mitigation strategies focused on reducing the vulnerability of a building to wind-blown embers are typically less expensive than those focused on reducing the vulnerability to radiant heat. While a metal roof may provide optimal wildfire resistance, for example, upgrading to an asphalt fiberglass composition shingled roof with a metal drip edge and gutter system is effective in mitigating ignition vulnerability to the roof and is often the more affordable option. Small changes such as clearing combustible materials from on top of and under decks can make a big difference for a relatively small cost. In some situations, only one vulnerable aspect or component of the home will require retrofitting depending on the source of ignition and conditions of the parcel. The suite of risk-reduction actions to a structure can be prioritized on a case-by-case basis according to costs and benefits and homeowner needs and budget.

Given the heterogenous composition, design, and building materials of home construction, it is difficult to assign a cost for retrofitting a single structure or group of structures. This research is therefore intended to provide a range of scenarios and baseline cost estimates for upgrading various components of a home for improved wildfire resistance.

Some of the most effective strategies for increasing a home's resistance to wildfire involve maintenance and management of large, exposed surface areas, such as the roof, deck, near-home noncombustible zone, and surrounding property. Measures like removing vegetation, accumulated debris, and flammable materials on top of and around these vulnerabilities can reduce ignition potential from embers, direct flame contact, and radiant heat. Many of these effective risk-reduction strategies can be done affordably with little to no expense to the homeowner.

Structural improvements to the home and hardening efforts to reduce exposure will vary based on myriad considerations and contingencies. Outcomes from this analysis suggest that for a typical 2,000-square-foot home in California, retrofitting costs can be as low as $2,000 for minimal retrofits like installing metal flashing, to upwards of $100,000 if all retrofits to the highest level of protection are needed. Roof replacement is a major expense due to the quantity of materials needed, labor for demolition and installation, and potential peripheral costs like underlayment replacement. Yet, affordable mitigation measures such as replacement of exterior vents with ember- and flame-resistant vents, installing metal flashing at all deck-to-wall intersections (and roof-to-wall intersections), maintaining clean gutters and installing metal gutter guards, and replacing bark mulch with noncombustible mulch such as gravel, go a long way in reducing home vulnerability to wind-blown embers during a wildfire and cost between $10,000 and $15,000. Complementary measures such as enclosing eaves with noncombustible soffit material, ensuring windows are dual-paned, metal-clad wood framed with tempered glass, and replacing the first 10 feet of fencing with noncombustible material are also important retrofitting strategies. These strategies mostly enhance resistance to radiant heat exposures. Full replacement and upgrading of all exterior components with the highest wildfire-resistant building materials and assemblies can cost as much as $100,000 for the typical home identified in this study, depending on product selection, labor, and contingencies that may be uncovered during demolition. Full-replacement scenarios are needed when an extended radiant heat exposure is expected. Costs will increase with a more complex home design. For more details on the suite of retrofitting scenarios, building materials, and associated costs used in this study, see Appendix A.

Barriers to Retrofitting

The concept and actual work of retrofitting homes can encounter financial, social, and political barriers:

- Perception of risk influences homeowners' decisions.[42] People may believe that the risk of wildfire damage is too low to justify the cost of preparation, including retrofits. They may believe that they will be physically protected by fire departments or financially protected by insurance agencies. They may believe that responsibility for risk management lies with their municipality or nearby property owners. Regardless of the characteristics that allow structures to burn and the resulting economic impacts, research has shown that private landowners underinvest in risk mitigation despite the latent risk of a future wildfire.[43] A general lack of preparedness and continued underinvestment in proactive mitigation measures are not exclusive to individual homeowners or wildfire hazards alone – these factors are similarly demonstrated with other natural hazards at broader state, national, and global scales.[44]

- Loss of momentum. Fires generate public support for mitigation, but the urgency tends to wane over time.[45] For example, vegetation should be cut back every year, decks, roofs, and gutters need to be regularly maintained and cleared of debris, and vents could be replaced. Without an imminent threat, maintaining community and homeowner momentum for home mitigation is a challenge. Rebuilding following a wildfire presents a unique opportunity to build back better and with improved construction materials, yet evidence suggests post-fire construction exhibits minimal if no adaptation practices.[46]
- Lack of technical expertise and workforce. Retrofitting requires a building assessment and technical expertise to determine which components of the structure need to be replaced or modified to improve wildfire resiliency. This requires an interdisciplinary, specialized knowledge base that draws from diverse fields including fire ecology, urban planning, civil and structural engineering, landscape architects, and the construction industry.[47] In addition, a construction and landscaping workforce is needed to implement and perform the needed structural improvements to the home and property.[48] Specialists in mitigating structural damage in a wildfire may be hard to locate. Smaller towns, particularly, may not have the resources and capacity necessary to pursue planning and regulation to reduce wildfire risks.[49]
- Cost and logistics are often noted as the major barrier to retrofitting homes. The costs for home improvements and structural retrofits are generally assumed by individual homeowners. It is not surprising that their willingness to pay to reduce risk is subject to household budget constraints.[50] In a 2001 study of collective fire protection in a small Michigan community located in the WUI, researchers found that homeowners' perceived value at risk (i.e., the value of their property) and their ability to pay weighed heavily in their willingness to pay for risk reduction.[51] Additionally, logistics can be challenging for homeowners. The time required to undertake a retrofit project may be in short supply. Administrative requirements and potential permitting processes can be complex and especially difficult for those who struggle with online searches, forms, and correspondence. People may be unfamiliar with pertinent local, state, and federal regulations.
- Lack of federal assistance. Despite the fact that managing the built environment has been shown to be critically important in reducing community wildfire risk, there has been very little investment at the federal level to support home hardening efforts at the parcel level and on private lands.[52] The amount of federal funding allocated to improving community wildfire resilience and risk reduction of the built environment is insufficient, especially compared to firefighting budgets.[53] Inadequate program budgets and lack of qualified staff have been cited by administrators of regulatory and voluntary wildfire risk-reduction programs as the top obstacles to program effectiveness.[54]

