Construction Costs for a Wildfire-Resistant Home

California Edition

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Construction Costs for a Wildfire-Resistant Home

California Edition

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About Headwaters Economics
Headwaters Economics is an independent, nonprofit research group whose mission is to improve community development and land management decisions.
https://headwaterseconomics.org/

About the Insurance Institute for Business & Home Safety (IBHS)
The Insurance Institute for Business & Home Safety (IBHS) is an independent, nonprofit, scientific research and communications organization supported solely by property insurers and reinsurers. IBHS's building safety research leads to real-world solutions for home and business owners, helping to create more resilient communities.

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Executive Summary

Increasing home loss and growing risks require reevaluating the wildfire crisis as a home-ignition problem and not a wildland fire problem. A home's building materials, design, and nearby landscaping influence its survival. Together with the location, arrangement, and placement of nearby homes, constructing a wildfire-resistant home is critical in light of increasing wildfire risks.

California is a leader in the country with a statewide building code and other property-level vegetation requirements addressing wildfire impacts to the built environment. Applicable to all new developments located in State Responsibility Areas (SRAs) and the highest fire severity zones in Local Responsibility Areas (LRAs), California's Building Code Chapter 7A is intended to reduce the vulnerability of homes to wildfire.

Yet given the magnitude of California's wildfire risks and increasing home development in wildfire-prone areas, constructing a home beyond Chapter 7A requirements may be needed to ensure greater wildfire resistance. Understanding the comparative costs of wildfire-resistant home construction in California can inform future wildfire policy and decision-making.

This report compares the costs for constructing three different versions of a wildfire-resistant home in California:

- Baseline home compliant with the minimum requirements of Building Code Chapter 7A;
- Enhanced home augmenting Chapter 7A requirements with a vertical under-deck enclosure around the perimeter of the deck and a noncombustible zone around the home (0 to 5 feet), including under the deck and extending five feet out from the deck perimeter; and,
- Optimum home constructed to the most stringent, fire-resistant options (e.g., use of a noncombustible material), or in some cases, a "Code plus" option (an option not currently included in Chapter 7A). Optimum performance levels were selected based on recent research findings and best judgment.

Baseline, Enhanced, and Optimum strategies to reduce the vulnerability of homes to wildfire were analyzed in response to recent proposed initiatives in California. In February 2022, the California Department of Insurance, in partnership with the California Office of Emergency Services (Cal OES), California Department of Forestry and Fire Protection (CAL FIRE), the Governor's Office of Planning and Research, and the California Public Utilities Commission, launched the *Safer from Wildfires* framework, an approach to provide homeowners with a list of recommended actions to reduce the risk to homes and properties.

Outside state government, the Insurance Institute for Business & Home Safety (IBHS) released Wildfire Prepared Home™—a designation program certifying that a home meets the mitigation requirements associated with *Safer from Wildfires*. The Enhanced wildfire-resistant home described in this report is consistent with the IBHS Wildfire Prepared Home™ designation.

Due to the variability in California's geography, homeowner preferences, and market trends, costs were compared and analyzed for homes in both northern and southern California. The focus of this report is on construction costs for ignition resistance and does not address vegetation management beyond the five-foot perimeter around the home and under the footprint of any attached deck.

Table ES.1. Summary of Baseline, Enhanced, and Optimum Scenarios.

	Baseline	Enhanced	Optimum
Summary	Compliant with California's Building Code Chapter 7A.	Compliant with Chapter 7A, plus enclosed deck and noncombustible near-home zone.	Beyond Chapter 7A compliance to highest wildfire-resistant measures.
Description	Home meeting the minimum standard of Chapter 7A and current Public Resource Code (PRC) requirements. It does not include a 0-5 foot ember-resistant zone.	Baseline home requirements with the addition of noncombustible near-building landscaping and enclosed under-deck area. Consistent with IBHS's Wildfire Prepared Home™ designation.	Home meeting the most stringent and restrictive options for compliance with Chapter 7A and current PRC requirements. It includes additional building materials and design features beyond what is required in the code ("Code plus"), or preferential selection of building materials and design features that meet the most restrictive requirements in the code. Consistent with IBHS' Wildfire Prepared Home™ Plus designation.
Costs	$	$	$$$

Wildfire-Resistant Home Construction Costs

Building materials and assemblies for five primary home components were considered, including:

- **Roof –** roof covering, vents, roof edge, and gutters (including gutter covers and drip edge)
- **Under-eave area –** eaves, soffit, and vents
- **Exterior wall –** siding, windows, doors, trim, and vents
- **Attached deck –** horizontal surface area, rails, and under-the-deck footprint
- **Near-home landscaping –** the immediate five-foot perimeter around the home and attached deck (including mulch and fencing)

Cost estimates for individual building materials were provided through RSMeans, a national database of construction costs for residential, commercial, and industrial construction. Cost estimates included building material, labor, equipment, and contractor overhead costs such as transportation and storage fees. RSMeans includes national averages as well as cost indices that compare regional variability across the country. Redundant building materials used in all three versions of the wildfire-resistant home such as dual-paned, tempered windows and flame- and ember-resistant foundation (crawl space) vents were noted in the report but were not included in the data analysis because there would be no comparative cost difference.

In northern and southern California, building an Enhanced wildfire-resistant home increased construction costs by approximately $2,800 over the Baseline home. Constructing a home to Optimum wildfire resistance increased overall costs by $18,180 in northern California and by $27,080 in southern California (Fig. ES.1).

Individual components such as the roof, exterior walls (including siding), and near-home landscaping added the largest proportional increases compared to baseline Chapter 7A code requirements. For instance, using steel roofing product and associated roof assembly materials for optimal wildfire resistance cost approximately $10,240 more than Class A fire-rated asphalt composition shingles. Similarly, using pea gravel (rock mulch) rather than wood mulch for near-home landscaping was more expensive.