Positive Developments

Wildfire preparation likely will be an ongoing process involving incremental improvements over many years and influenced by homeowners' perceptions of risk. Extreme temperatures, drought, and news of other fires motivated action, according to results of a 2019 case study in Australia.[55] Many homeowners removed litter from around buildings, relocated outdoor furniture, and watered lawns and gardens during fire season, but substantial retrofitting was generally conducted in stages over time as finances became available or other incentives prompted change. Research has shown that a sense of community and community problem-solving can strongly influence homeowner preparation for wildfire.[56]

While the barriers to retrofitting are daunting, there are positive developments. Fortifying the resiliency of the built environment is an emerging area of funding for FEMA and the U.S. Department of Housing and Urban

Development.[57] The importance of retrofitting homes to become more resilient to wildfires is being recognized at the state level as well. California's Wildfire Mitigation Program is a model for educating and incentivizing property owners to retrofit their homes. With a similar objective, the Colorado Legislature approved a Wildfire Resilient Homes Grant program in 2023 for Colorado homeowners. An assessment of the home ignition zone and adjacent defensible space is required prior to applying.

In rare cases, action is being taken at the local level. Located in a fire-prone area, the City of Leavenworth, WA, established a retrofit grant program to support improvements to older homes owned by community members with lower incomes. In addition, the county's public utility district offers rebates for replacing windows and patio doors, which can complement wildfire resiliency improvements.

It is becoming increasingly clear that fortifying homes and neighborhoods is an efficient and effective path to wildfire resiliency.

6. Conclusion

Communities can be built to withstand wildfires. Homes can be made more fire resistant. We have the tools and knowledge to reduce community wildfire risks.[58]

Retrofitting has been shown to be a cost-effective approach to increasing the resilience of homes and neighborhoods. All homes in wildfire-prone areas should be retrofitted and new homes should be constructed with wildfire in mind. The status quo of managing the wildlands and natural environment while overlooking the built environment cannot continue. Homes must be built to be stronger, smarter, and more durable in light of the increasing pace and scale of wildfire risks.

But reducing wildfire risk to homes and neighborhoods must become widely accepted by the people and communities facing risk. One resident can do all that is necessary to reduce home ignition potential, but if a neighbor does nothing, the fire threat remains. Home and property wildfire mitigation strategies are most effective when every home in the neighborhood participates. Building codes, vegetation management regulations, and land use planning measures can help compel compliance at the scales needed to broadly reduce wildfire risk at the community level.

Additionally, we need a new workforce of home improvement and construction professionals who are familiar with wildfire mitigation techniques.[59] This specialized workforce must have an interdisciplinary approach and diverse skillset to focus on the proactive application of mitigation techniques. Relevant fields include fire ecology, engineering, architectural design, urban planning, and construction.

Analysis from this report draws from previous work and supports findings suggesting that some of the most effective strategies to reduce structure vulnerability to wildfire can be done affordably. Risk-reduction strategies such as removing flammable materials from on top of, and underneath, the deck, clearing gutter systems, and removing vegetation and debris from the roof are critical maintenance tasks with little to no cost to the homeowner. Maintaining a near-home noncombustible zone, installing metal flashing at vulnerable junctions like the deck-to-wall intersections, and installing flame- and ember-resistant vents can increase chances of home survival. The cost can range from $2,000 to $15,000 depending on the design, complexity, topography, and size of the home. Investing in broader vegetation management and ensuring defensible space around the home is also an important priority and can strengthen the overall effectiveness of other structural mitigation measures. More expansive retrofits, such as the replacement of a roof, deck, and windows, and enclosing eaves, will increase costs but can also provide benefits for energy efficiency, durability, and long-term maintenance. Retrofitting an entire home to the highest wildfire-resistance standards (i.e., incorporating ember, direct flame, and radiant heat resisting measures) can be costly and exceed $100,000. *However, a full retrofit is likely not necessary in most cases, and selective, targeted replacement of particular components and assemblies may reduce risk effectively and more affordably.*

As development accelerates in wildfire-prone areas, communities must have access to funding and technical support for home hardening. State and federal governments will likely need to provide financial support, resources, and technical assistance. We must strategically and deliberately invest in reducing community wildfire risk so that people, homes, and businesses are better prepared before a wildfire disaster occurs.[60]

Establishing, funding, and staffing a federal program dedicated to reducing risk in the built environment – including retrofitting homes – is necessary not just for wildfires but for *all* natural hazards. Our standard home construction no longer addresses the risks we expect to face in the future. However, we have the research, science, engineering, and tools to do better. We must invest now in creating ignition-resistant homes and communities that can survive a future of increasing wildfire.

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60 Wildland Fire Mitigation and Management Commission. (2023). On Fire: The report of the Wildland Fire Mitigation and Management Commission. Washington, DC: U.S. Department of Agriculture. Retrieved from https://www.usda.gov/sites/default/files/documents/wfmmc-final-report-09-2023.pdf

Appendix A: Retrofitting a Home for Wildfire Resistance

Data Tables

Spring 2024

ABOUT THE DATA

Data are from the report Retrofitting a Home for Wildfire Resistance. Except as noted, pricing is from RSMeans, a national database of construction materials, demolition, labor, and contractor O&P costs.

RSMeans is updated quarterly, includes average construction cost indices from more than 970 cities, and uses the latest negotiated labor costs for average wages in 30 major cities. Prices include the cost of material as installed (i.e., material plus estimated labor and contractor overhead and profit costs). In some cases, pricing was not available through RSMeans and costs were derived from building subjec matter expert, supplier, or local distributors.

Pricing also includes and average California Sales Tax rate of 8%, Design Contingency and Escalation to January 2023. It is recommended that 3% be added for each additional year.

Column Definitions

Assembly: major groupings, or systems, of features for the roof and exterior wall components.

NIST REF. App. Table A Tech. Note #2205: corresponding row for Structure Component per NIST Technical Note #2205, Appendix Table A (https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2205.pdf)

Component: describes the part of the house that was priced.

Subcomponent: building material comprising the primary home component.

Original Construction Material: combustible building material assumed in original construction.

Replacement/Retrofit Material: building material suggested for wildfire resistance.