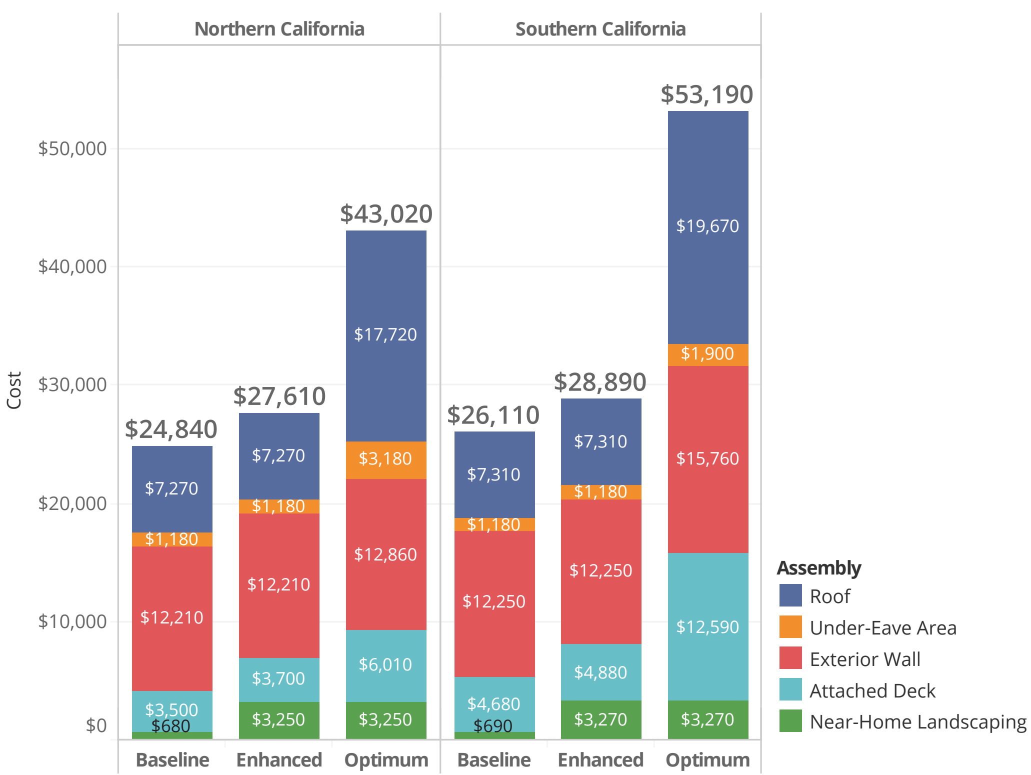


Fig. ES.1: Cost difference of building assemblies in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

Roof

Roofs are highly vulnerable to ignition due to their relatively large horizontal surface area. The exposure of roof coverings to a range of climatic conditions, including wind, rain, and sun, means the roof covering will require maintenance and eventual replacement. Many Class A fire-rated roof covering options are available (e.g., asphalt fiberglass composition shingles). A main reason the roof is vulnerable is because the roof edge—including gutters and roof-to-wall intersections where roof covering meets other materials (e.g., siding used in dormers and split-level homes)—is exposed to ember ignitions. These areas must be properly protected by adding additional flashing at roof-to-wall locations.

For the Optimum home in northern California, a standing seam steel roof was selected for wildfire resistance instead of Class A asphalt composition shingles that were on the Baseline and Enhanced homes. Additional optimal wildfire-resistant measures to the roof included selecting a fire-resistant underlayment underneath the roof covering and using a noncombustible roofing edge (including fiber-cement fascia, metal gutters, metal gutter guards, and a metal drip edge). Optimum wildfire-resistant roofing materials and assemblies for a home in northern California resulted in an increase in costs of approximately $10,450 over Class A asphalt composition shingles used in the Baseline and Enhanced homes (Fig. ES.2).

In southern California, the Optimum wildfire-resistant home featured clay barrel-style tiles that were more expensive than the asphalt composition shingle roof used in the Baseline home. A barrel tile roof covering, including noncombustible end caps and an underlying mineral-surfaced roll roofing material, was $12,870 above the cost of asphalt composition shingles. For the roof edge of the Optimum home in the south, metal drip edge, metal gutters, and metal gutter guards were selected, adding approximately $310 to the overall costs in comparison to using a vinyl gutter system. Unlike the Baseline and Enhanced homes, no fascia was used in the Optimum home resulting in a cost savings of $820. In total, the difference in construction costs between a barrel tile roof covering used in the Optimum home and an asphalt composition shingle roof covering used on the Baseline and Enhanced homes in southern California was approximately $12,360.

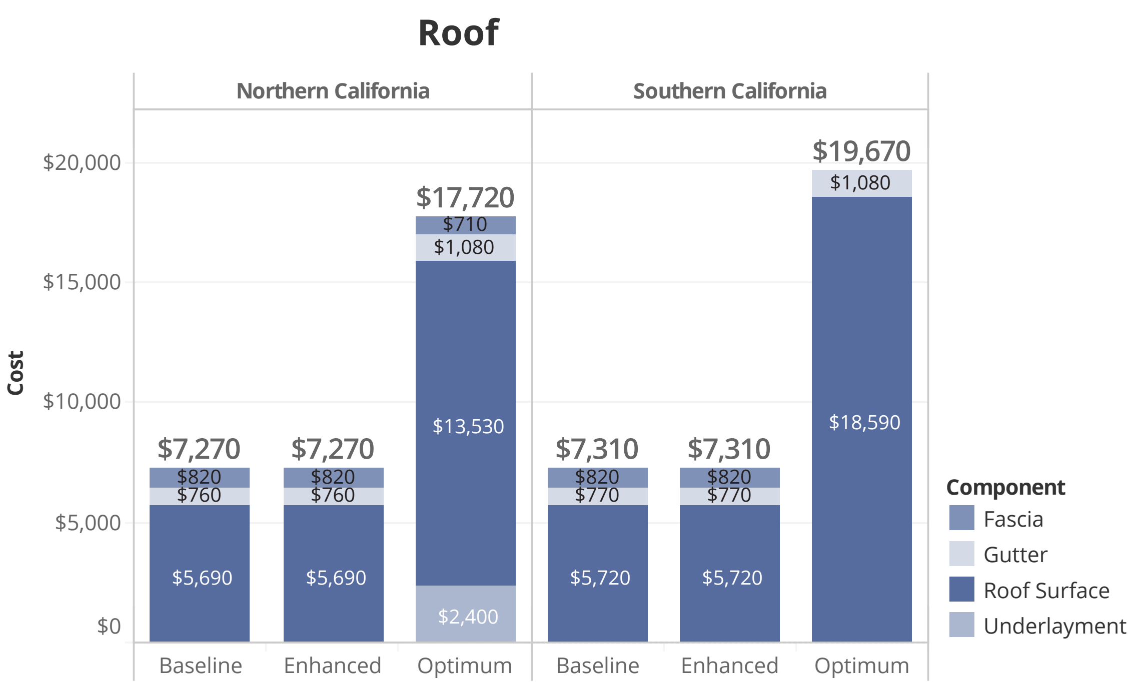


Fig. ES.2: Cost difference of roofing assembly in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

Under-Eave Area

Research suggests eaves are extremely important in structure survivability.[1] Eaves play an important role for building design but they also create vulnerabilities and pathways for the building to ignite. Embers can travel through vents in the eave into the attic and accumulate in gaps between blocking and rafters in open-eave construction. Should flames reach the under-eave area, open eaves can also trap heat. Once there is an ignition in the under-eave area, fire will spread laterally more quickly.