Specifications: detail about the material and dimensions of priced costs.

Demolition Labor: estimated costs for demolition and labor per one unit of work.

Demolition Overhead: estimated costs for demolition overhead for contractor per one unit of work.

New Material: estimated costs for replacement/retrofit material per one unit of material.

Install Labor: estimated costs for installation and labor per one unit of work.

New Overhead & Profit: estimated costs for install overhead for contractor per one unit of work.

Total Northern CA: total est. cost per unit of material for northern CA (based on est. for Redding/Marin County).

Unit: the unit of measure that describes the quantity.

- CY = cubic yard
- Ea = each
- LF = linear feet
- MSF = thousand square feet
- SF = square feet
- SQ = squares (100 sf)
- SY = square yard
- VLF = vertical linear feet

Assumptions: considerations for assembly of components, suggested retrofitting strategy, and conditions for recommended building materials.

HEADWATERS ECONOMICS

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Component	Sub-Component	Original Construction Material	Replacement/ Retrofit Material	Specifications	Demo Labor (D)	Demo Over. (O&P)	New Material (M)	Install Labor (L)	New Over. (O&P)	TOTAL -- Northern CA	Unit	NIST REF. App. Table A Tech. Note #2205	Assumptions
Exterior Walls													
Cladding	Siding	Wood-based/vinyl cladding	Fiber cement	Fiber cement siding, lap siding, woodgrain texture, 5/16" thick x 7-12" wide, 6-1/4" exposure.	$0.91	$0.56	$1.57	$2.15	$1.48	$6.67	SF	10	Assumes removal of horizontal wood clapboards. Cost similar to demo of other flammable sidings.
	Barrier wrap		Weather barrier wrap		n/a	n/a	$0.22	$0.18	$0.20	$0.60	SF		Cost based on Tyvek basic wrap; assuming 2-story home on slope, 10% overlap, 10% loss for cuts.
	Metal flashing		Flashing for siding transition & openings	Valley flashing, sheet metal flashing, aluminum, flexible, mill finish, 0.019" thick, incl up to 4 bends	n/a	n/a	$0.82	$5.67	$3.24	$9.73	SF		Distinction between global and selective replacement made by unit calculation. Trims & flashing generally need to be accounted for in either approach. Assuming original T-111 siding or lap siding is wood, then 6" metal flashing and noncombustible zone is req'd and either: 1) replace with noncombustible cladding; 2) kerf-cut half-depth of siding with 45-degree angle and/or 3) install metal flashing under lap siding (i.e., chimney chase).
	Fire-rated wallboard		In addition to above 3 rows, include a layer of Type X exterior wallboard for added resilience.	Fire-rated panelized gypsum wallboard, on walls, fire-resistant, 1/2" thick, finish excluded	n/a	n/a	$0.39	$0.50	$0.35	$1.24	SF	10	Ensure new wallboard is protected from weather as specified by manufacturer.
Trim	Trim	Wood-based/vinyl trims	Fiber cement, 5/4" x 5.5"	Demo millwork and trim, replace with HardieTrim HZ10 0.75" x 3.5" x 144" Fiber Cement Rustic Grain trim board	$0.64	$0.41	$2.50	$3.63	$2.54	$9.72	LF	10	
	Metal flashing		Flashing for siding transition and openings	Valley flashing, sheet metal flashing, aluminum, flexible, mill finish, 0.019" thick, incl up to 4 bends	n/a	n/a	$0.92	$1.84	$1.38	$4.14	LF		
Ext. Wall Vents	Gable vents	Non-flame- and ember-resistant vents (plastic or metal); surrounding cladding can be wood or other combustible material	Metal flame- and ember-resistant vent	Remove louvered gable vent and replace with flame- and ember-resistant vents	$21.55	$13.15	$32.40	$225.00	$128.70	$420.80	Ea	13	This is a high-priority retrofit, very vulnerable. If roof is being replaced, this vent can be eliminated (clad over) and venting exhaust moved to ridge venting.
Ext. Wall Vents	Vulnerable crawl space vents	Typical non-ember- and flame-resistant vent	Metal flame- and ember-resistant vent. Increase quantity of vents as required by code.	14" x 6" bonderized steel flame- and ember-resistant foundation vent [41 sq-in NFVA].	$9.44	$2.36	$61.27	$125.00	$31.25	$229.32	Ea	15a	Remove crawl space vents consisting of only metal mesh screening and replace with a flame- and ember-resistant option. Typical brands include Vulcan, Brandguard, Embers Out. Target 1 sq ft NVFA per 150 sq ft floor area. Assume 50% more vents must be added based on BrandGuard 6" x 14" Vent with NFVA 23 to typical NFVA 50.
Ext. Wall Vents	Dryer vents	Typical non-ember- and flame-resistant vent	Metal dryer vent with galvanized metal flap		$14.17	$0.94	$28.50	$14.17	$10.67	$68.45	Ea	16	
Ext. Wall Vents	Makeup air intake vent	Typical non-ember- and flame-resistant vent, with 1/4" or larger metal mesh	Metal flame- and ember-resistant vent		$4.72	$0.94	$66.20	$14.17	$20.08	$106.11	Ea	17	
Ext. Wall Penetrations	Gaps w/in exterior walls	Gaps at poorly installed vents or other exterior elements	Fire caulking, apply caulk to specific locations that represent locations where embers could accumulate.	Joint sealants, caulking and sealants, acoustical sealants, elastomeric, cartridges, 1/2" x 3/4" bead in place	n/a	n/a	$1.49	$1.66	$1.23	$4.38	LF	18a/20	

Component	Sub-Component	Original Construction Material	Replacement/ Retrofit Material	Specifications	Demo Labor (D)	Demo Over. (O&P)	New Material (M)	Install Labor (L)	New Over. (O&P)	TOTAL -- Northern CA	Unit	NIST REF. App. Table A Tech. Note #2205	Assumptions
Roof													
ASSEMBLY: Roofs													
Roof surface	Skylight	Plastic dome skylight	Tempered flat glass skylight	22" x 46" standard fixed tempered skylight	$85.00	$42.50	$875.88	$170.00	$261.50	$1,434.88	Ea	22/23	Tempered laminate on exterior from V-lux. Standard size is 21" x 46". Most rectangular skylights have a roof curb (usually 2" x 6" on edge) that is fastened and flashed into the roofing material. With a metal roof, a set of flashings is designed to cover this curb and connect to the roof.
Roof surface	Skylight	Operable skylight, plastic glazing, PVC or vinyl frame or wood	Aluminum clad or fiberglass unit with tempered glazing, manually operable	Remove plastic or glass skylight (up to 2' x 3'). Install operable double-glazed 22" x 46" skylight unit. Assumes all skylights are tempered if glass. Assumes caulking, flashing, and patching roofing material is included.	$85.00	$42.50	$1,052.60	$171.81	$219.86	$1,571.77	Ea	1b	If the original skylight has a 3' x 4' curb and the new skylight is that size or slightly larger, then it is relatively easy to replace the skylight depending on ease of access, roof pitch and type of roof. However, if the curb is too small/too big, then some modifications to the roof will have to be made adding costs for time and labor. E.g., demo cost includes two workers setting up secure ladders, removing skylight, and safely lowering to the ground (~<1 hr). Demo cost includes drive time and dumping fees, assuming that this is part of a shared load with other materials. It would cost more if this was a per-item cost not combined with other demo work.
Roof-to-wall intersections	Roof-to-wall siding	Combustible siding (wood lap siding assumed)	noncombustible siding (fiber cement)	Fiber cement lap siding, smooth texture, 5/16" thick x 7.5" wide 6.25" exposure. Assumes RS Means includes nails, caulking, and pre-finished siding.	$0.87	$0.53	$1.57	$2.15	$1.48	$5.20	SF	3a	Assumes roof and step flashing are correctly installed.
	Fascia	Wood-based fascia with 12" of roof	Fiber cement, 5/4" x 5.5"	Demo fascia, replace with HardieTrim HZ10 0.75" x 3.5" x 144" Fiber Cement Rustic Grain trim board.	$0.64	$0.41	$2.50	$3.63	$2.54	$9.72	SF		Substituted comparable interior hardwood trim is applied. Fasteners and sealant included.
	Roof-to-wall siding (metal flashing)	Combustible siding	Tall metal (step) flashing; keep combustible siding (>6").	Sheet metal flashing, aluminum, flexible, mill finish, .016" thick, 12" x 12" step flashing incl up to 4 bends. Converted to L.F> accounting for 2" overlap.	n/a	n/a	$0.62	$0.19	$0.21	$1.02	LF	3b	If existing combustible siding at dormer or split level is kept, install tall step flashing; cut siding back to 6" from roof surface. Requires weaving new flashing with existing roof shingles; less robust and wildfire-resistant option.
	Roof-to-wall siding (asphalt shingle replacement)	Wood shake/shingle roof	Asphalt shingles, Architectural	Asphalt roof shingles, Premium laminated multi-layered shingles, Class A, 260-300 lb/sq, pneumatic nailed.	$80.00	$49.00	$192.30	$88.93	$86.24	$496.47	SQ		Reroof as required to incorporate new step flashing. Units converted from SF to SQ. Assumes code-compliant roof sheathing and underlayment is in good condition.
Roof surface	Roof covering	Wood shake/shingle roof	Asphalt shingles, Architectural	Asphalt Roof Shingles, Premium laminated multi-layered shingles, Class A, 260-300 lb/sq, pneumatic nailed	$80.00	$49.00	$192.30	$88.93	$86.24	$496.47	SQ	5a	Demo units converted from SF to SQ; assumes 1 layer of roofing to be removed and 1 layer of underlayment; assumes code-compliant roof sheathing condition existing. No change to roof penetration gaskets. (Units equal 4.96 SF).
	Roofing underlayment	30# building felt	Synthetic underlayment	Owens Corning Titanium UDL50	$9.44	$4.72	$97.81	$14.11	$7.08	$133.16	SQ		UDL50 is about $185/roll, for 25SF, which = $0.89/ SF, $89/SQ; installs quickly. The cost of $245.78/roll, 225SF = $1.18/SF, which is a conservative estimate.
	Roofing underlayment		Weather wrap	Ice and water shield as required.	$9.44	$4.72	$129.78	$14.17	$7.08	$165.19	SQ		
Roof edge	Drip edge	No drip edge assumed	Metal drip edge	Aluminum drip edge, white finish, .016" thick, 5" wide	n/a	n/a	$1.01	$1.11	$0.81	$2.93	LF		
Roof surface	Ridge Vent	a) No ridge vent assumed	Ridge vent	Flexible roll ridge vent	n/a	n/a	$2.49	$2.43	$2.10	$7.02	LF		
	Ridge Vent	b) Plastic ridge vent, without external baffle	Noncombustible ember- and flame-resistant ridge vent, baffle included (cap not included)	Noncombustible ember- and flame-resistant ridge vent, includes baffle (no cap)	$0.80	$0.49	$9.15	$9.45	$13.88	$33.77	LF		This assumes a new roof covering install (i.e., asphalt shingles) and replacement of original plastic ridge vent with noncombustible flame- and ember-resistant ridge vents. Baffle included. Install metal ridge cap as needed.