Vents in the under-eave area are inlet vents and therefore allow air to enter the attic space. During a wildfire, vent openings can allow the entry of wind-blown embers into the interior attic space. If combustible materials in the attic ignite, the house can burn from the inside out.[2] The importance of ember and flame entry through vents during a wildfire, and as per requirements in Chapter 7A, have resulted in the development of vents designed to resist the intrusion of flames and embers.

For the Optimum wildfire-resistant home in northern California, an enclosed soffited eave design using a fiber-cement material and flame- and ember-resistant strip vents added approximately $2,000 over the open-eave design used in the Baseline and Enhanced homes (Fig. ES.3).

For the Optimum wildfire-resistant home in southern California, an enclosed soffit covering using a three-coat stucco application and flame- and ember-resistant strip vents added approximately $720 over an open-eave design used in the Baseline and Enhanced homes.

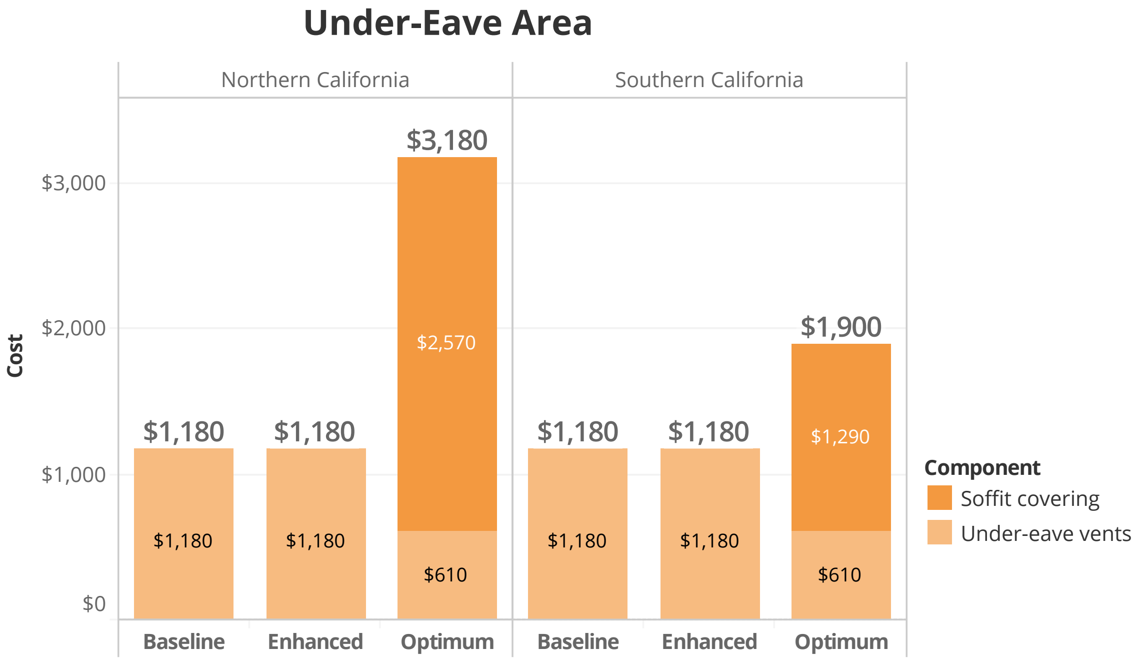


Fig. ES.3: Cost difference of under-eave assembly in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

Exterior Wall

Exterior walls and components in the wall assembly can be vulnerable if exposed to embers, flames, or prolonged exposure to radiant heat from burning items located close to the home. These exposures can ignite combustible siding and the resulting flames can spread vertically and laterally to other wall components such as windows and the under-eave area. Siding extending close to the ground can be vulnerable to ignition by embers accumulating at the base of the wall that ignite it or components in the wall assembly (e.g., wood sheathing).

With the exception of non-reinforced single- or double-hung vinyl windows, research has shown that glass is the most vulnerable component of a window during a wildfire.[3] Vinyl frame windows are susceptible to damage from radiant heat, but this typically does not result in failure of the window. Glass in a window can break from exposure to radiant heat or direct flame contact. When glass in a window breaks, the combustible materials inside the home can be more easily ignited from the flames and/or embers that enter. Wood- and vinyl-framed windows can burn or melt when exposed to radiant heat or flames.

An informal survey with window manufacturers and suppliers indicated that whereas Chapter 7A only requires one pane in a dual-paned window to be tempered, many window manufacturers only supply windows with both panes tempered. Other manufacturers will supply what the customer requests but will default to one-pane tempered. Since all comparative versions of the wildfire-resistant home are Chapter 7A-compliant, the price of windows would not result in a net cost difference and were therefore not included in the data analysis. The window manufacturers surveyed indicated an increased cost for dual-paned tempered windows; however, the difference in cost between single-paned and dual-paned windows and tempered and annealed glass is not included in this report.

Doors (including window glass set in doors) and door frames can fail for the same reasons as windows. Embers can accumulate in the small gaps between the door and frame, resulting in ignition of the door-framing and weather-sealing material.

Overall, building a home in northern California with optimal wildfire-resistant exterior walls—including the siding, trim, and doors—costs approximately $650 more than the Baseline and Enhanced homes (Fig. ES.4). For exterior siding (not including windows and doors), the Optimum home in the north used fiber-cement siding, fiber-cement trim, and a galvanized metal dryer vent. These optimal wildfire-resistant building materials cost $1,240 more than the wood composite siding, wood composite trim, and vinyl dryer vent selected for the Baseline and Enhanced home. By contrast, metal pedestrian and garage doors in the Optimum home were approximately $590 cheaper than the wood pedestrian and garage doors used in the Baseline and Enhanced homes.

In southern California, exterior wall construction materials for the Optimum home cost approximately $3,510 more

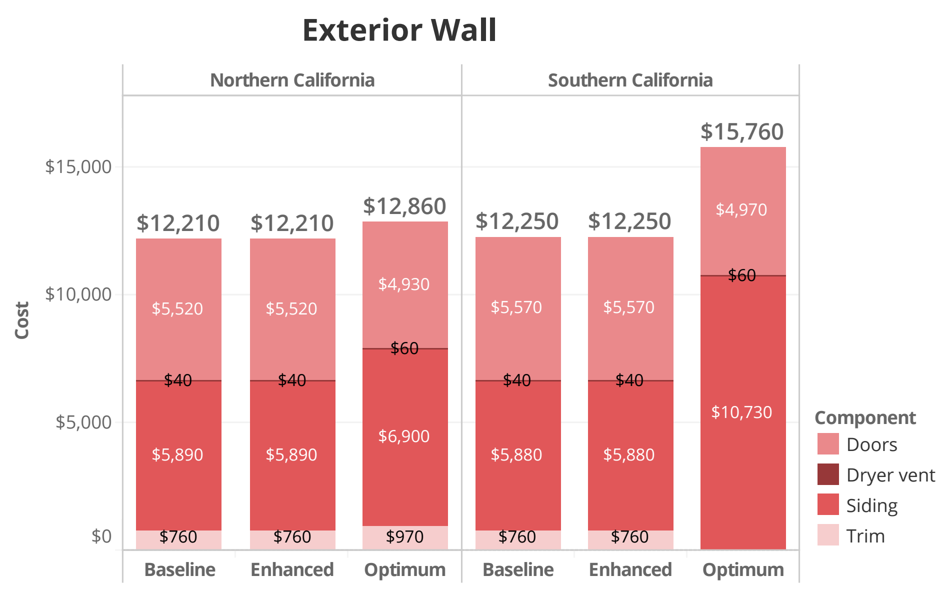


Fig. ES.4: Cost difference of exterior wall assembly in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