Component	Sub-Component	Original Construction Material	Replacement/ Retrofit Material	Specifications	Demo Labor (D)	Demo Over. (O&P)	New Material (M)	Install Labor (L)	New Over. (O&P)	TOTAL -- Northern CA	Unit	NIST REF. App. Table A Tech. Note #2205	Assumptions
Roof													
Roof surface	Roof covering	Wood shake/shingle roof	Steel roofing panels	Flat profile, 1-3/4" standing seams, 10" wide, standard finish, 26 ga.	$6.35	$4.00	$5.39	$1.65	$1.30	$18.68	SF	5b	Price D-profile and standing seam mech lock; cost quoted here includes 1 layer of roofing to be removed and new underlayment (both synthetic and firestopping). Metal roofing prices vary substantially based on material, labor, roof complexity, and demo costs.
	Roofing underlayment	none	Fire-resistant underlayment	VersaShield 350 sq. ft. fire-resistant roofing underlayment roll. Required at metal roof only	n/a	n/a	$101.98	$14.17	$7.08	$123.23	SQ		Standalone cost, if required.
	Roofing underlayment	30# building felt	Synthetic underlayment	Owens Corning Titanium UDL50	$9.44	$4.72	$97.81	$14.11	$7.08	$133.16	SQ		
	Roofing underlayment			Ice and water shield as required.	$9.44	$4.72	$129.78	$14.17	$7.08	$165.19	SQ		
Roof edge	Drip edge	No drip edge assumed	Metal drip edge	Aluminum drip edge, white finish, .016" thick, 5" wide	n/a	n/a	$1.01	$1.11	$0.81	$2.93	LF		
Roof surface	Ridge Vent	No ridge vent assumed	Noncombustible ember- and flame-resistant ridge vent, including baffle and cap	Noncombustible ember- and flame-resistant ridge vent; demo ridge shingles, including baffle and cap	$6.38	$3.19	$14.10	$14.17	$21.19	$59.03	LF		This assumes a new roof covering install (asphalt) and install of noncombustible flame- and ember-resistant ridge vents, thus higher demo costs.
Roof surface	End-caps (tile roof)	Clay barrel tiles or metal D-style roofing	Noncombustible end-cap (i.e., bird stopping)	Noncombustible end-cap (i.e., bird stopping) at eaves and ridge runs.	n/a	n/a	$7.84	$5.67	$6.75	$20.26	SF	7	These interventions do not account for major maintenance items that significantly compromise the performance of the roof installation, such as clay tile roof with cracked tiles in the field. These issues could impact fire resilience but vary too much for this analysis.
Roof surface	Ridge vents	Plastic ridge vent, without external baffle	Noncombustible ember- and flame-resistant ridge vent, baffle included (cap not included)	Noncombustible ember- and flame-resistant ridge vent, includes baffle (no cap), demo ridge shingles	$0.80	$0.49	$9.15	$9.45	$13.88	$33.77	LF	11	This assumes keeping the original (slightly complex) roof and replacing original plastic ridge vents with noncombustible flame- and ember-resistant vents. Demo costs are higher than new roof covering.
	Asphalt shingles (ridge vent replacement)		Ridge shingle replacement	Asphalt Shingles, Ridge Shingles, pneumatic nailed (incl new cap shingles)	n/a	n/a	$2.76	$0.94	$1.00	$4.70	LF		
	Ridge vents		Metal ridge cap	24-gauge Kynar Steel vented ridge cap roof flashing	n/a	n/a	$9.40	$4.72	$7.06	$21.18	LF		If ridge capping with shingles, then metal ridge cap is not needed.
Roof surface	Roof Surface - combustible through-roof (off-ridge) vent	Non-flame- and ember-resistant vents (plastic or metal)	Noncombustible off-ridge vent	Off-ridge, ember- and flame-resistant vent [90 sq-in NFVA]	$8.50	$4.25	$120.51	$16.54	$50.00	$199.80	LF	12	Alternative unit: $126/SF; approx. $200 for each off-ridge noncombustible flame- and ember-resistant vent.
	Asphalt shingles (off-ridge vent replacement)		Ridge shingle replacement	Asphalt roof shingles, Premium laminated multi-layered shingles, Class A, 260-300 lb/sq, pneumatic nailed	n/a	n/a	$192.30	$88.93	$86.24	$367.47	SQ		

Component	Sub-Component	Original Construction Material	Replacement/ Retrofit Material	Specifications	Demo Labor (D)	Demo Over. (O&P)	New Material (M)	Install Labor (L)	New Over. (O&P)	TOTAL -- Northern CA	Unit	NIST REF. App. Table A Tech. Note #2205	Assumptions
Eaves & Gutters													
ASSEMBLY: Gutters													
Gutter system	Gutter guard	Aluminum gutter without guard	Install gutter guard	All metal gutter guard, aluminum mesh, 6” wide	n/a	n/a	$2.74	$0.90	$0.84	$4.48	LF	8a	
	Gutters	Vinyl gutters with or without guard	Replace gutter system with metal	Aluminum gutters, stock units, plain, 5" box, .027" thick	$7.08	$1.42	$3.50	$3.89	$2.89	$18.78	LF	8b	Downspouts are excluded from cost.
	Drip edge	Gutter without drip edge; exposed wood	Install drip edge	Aluminum drip edge, white finish, .016" thick, 5" wide	n/a	n/a	$1.01	$1.11	$0.81	$2.93	LF	8b	
ASSEMBLY: Under-Eave Area													
Open eave	Blocking between rafter tails	Blocking that has gaps	Firecaulk any gaps	Joint sealants, caulking and sealants, acoustical sealants, elastomeric, cartridges, 1/2" x 3/4" bead in place	n/a	n/a	$1.49	$1.66	$1.23	$4.38	LF	20	Install and material cost used are similar to acoustical sealant, used around all blocking. Sometimes gaps will be present / develop between blocking and adjacent components (top place, sheathing, rafters). The purpose of the caulk is to fill any gaps that are present, making it much more difficult for embers to accumulate in these locations.
	Vents	Circular combustible vents	Circular noncombustible vents	Round flame- and ember-resistant eave vent (4" diameter) (mesh) [9 sq-in NFVA].	$0.71	$0.07	$20.66	$14.17	$17.41	$53.02	LF		The first story of a house is assumingly fairly easy to access; second- and third-story vent replacements will have a higher labor cost due to need for ladders and fall protection.
Open eave	Enclose eave w/ soffit	Assumes an open-eave vent	Convert to an enclosed eave. Unvented fiber-cement soffit board (panel)	Fiber cement panel siding, smooth texture, 5/16" thick	$0.47	$0.12	$1.24	$1.21	$0.88	$3.92	SF	14b	There is a significant cost difference in labor for soffits verses siding vents and installation. Generally soffits require ladders and multiple workers, sometimes fall protection as well, plus additional costs for time, debris removal, and labor.
	Vents		Noncombustible soffit vents - 2" x 22.25" soffit vent (5 pieces) [89 sq-in NFVA].	14" x 6" bonderized steel flame- and ember-resistant soffit vent	n/a	n/a	$48.96	$28.33	$27.76	$105.05	Ea		Strategy depends on soffit boards positioning: if attached to bottom of roof rafters, then cheaper but more difficult to vent as vents are needed at every blocking; but if attached as horizontal return, then a longer single foundation vent could work.
Enclosed eave	Soffit	Combustible soffit	Replace with horizontal noncombustible soffit	Fiber cement panel siding, smooth texture, 5/16" thick	$0.94	$0.24	$1.24	$1.21	$0.88	$4.51	SF		
	Vents		Replace vents	14" x 6" bonderized steel flame- and ember-resistant soffit vent	$0.94	$0.24	$48.96	$28.33	$27.76	$106.24	Ea		Using soffit reference for foundation vent.
Enclosed eave	Vents	Non combustible soffit w/ vulnerable vents	Replace vents	14" x 6" bonderized steel flame- and ember-resistant soffit vent	$0.94	$0.24	$48.96	$28.33	$27.76	$106.24	Ea		

Component	Sub-Component	Original Construction Material	Replacement/ Retrofit Material	Specifications	Demo Labor (D)	Demo Over. (O&P)	New Material (M)	Install Labor (L)	New Over. (O&P)	TOTAL -- Northern CA	Unit	NIST REF. App. Table A Tech. Note #2205	Assumptions
Deck													
Full decking support system	Deck demo -- bamboo replacement	Untreated wood decking (redwood or sim) on elevated wood frame	Dimensional lumber PT to raise sub members to 4" min width, Aluminum clad Bitumen flashing, aluminum flashing	Demo existing deck boards only.	$1.70	$0.94	n/a	n/a	n/a	$2.64	SF		
Full decking support system	Joists and beams		Decking support system with bitumen flashing	Double any substructure joists and beams that are 2"x dimensional so all subsurface lumber is 4"x per CA Code Chapter 7A deck renovations, add aluminum clad bitumen flashing on top of joists, solid 6" aluminum flashing around post bases.	n/a	n/a	$8.69	$14.17	$22.91	$6.87	SF		
Decking surface	Higher-density material		Class A Fire Rating deck covering	Moso Xtreme Bamboo Decking; hidden fasteners, top mounted Class A fire rated deck boards only.	n/a	n/a	$7.92	$5.67	$13.63	$40.85	SF		
Full decking support system	Deck demo -- concrete replacement	Untreated wood decking (redwood or sim) on elevated wood frame	Metal frame with light-weight concrete slab	Complete demolition, wood framing, deck or porch decking - replace with steel-framed deck and concrete paved; 16-gauge steel decking, 5"-3" lightweight concrete pad (3" in peaks, 5" in valleys), using 10'x10' deck dimensions; no new piers assumed; does not include engineering/ professional services which will likely be needed.	$1.42	$0.35	n/a	n/a	n/a	$1.77	SF		If the deck is cantilevered from the house or free standing, the ground composition, height of the deck, and square footage will all effect the cost. The estimate used here assumes the piers are suitable for the new structure, though in most cases the increased load from steel and concrete will require adding new or additional piers. For this example we are assuming a 10'x10' deck that is 10 feet off the ground at the high point, with the ground sloping to 4' at the house side, and the deck structure is also cantilevered to the house reducing the likelihood that the new piers will be necessary.
ASSEMBLY: Decking													
Full decking support system	Footings		Excavation and footings	Porch or deck framing, post footing, 4' deep, 8" diameter, includes excavation, backfill, tube form & concrete	n/a	n/a	$14.39	$146.60	$94.85	$255.84	Ea		
	Metal frame		Metal framing	Porch or deck framing, steel, joists, 2" x 8" x 10'	n/a	n/a	$50.77	$27.20	$38.98	$116.95	Ea		
	Metal decking		Metal deck for concrete	Metal decking, steel, slab form, uncoated, 9/16" D, 28-gauge, type UFS	n/a	n/a	$2.10	$0.40	$0.52	$3.02	SF		
Decking surface	Concrete slab		Light weight concrete deck, including rebar		n/a	n/a	$23.18	$18.13	$20.66	$61.97	SF		
Deck-to-wall	Siding	Wood-based/vinyl cladding, replace as needed	Fiber cement	Fiber cement siding, lap siding, woodgrain texture, 5/16" thick x 7-12" wide, 6-1/4" exposure.	$0.91	$0.56	$1.57	$2.15	$1.48	$6.67	SF		Remove horizontal wood clapboards - additional flashing needed if siding is not horizontal lap.
Decking surface	Plastic composite material	Untreated wood decking (redwood or sim) on elevated wood frame	Trex or Sim composite decking	Selective demolition, wood framing, deck or porch decking, replace with composite fabrications, woodgrained decking, 1" x 6", grooved edge	$0.47	$0.29	$4.28	$1.52	$1.37	$7.93	LF	28	Underdeck maintenance and removal of debris is essential; cost is for polyethylene composite decking; PVC composite decking may be more costly.