than the Baseline and Enhanced homes. For the Optimum home in the south, the siding material was a three-coat stucco rather than a wood composite siding product. Stucco siding and an approved flame- and ember-resistant vent added approximately $4,870 to the overall costs for optimal wildfire-resistant exterior wall construction. Similar to the Optimum wildfire-resistant home in the north, pedestrian and garage doors made with metal were approximately $600 cheaper than wooden pedestrian and garage doors used in the Baseline and Enhanced homes.

Attached Deck

Similar to a roof, a deck can cover a large horizontal surface area and can be vulnerable to embers and under-deck flame impingement exposures. A burning deck can expose the side of the house to extended radiant heat and/or direct flame contact. The deck walking surface and structural support members, as well as what is stored on or below the deck are therefore important considerations.

Most commonly used deck board products (including wood and plastic composite boards) are combustible. Decks with noncombustible walking surfaces include lightweight concrete or a flagstone product. Regardless of the walking surface, decks are typically supported by solid wood joists, beams, and columns that will be vulnerable to ignition if nearby combustible materials ignite.

Enclosing the under-deck area vertically around the perimeter can minimize the accumulation of vegetative debris, vegetation, and other combustible materials. For enclosed decks, installing vents to ensure that excessive moisture does not accumulate in the under-deck area is critical to avoid moisture-related degradation.

For the Baseline and Enhanced homes in northern California, a deck made with redwood decking boards, rails, and pressure-treated lumber for the structural support system was used. The Enhanced home additionally had an under-deck area enclosed with 1/8-inch metal mesh screening. For the Optimum home, a metal railing and plastic-capped composite decking boards were used, and foil-faced bitumen tape was applied on the top of the pressure-treated lumber (joists) for the structural support system. In addition, a metal deck board was used at the deck-to-wall junction to create a noncombustible area next to the home. Including an enclosed mesh screen for the under-deck area of the Enhanced home added $200 to the redwood decking

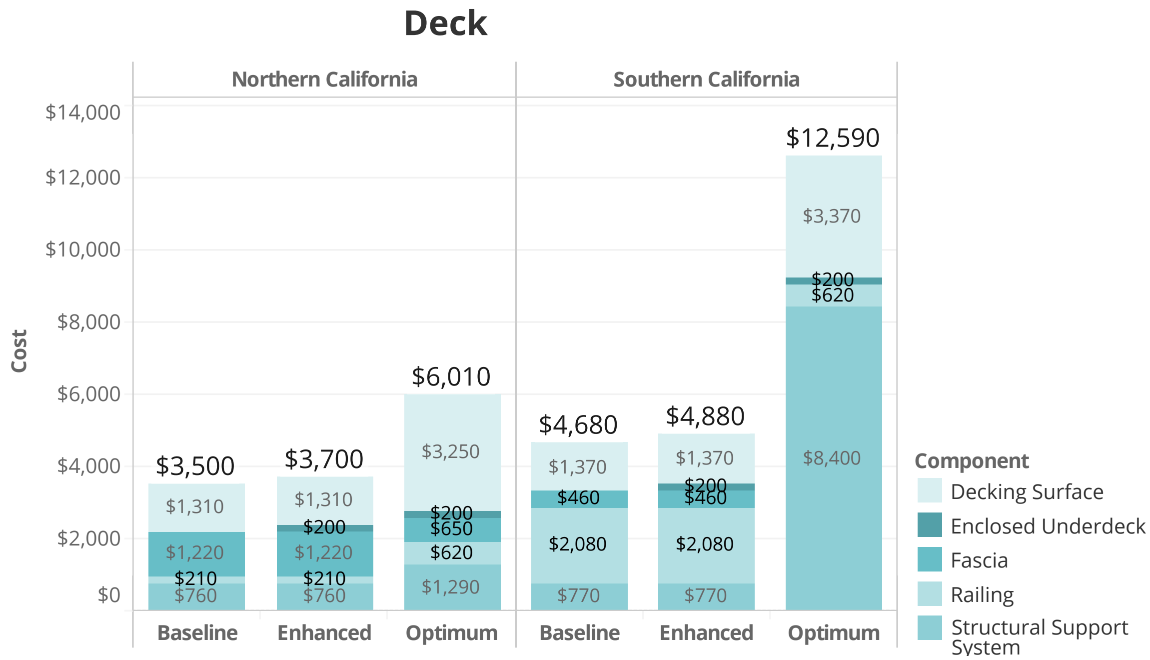


Fig. ES.5: Cost difference of attached decking assembly in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

assembly used in the Baseline home. Optimum wildfire-resistant features increased deck building costs approximately $2,510 over the Baseline home in northern California (Fig. ES. 5).

For the southern California home, the costs of a Baseline deck made with plastic composite (wood-grain textured) non-capped decking material were compared to building material costs for an Optimum deck using metal deck boards and a steel structural support system. The Enhanced home used the same decking building materials as the Baseline home and included a vertical enclosure consisting of 1/8-inch mesh screen around the perimeter of the deck. Similar to the home in northern California, enclosing the under-deck area with a mesh screen added approximately $200 to the costs for a Baseline deck. For the Optimum home in southern California, constructing an attached deck made with metal deck boards and a steel structural support system increased construction costs by approximately $7,910 over a deck built with plastic-composite boards, framing, fascia, and rails.

Near-Home Landscaping

Landscaping makes the home vulnerable when it ignites and allows fire to burn directly to the home. Ignition of near-home combustible materials (e.g., mulch, plants, vegetative debris and other combustible materials) from embers allows flames to touch the home regardless of how well broader vegetation management (defensible space) has been implemented and maintained.

Reducing the availability of fuels within five feet of the home is an important mitigation strategy. The type of vegetation, mulch, and other near-home landscaping features and combustible materials in this zone will affect vulnerability to ember ignitions and the potential for radiant heat and direct flame contact to the home. For this report, the immediate near-home landscaping (0 to 5 feet) included an analysis for combustible and noncombustible mulch and options for a privacy fence; vegetation such as plants and trees were not included in the cost comparison.