Component	Sub-Component	Original Construction Material	Replacement/ Retrofit Material	Specifications	Demo Labor (D)	Demo Over. (O&P)	New Material (M)	Install Labor (L)	New Over. (O&P)	TOTAL -- Northern CA	Unit	NIST REF. App. Table A Tech. Note #2205	Assumptions
Deck													
Decking surface	Concrete patio	Untreated wood decking (redwood or sim) on elevated wood frame	Replace deck with concrete patio	Selective demolition, wood framing, deck or porch decking replace with Structural concrete, in place, slab on grade (3500 psi), over 10000 S.F., 4" thick, includes concrete (Portland cement Type I), placing and finishing, excludes forms and reinforcing	$0.82	$0.51	n/a	n/a	n/a	$1.33	SF		Additional costs for complete demolition, removal of debris, and labor for pouring a concrete slab deck may increase overall costs.
	Concrete patio -- added depth of slab		Thickened edge for slab	Structural concrete, thickened edge for slab on grade (3500 psi), depth is added to and poured monolithically with slab, 8" wide x 8" deep, unreinforced, includes forms(4 uses), concrete (Portland cement Type I), placing and finishing	n/a	n/a	$3.43	$3.13	$3.28	$9.84	SF		
Deck-to-wall	Metal grate	Untreated wood decking parallel to house (red-wood or sim) on elevated wood frame	Metal grate adjacent to house	Selective demolition, wood framing, deck or porch decking; Aluminum replacing deck board at deck-to-wall, 9-1/2" wide, 14 ga, 2' rib	$0.47	$0.29	$63.75	$5.67	$34.71	$104.13	LF (demo)	29	
	Metal flashing		Flashing for siding transi-tion & openings	Deck Flash Barrier, 6" width, 25' length	n/a	n/a	$0.73	$1.46	$0.55	$2.74	LF		
Steps	Stair demo	Wood steps	Noncombustible steps	Selective demolition, wood fram-ing, deck or porch decking	$0.47	$0.29	n/a	n/a	n/a	$0.76	LF (demo)	32b	The stair includes handrail
	Stairs			Stair, shop fabricated, steel, 3'6" wide, incl 2-line pipe railing, stringers, metal pan treads, excl concrete for pan treads, per riser	n/a	n/a	$533.28	$30.10	$112.99	$676.37	Riser		
Steps	Handrail	Wood railing	Noncombustible metal railing	Selective demolition, millwork and trim, railings and balusters, replace with railing, pipe, aluminum, satin finish, 2 rails, 3'6" high, posts @ 5' OC, 1-1/4" diameter, shop fabricated	$3.19	$2.02	$60.72	$10.97	$14.21	$91.11	LF	32d	
Under-deck area	Deck screening	Open	a) Noncombustible skirting; add ember/ flame vents	Pier and post construction, install skirting (and appropriate venting since skirting will result in a crawl space).	n/a	n/a	$13.19	$18.89	$16.04	$48.12	SF	18b	Suggested deck skirting assumes fiber-cement panels and in-stalling flame- and ember-resistant vents into the panels. Spacing of piers at 48" OC with 4" clearance. Not recommended in most cases due to venting considerations.
	Deck screening	Open	b) Mesh screen skirting; no vents necessary		n/a	n/a	$8.58	$9.44	$9.01	$27.03	SF		For most mobile homes, skirting with mesh screening is recom-mended.

Component	Sub-Component	Original Construction Material	Replacement/ Retrofit Material	Specifications	Demo Labor (D)	Demo Over. (O&P)	New Material (M)	Install Labor (L)	New Over. (O&P)	TOTAL -- Northern CA	Unit	NIST REF. App. Table A Tech. Note #2205	Assumptions
Doors & Windows													
ASSEMBLY: Windows & Screens													
Storm window	Storm window	Wood or vinyl storm window	Replace with metal storm window	Aluminum, residential, double-hung, combination, storm and screen, custom, clear anodic coating, 2'-0" x 3'-5" high	$37.78	$18.89	$160.66	$80.33	$34.93	$332.59	Ea	21	Storm windows are intended to be kept on year-round if covering vulnerable window.
Wood or vinyl window	Shutter	Wood or vinyl storm window	Cover with roll-down hurricane shutter	Extruded aluminum slats, frame, manual roll down, mounted on top of exterior window. Pull down with thumb turn.	n/a	n/a	$13.19	$18.00	$15.59	$46.78	SF	22/23	Estimate is for nonmotorized shutters that are closed with a crank shaft. Price based on 4 windows 2' x 4', 1 door 8' x 10' Total SF = 32+80 = 112SF. Total = $8,862.44. The style is here: Compaqued; Qom3 Security Rolling Shutters; manual; aluminum solid single walled extruded slat profile. See more here: https://disastersafety.org/wp-content/uploads/2019/03/IBHS-Selection-Guide-for-Shutters-Other-Protective-Barriers.pdf"
Exterior screens	Metal screen	Plastic or vinyl screen at double-hung single-action window where screen is on the outside	Replace with metal screen	Window screens, residential, aluminum mesh and frame, 2' x 3'	n/a	n/a	$4.31	$0.87	$1.01	$6.19	SF	21	
ASSEMBLY: Windows													
Wood or vinyl window	Window replacement	Wood or vinyl window	Double pane, tempered, metal-clad wood frame casement	Demo is for 12 sq ft and new window is 2'x3'; demo includes removal of trim.	$16.14	$10.15	$598.32	$46.31	$84.54	$755.46	Ea	22/23	Demolition could involve asbestos and require additional professional services beyond labor and material for replacement of original window.
	Tape & flashing		Tape and flashing at head	Self-adhering sheet or roll flashing, cross-laminated, HDPE, 25 mil, 4"	n/a	n/a	$0.31	$0.39	0.33	$1.03	Ea		
	Tape & flashing		Tape and flashing at sill	Self-adhering sheet or roll flashing, cross-laminated, HDPE, 25 mil, 6"	n/a	n/a	$0.47	$0.42	0.37	1.26	LF		
	Ext penetrations		Foam solid all voids	Fill gaps in exterior siding with fire block liquid foam.	n/a	n/a	$1.71	$5.67	$1.25	$8.63	SF		Assuming first story, easily accessible, and clean gaps. Using the average labor rate for a loaded worker, $48/hour. Assuming there is prep (cleaning out the gap, and cleanup), shaping and painting the foam after it dries.
	Window trim (interior)		Interior trim	Moldings, casings, modern profile, 9/16" x 2-1/4", poplar (interior trim replacement)	n/a	n/a	$2.89	$2.02	1.54	$6.45	LF		Does not include painting or refinishing of interior trim.
	Window trim (interior)		Refinish interior trim	Two coats of premium semigloss paint	n/a	n/a	$0.32	$14.17	$7.25	$21.74	SF		Finish painting is performed by the contractor, assuming brush-on paint vs. full home wrap spray (e.g., avg premium interior semi-gloss paint @ 400 sf/gal. Two coats applied. Labor expectation includes taping or blocking for edges.)
	Window trim (exterior)		Exterior trim	Three coats of premium semi-gloss paint, first story only	n/a	n/a	$0.49	$21.25	$10.87	$32.61	SF		All second- or third-story windows will cost more due to need for ladder or scaffolding and fall protection.
	Window trim (exterior)		Refinish exterior trim	Paints & coatings, exterior door frames & trim only, brushwork, finish coat, exterior latex	n/a	n/a	$0.15	$0.68	$0.45	$1.28	LF		

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Doors & Windows													
ASSEMBLY: Doors													
Front or side door	Kick plate	Vinyl or Wood	Metal kick plate	Assuming door is 36" wide, stainless steel kick plate will be 34" x 10".	n/a	n/a	51.9	$28.33	$40.14	$120.37	Ea	24	Standard size for a 10" x 34" stainless steel kick plate
	Door replacement	Vinyl or Wood	Metal clad replacement	Demo exterior door, single, 3' x 7' high, 1-3/4" thick and replace with doors, residential, steel, prehung, insulated, exterior, embossed, full panel, 3' x 7'.	$22.26	$13.60	$1,016.73	$59.82	$134.46	$1,246.87	Ea	24	
	Door replacement	Vinyl or Wood	Fiberglass replacement	Fiberglass, exterior, prehung door, 1-3/4", 3' x 7'	$22.26	$13.60	$1,267.70	$59.82	$153.76	$1,517.14	Ea	24	
	Weather-stripping	Metal or Fiberglass	Weatherstripping jamb and head	Weatherstripping, doors, metal frame, spring-type, bronze, for 3' x 7' door	n/a	n/a	$60.39	$70.83	$37.77	$168.99	Ea		All gaps, screen, vents, and other penetrations like dog doors should be addressed.
	Weather-stripping		Weatherstripping threshold	Weatherstripping for thresholds; door sweep, flush-mounted, aluminum	n/a	n/a	$47.09	$18.45	$16.42	$81.96	Ea		
Sliding door (deck)	Door replacement	Vinyl or Wood	Fiberglass replacement	Doors, glass, sliding, fiberglass, premium, 5/8" tempered insu-lated glass, 8'-0" x 6'-8" (rough opening 97-5/8" X 82-1/2")	$76.94	$48.56	$6,235.72	$226.67	$3,231.20	$9,819.09	Ea	24	Labor is approx 2 h for 2 workers including balance, level, and finishing work.
	Door replacement	Vinyl or wood	Metal clad replacement	Demo of special doors, sliding glass. Replace with doors, glass, sliding, aluminum, premium, 5/8" tempered insulated glass, 6'-0" x 6'-8".	$76.94	$48.56	$1,994.85	$226.15	$334.57	$2,681.07	Ea	24	
Screen door	Door replacement	Wood or plastic -framed	Metal replacement	Doors, storm, aluminum, residential, combination storm and screen, clear anodic coating, 6'-8" x 3'-0" wide, incl frame	$12.00	$8.00	$125.00	$40.00	$82.50	$267.50	Ea	25/26	
Garage Door	Kick plate	Vinyl or Wood	Metal kick plate	Add 10" stainless steel kick plate to 7' x 9' garage door.	n/a	n/a	$155.82	$56.67	$53.12	$265.61	Ea	27	Assuming standard side garage door, 7' x 9'.
Garage Door	Door replacement	Vinyl or Wood	Metal clad replacement	Demo door, special doors, over-head, residential, 16' x 7' high, remove and replace with doors, residential, garage, overhead, sectional, metal, standard, 16' x 7', incl hardware, excl frame	$132.22	$82.92	$1,737.45	$150.28	$255.71	$2,358.58	Ea	27	
	Door replacement	Vinyl or Wood	Fiberglass replacement	Demo door, special doors, over-head, residential, 16' x 7' high, remove and replace with doors, residential, garage, overhead, sectional, fiberglass, standard, 16' x 7', incl hardware, excl frame	$132.22	$82.92	$3,153.15	$150.28	$384.41	$3,902.98	Ea	27	
Garage Door	Weatherstripping	Metal or Fiberglass	Weatherstripping jamb and head with this rubber	Sealing only head and jam with Dura-Lift rubber seals	n/a	n/a	$80.26	$70.83	$37.77	$188.86	Ea	27	All gaps, screen, vents, and other penetrations like dog doors should be addressed with thick rubber; cost is based on Dura-Lift rubber seals (17') requiring two but will have excess material for most doors. $15 for Liquid Nails, caulk, and fasteners added.
	Weatherstripping		Weatherstripping threshold	Weatherstripping for garage door bottom, aluminum, clear, for 12' door	n/a	n/a	$33.24	$32.87	$24.23	$90.34	Ea		

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Landscaping													
ASSEMBLY: Near-Home Landscaping													
Ground cover	Gravel	Bark mulch	Pea gravel	Soil preparation, mulching, aged barks, 3" deep, hand spread. Near home, remove wood (any combustible) mulch and replace with noncombustible alternative.	$14.17	$245.68	$147.00	$25.38	$31.39	$463.62	CY	30	Assuming a cubic yard of mulch weighs 600 lbs (average between 400-800 lbs). Dump fees = $27.75/330lbs, plus the time and expense to drive to the dump and remove the material, plus P&O.
	weed barrier				n/a	n/a	$0.66	$0.23	$0.44	$1.33	SY		Not required but commonly used.
Fence	Fence	Redwood plank	HardiePanel with steel posts with framing slot.	Replace wooden plank fencing with fiber cement panels, does not include cost of painting	$4.53	$5.90	$5.00	$28.33	$16.67	$60.43	SF	31	This number is estimated based on expectation of clear landscaping around the fencing, with minimal difficulty in demo. Dump fee is: $33.50 per 330 lbs. The weight of 1" redwood plank per sf is ~2.33lbs. Assumption is the removal of an 8'x10' wooden fence in 30-60 mins. Additional materials like stucco, concrete, and metal are not priced out. Note function of fence for privacy; sound "barrier"; aesthetic; shield from radiant heat (fire); cost/affordability which some types of noncombustible fencing material don't provide.