Until the guidelines for creating and maintaining an ember-resistant zone are established by the California State Board of Forestry and Fire Protection, there are no requirements for near-home landscaping (0 to 5 feet) in California regulations. Typical

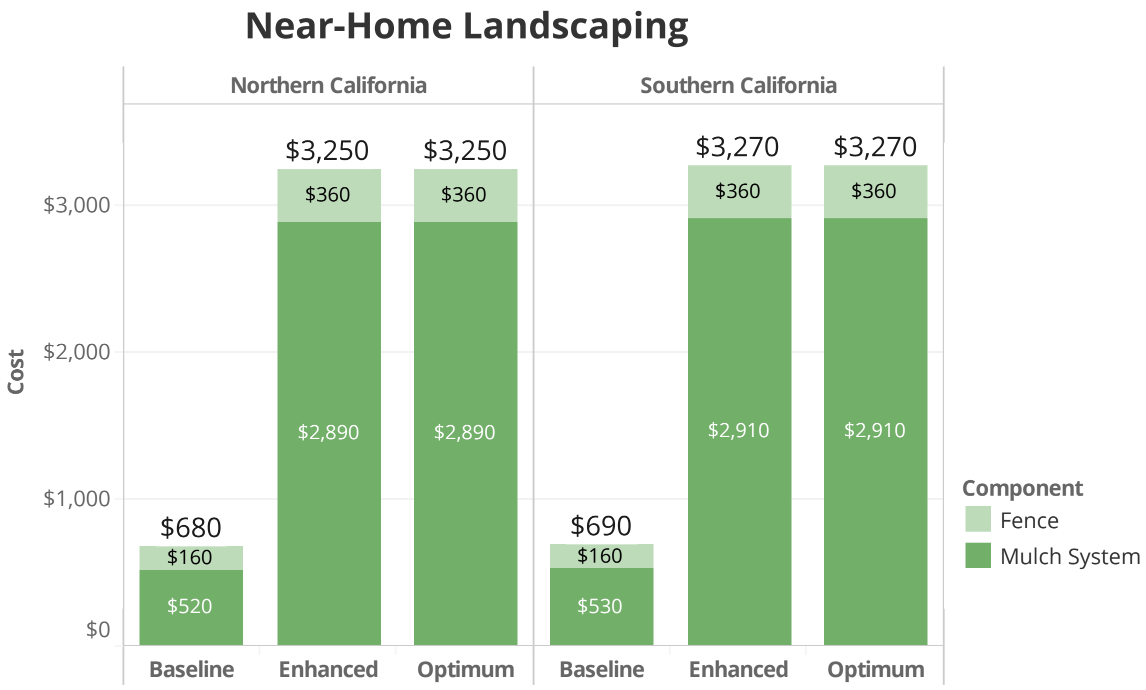


Fig. ES.6: Cost difference of near-home landscaping in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

landscaping practices for bark mulch and wooden fencing were assumed for the Baseline homes located in northern and southern California.

For the Enhanced and Optimum wildfire-resistant homes in northern and southern California, the bark mulch was replaced with pea gravel and included landscape fabric (polypropylene mesh erosion control fabric). The privacy fence was six feet high and made with galvanized metal chain links. A metal gate, concrete, and hardware were included in the cost analysis. Wildfire-resistant features within the near-home landscaping—including gravel mulch, weed barrier, and a noncombustible privacy fence—cost approximately $2,570 more than using bark mulch and a wood privacy fence. It should be noted that while noncombustible mulch may be more expensive than combustible mulch, it is more durable and has a longer lifespan and therefore may save money over the long term (Fig. ES.6).

Investing in Wildfire Resistance is Worth the Cost

Despite the added costs, investing in wildfire-resistant homes and neighborhoods increases overall community resilience for generations to come.

Research findings suggest that the cost of constructing a home with enhanced wildfire resistance—including an enclosed under-deck area and noncombustible zone from zero to five feet from the home—is not significantly higher than the cost of constructing a Baseline home compliant with Chapter 7A. Constructing a home to optimal wildfire resistance will increase overall costs by $18,200 to $27,100 but will return greater long-term benefits in energy efficiency and durability. Wildfire-resistant construction adds approximately 2%-13% to the entire cost of a new home. (Baseline/Enhanced building materials add 2%-8%; Optimum building materials add 4%-13%).

Chapter 7A has been reviewed and modified every three years since it was fully adopted in 2008. As it evolves, Chapter 7A in California's building code can still be improved by adding provisions to reduce the vulnerability of homes to ignition from a threatening wildfire. The combination of better planning of housing developments, fuels reduction on nearby wildlands, management of vegetation and other combustible materials on the property, and construction of a home with wildfire-resistant building materials and design features can reduce the vulnerability of the built environment. With ever-increasing losses, damages, and risks, we cannot afford to wait.

Chapter 1
Introduction

Wildfires are profoundly affecting the people and communities of California. Far outpacing the rest of the country, the state's recent wildfires are setting a new precedent for wildfire behavior and impact. Designing, constructing, and landscaping a home and property to wildfire-resistant codes and related regulations can reduce wildfire risks.

While there is growing recognition that hardening a home and managing nearby vegetation can reduce the vulnerability of homes and buildings to wildfire, the costs of wildfire-resistant construction in the state of California are not well established.

This report compares the costs of constructing wildfire-resistant homes in California. Three different versions of a wildfire-resistant home were evaluated and compared:

- Baseline home compliant with the minimum requirements of Chapter 7A in the California Building Code;
- Enhanced home augmenting Chapter 7A requirements with a vertical under-deck enclosure around the perimeter of the deck and a noncombustible zone around the home (0 to 5 feet), including under the deck and extending five feet out from the deck perimeter; and,
- Optimum home constructed to the most stringent, fire-resistant options (e.g., use of a noncombustible material), or in some cases, a "Code plus" option (an option not currently included in Chapter 7A). Optimum performance levels were selected based on recent research findings and best judgment.

Due to the variability in California's markets, geography, and homeowner preferences, home costs were compared and analyzed for both the northern and southern regions of California.

Homes and buildings located in all State Responsibility Areas (SRAs) and the highest fire severity zones (the High and Very High Fire Hazard Severity Zone) in Local Responsibility Areas (LRAs) must comply with provisions of California Building Code Chapter 7A. This chapter within the building code provides requirements for wildfire-resistant construction and design features to reduce the vulnerability of buildings to wildfire. Yet building an enhanced version of a home—sometimes exceeding the minimum state code requirements provided by Chapter 7A—is important in light of California's increasing wildfire risks.[4]

In response, California's Department of Insurance in partnership with the California Office of Emergency Services (Cal OES), California Department of Forestry and Fire Protection (CAL FIRE), the Governor's Office of Planning and Research, and the California Public Utilities Commission announced in 2022 *Safer from Wildfires* framework, a recommended list of home risk reduction measures, defensible space, and community actions to improve wildfire resilience. Outside of state government, the Insurance Institute for Business & Home Safety (IBHS) launched Wildfire Prepared Home™ in 2022, a designation program certifying that a home meets the mitigation requirements associated with the program. To achieve a designation, a home must undergo a third-party inspection to verify that all mitigation actions have been taken.

This report addresses a gap in knowledge regarding the cost of constructing a home to withstand wildfire in California. For purposes of comparing diverse costs and the range of applicable building materials, three different versions of a home were evaluated and compared in northern and southern California: 1) a Baseline home representing a home compliant with Chapter 7A; 2) an Enhanced home addressing the near-home noncombustible zone and under-deck area; and, 3) an Optimum home built to high wildfire resistant measures, the most stringent evaluated in this report and based on the latest science and best judgment. The Optimum level included noncombustible compliance options from Chapter 7A and, in some cases, "Code-plus" options.

This report expands on a 2018 study conducted by Headwaters Economics and the Insurance Institute for Business & Home Safety (IBHS) assessing costs for wildfire-resistant construction in southwest Montana.[5] Findings from both reports contribute key insights for policies regarding the economic barriers and opportunities for creating fire-adapted communities.

Increasing Wildfire Risks

In recent decades, wildfires have become more severe, wildfire season has become longer, and wildfires have occurred more frequently. Increasing climate change trends including warming air temperatures, earlier snowmelt, and prolonged droughts are generating conditions conducive to extreme wildfire behavior (Fig. 1.1).

As conditions become warmer and drier, the likelihood for wildfires to grow in size and severity has increased. Since the mid-1980s, the number of acres burned in western U.S. forests has more than doubled. This trend is closely correlated with increasing fuel aridity.[6] Accumulated dried fuels can also exacerbate wildfire severity. From 1985 to 2017, the number of acres burned by high-severity wildfires increased by more than 700%, with direct implications to forest health, tree mortality, and soil erosion.[7]

Compared to the 1970s, the average wildfire season in the western United States has been extended by 84 days.[8] Globally, the length of the wildfire season increased nearly 20% over the same time period.[9] In many places, wildfires are burning year-round, thereby eliminating any traditional definitions of a wildfire "season."[10]

At the same time, more homes are being built in areas most exposed and likely to burn. Referenced largely as the "wildland-urban interface" (WUI), it is the fastest-growing land use type in the country. Despite occupying less than one-tenth of the land area in the conterminous United States, 43% of all new homes were built there between 1990 to 2010.[11] Recent development trends imply growth in the WUI has not slowed down in the past decade. Further those figures do not yet capture potential changing demographics and migration patterns resulting from the COVID pandemic.

Approximately 37 million people live in the highest wildfire hazard areas (Fig. 1.2).[12] In the West, wildfire risk is ubiquitous. Exposure to homes by direct sources (e.g., the wildfire front itself or directly by embers) and indirect sources (e.g., ember-ignited vegetative debris or other near-home combustibles that result in radiant heat or direct flame contact exposure to the home, or home-to-home fire spread) is widespread even in areas often considered safe from wildfire.

The converging trends of increasing wildfire risks and home development in wildfire-prone areas means more homes are being destroyed or damaged in wildfires. Since 2005, nearly 90,000 structures have been destroyed by wildfires.[13] Nearly two-thirds of the structures destroyed have been in California, including 18,800 structures in the town of Paradise that were destroyed in the particularly devastating 2018 Camp Fire.

Fig. 1.1: Wildfire risks are increasing alongside ongoing growth in wildfire-prone areas.

Reflecting the escalating pace and scale of wildfire risks, more money is spent on wildfire suppression. In a recent study, federal suppression costs totaled $48 billion between 1985 and 2019.[14] A study by the Office of the Inspector General (OIG) in 2006 indicated that 50% to 95% of all suppression costs were spent on home protection.

Beyond suppression costs, the financial impact of wildfires is substantial. A report by the National Institute of Standards and Technology (NIST) estimated an economic burden between $71.1 billion and $348 billion per year on the U.S. economy, and annual losses ranging between $63.5 billion and $285 billion.[15] In California alone, a recent report determined the wildfire season in 2018 caused $150 billion in direct and indirect losses.[16]

Additional research has determined that suppression costs represent a small portion of the much larger wildfire cost portfolio when short-term damages and long-term expenses are accounted for. A study by Headwaters Economics in 2018 supported previous research findings that indicated suppression costs comprised less than 10% of total wildfire costs.[17] Further, almost half (46%) of the long-term costs of wildfires are borne at the local level and by community residents, businesses, and municipal government.

The costs for wildfire protection and suppression are only going to increase as wildfire risks rise. While federal suppression is widely successful—containing and extinguishing 95% to 98%[18] of all wildfires—it is not reasonable nor is it ecologically beneficial to assume all wildfires can, or should be, suppressed. Living in a fire-prone landscape requires neighborhoods, communities, and society to adapt to the inevitability of wildfire.

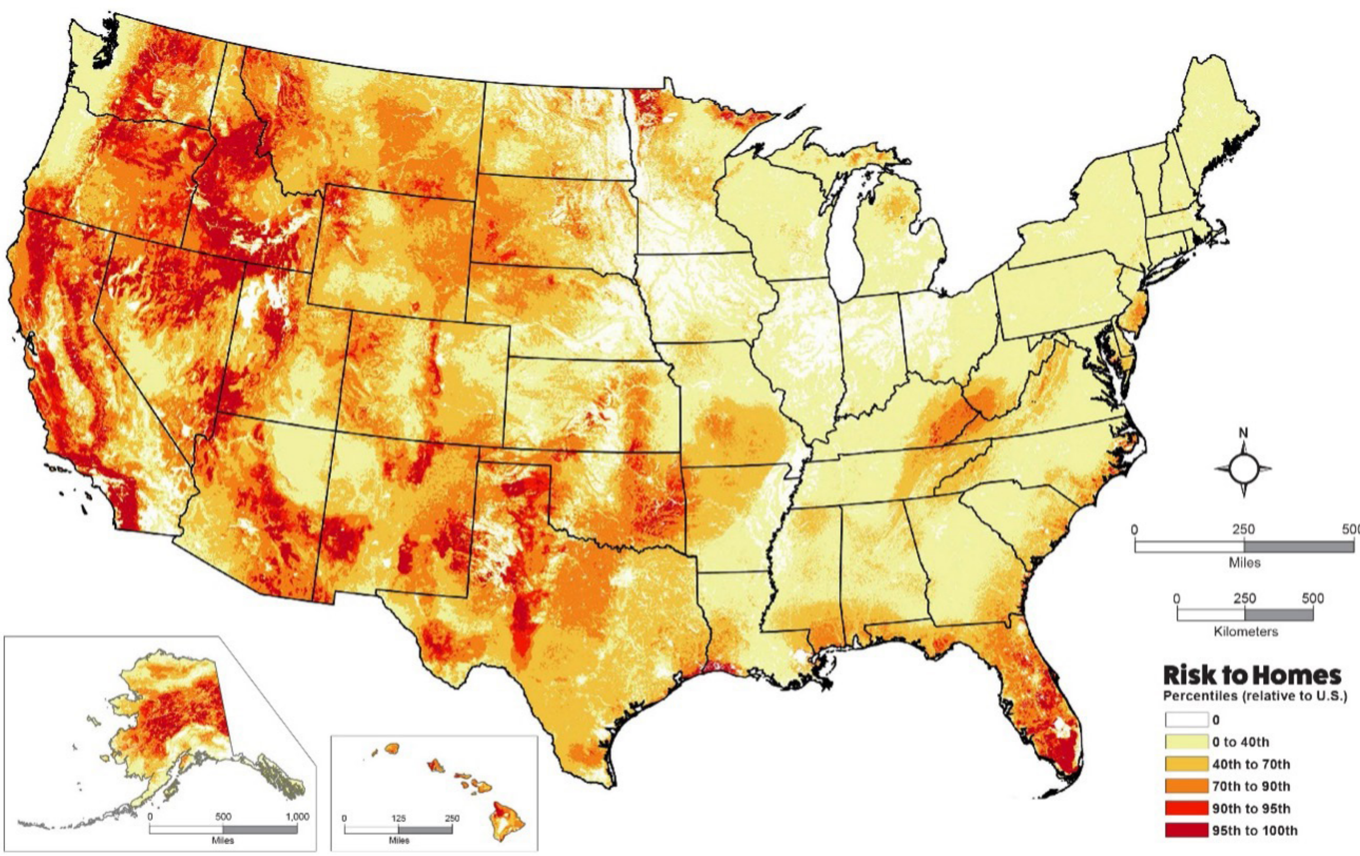


Fig. 1.2: Approximately 37 million people live in areas considered to be in the highest (90th percentile) wildfire risk. (Source: USDA Forest Service. 2022. Wildfire Risk to Communities.)

Understanding How Homes Burn

For decades researchers have studied the science of home ignition. Understanding the physics and fundamentals of home ignition—or the process by which a home ignites and burns—is essential in understanding the sequence of events that leads to a larger wildfire disaster.

A home can ignite and burn from any one of three different sources of wildfire exposure during a wildfire: wind-blown embers, radiant heat, and direct flame contact (Fig. 1.3).

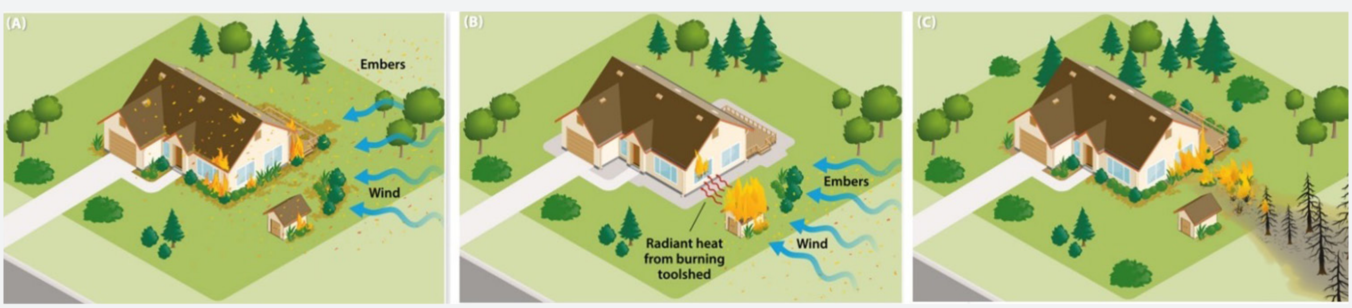
Post-fire analyses indicated a majority of home loss during a wildfire was due to embers and low-intensity surface fires.[19] Wind-blown embers have reportedly traveled miles ahead of a wildfire front to directly and indirectly threaten a home.[20] Direct ember ignition can occur when embers enter the building through openings such as vents or an open or broken window.[21] Once inside, embers can ignite furnishings or other combustible materials. Direct ember ignition can also occur when embers accumulate and ignite combustible parts of the building, such as a wood shake roof or combustible decking.

Embers can also result in indirect ignition if they ignite vegetation or other nearby combustible materials that cause a spot fire, exposing a portion of a building to either a direct flame or radiant heat.[22]

Radiant heat exposures that can result in ignition occur when nearby combustible materials burn, such as tree canopies, landscape vegetation, and neighboring buildings. The vulnerability of a building to radiant heat depends on the intensity and duration of the exposure. If the radiant heat level is high enough and the duration long enough, it can ignite a combustible product (e.g., wood siding), or it can break the glass in a window or door, making ember-ignition of interior materials more

Definitions

There are three types of ignition exposure to buildings during a wildfire:



Wind-Blown Embers. The most common cause of building ignitions during a wildfire. Traveling far ahead of a wildfire front, embers can directly threaten a home by landing on a combustible material or vulnerable component, such as the roof or open window. Indirect ember exposure occurs when embers ignite spot fires on nearby combustible material.

Radiant Heat. Exposure from radiant heat occurs when nearby combustible materials and fuels ignite. Influenced by duration and intensity, radiant heat can ignite a combustible material or break the glass of windows and doors.

Direct Flame Contact. When flames touch a building or combustible material.

Fig. 1.3: There are three different sources of wildfire exposure during a wildfire— wind-blown embers (A), radiant heat (B), and direct flame contact (C). (Source: Valachovic, Quarles and Swain. 2021. Reducing the Vulnerabilities of Buildings to Wildfire: Vegetation and Landscape Guidance. UC ANR 8695.)

likely. Exposures to lower levels of radiant heat can pre-heat materials, making them easier to ignite if exposed to flames.

Direct flame contact from the wildfire as it passes the property can be the trigger that leads to ignition of a building component, such as combustible siding. Once a building component ignites, it is easier for the fire to enter the building through an exposed vulnerability or through the stud cavity behind a component, such as wall siding. Fire can also spread vertically and laterally over a wall, impinging on and possibly breaking glass in windows or doors, or enter the attic through the under-eave area or attic vent. Once glass breaks, embers can readily enter the building and ignite interior furnishings.

Research has shown that a home's characteristics and its relation to its immediate surroundings principally determine home ignition potential. Research from the USDA Forest Service Rocky Mountain Research Station, Insurance Institute of Business & Home Safety (IBHS), National Institute of Standards and Technology (NIST), and other universities and institutions across the globe have further supported this understanding of factors influencing structure ignitability.[23]

Maintaining defensible space around the home including vegetation management within 100 feet of the building, coupled with wildfire building codes and referenced testing standards, will decrease the chance of home ignitions during a wildfire. While maintaining appropriate vegetation on the property is important in reducing the availability of fuels and minimizing wildfire spread, constructing a wildfire-resistant home is equally crucial in mitigating ignition vulnerabilities of the home in the first place. Acknowledging the importance of the development and maintenance of an effective defensible space on the property, the focus of this report is on construction costs for ignition resistance and does not address vegetation management beyond the five-foot perimeter around the home and any attached deck.

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 a material's response or reaction 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
Materials and systems that resist the *spread* of fire from the fire-exposed to a non-exposed side of an assembly (i.e., a wall or roof).

Ignition-Resistant
Material that resists *ignition* or 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.

Chapter 1

Building Materials, Design, and Landscaping

The materials used in construction, including design and assembly, influence a home's survival during a wildfire. Several components of a home are most vulnerable to wildfire and must therefore be built and designed to resist ignition from embers, radiant heat, and direct flame contact. The most vulnerable components include:

- **Roof –** roof covering, attic vents (outlet air), and roof edge, including gutter system
- **Under-eave area –** eaves, soffit, and attic vents (inlet air)
- **Exterior wall –** siding, windows, doors, gable end (attic) vents, and foundation (crawl space) vents
- **Attached deck –** surface area, rails, and under-the-deck footprint
- **Near-home landscaping –** the immediate five-foot perimeter around the home and attached fencing

Reducing home vulnerability to a wildfire requires an integrated systems approach. While the roof is generally considered the most vulnerable due to its relatively large surface area, windows, vents, eaves, and attached decks are also crucial considerations.

Additionally, defensible space in the near-home area complements building construction to reduce overall ignition potential of a building. Even if constructed with wildfire-resistant materials and design features, the home and its landscaping must be maintained to retain an adequate level of performance. The potential for extended radiant heat exposure and/or direct flame contact will depend on the defensible space on the property, including both vegetative and non-vegetative combustibles, and on the proximity of neighboring homes or outbuildings.

Overall land use planning decisions—including where homes are allowed on the landscape, proximity of neighboring homes, and siting of a home on an individual lot relative to neighboring structures, topography, and primary wind direction—are also important factors.

Structure of this Report

This report is structured in four sections. The first section (Chapter 2) provides background for California's evolving Building Code Chapter 7A and related policies for wildfire mitigation. Understanding the policy context, statutes, and construction requirements for home development in California is important because they are the most robust statewide requirements for wildfire resistance in the built environment in the country.

The second section (Chapter 3) describes the primary assemblies and components of the home considered most vulnerable to wildfire: the roof, under-eave area, exterior walls, attached decking (including under-deck footprint), and near-home landscaping.

The third section (Chapter 4) describes the methodological approach used in the comparative cost analysis, including the process for home selection and analysis of building material data. Results are summarized in the fourth section (Chapter 5), which also includes an itemized breakdown of building materials and associated costs of individual components. Mitigation strategies and cost comparisons of wildfire-resistant building materials and related assemblies are discussed with reference to a Baseline home compliant with Building Code Chapter 7A, an Enhanced wildfire-resistant home, and an Optimum home meeting the most stringent wildfire-resistant measures per performance testing and best judgment. We provide concluding remarks and key takeaways in the final chapter (Chapter 6).

Costs reported in this study do not reflect recent adjustments in the market resulting from the global coronavirus (COVID) pandemic. Supply shortages, increased transportation and shipping fees, and other economic and manufacturing stresses reported during the coronavirus pandemic were therefore not incorporated into final data analysis.

Chapter 2

Building Code Chapter 7A: Policy for Wildfire Resistance in California

While much of the country has yet to address construction requirements in wildfire-prone areas, California remains unique in its statewide adoption of several regulatory measures. These measures were codified in the Materials and Construction Methods for Exterior Wildfire Exposure as Chapter 7A of the state building code, with Phase I being implemented in 2005 and Phase II in 2008. Additional regulations and ordinances further support wildfire mitigation measures at the home and neighborhood scale.

At the national level, the International Code Council's International Wildland-Urban Interface Code (IWUIC) and Chapter 25 of the National Fire Protection Association's (NFPA) Standard for Wildland Fire Protection (NFPA 1140) provide model building codes for states to adopt in their entirety or with amendments. With Chapter 7A, California is one of a few states (including Nevada, Pennsylvania, and Utah)[24] with a statewide building code requiring wildfire-resistant measures for new construction.

Building code requirements divide the home or building into components (e.g., roof, exterior wall, vents, and decks) and provide material and component assembly (i.e., "system") options for compliance. An example of an assembly would be an exterior wall that includes the siding material, sheathing, framing, and other components used in the wall construction. Multiple options for complying with the provisions for a given component are provided. These options are separated by "or" statements in the code. While these options all provide ways to comply, they do not necessarily provide equivalent protection.

The Foundations of Building Code Chapter 7A

Early Legislation

California's first statewide policies addressing wildfire mitigation came in the wake of a series of devastating wildfires in the late 1950s and early 1960s. During this time period, the Wheeler Springs Fire (1947), Malibu/Zuma Fire (1958), Refugio Fire (1955), Bel Air Fire (1961), and Weldon Fire (1964) all burned in southern California.

Fig. 2.1: The Bel-Air Fire in 1961 (Photo: LA Public Library)

Following the 1961 Bel Air Fire, the importance of wind-blown embers as potential ignition sources became evident in post-fire reports documenting surviving unburnt vegetation surrounding destroyed structures (Fig. 2.1). In 1965, and shortly after the Weldon Fire, the state adopted Public Resources Code (PRC) 4291 establishing vegetation modification requirements around buildings.

In 1982, California enacted PRC 4201-4204. These provisions required State Responsibility Areas (SRAs) to be classified into Fire Hazard Severity Zones (FHSZs) and assigned ratings reflecting the degree of severity of fire hazard expected in the zones.[25] The California Department of Forestry and Fire Protection (CAL FIRE) is responsible for fire protection in SRAs.

In 1990, California enacted PRC 4290, which provided general fire safety regulations such as standards for roads (fire equipment access), signage (street and building identification), minimum private water supply reserves, and requirements for fuel breaks and greenbelts. Provision language clarified that local regulations could be more restrictive than these state regulations but not less restrictive.

Following the 1991 Oakland-Berkeley Hills (Tunnel) Fire, the Bates Bill (AB 337) was passed. This legislation acknowledged that suburban and more urban areas could be threatened by wildfire. It provided for the evaluation of the potential fire hazard in Local Responsibility Areas (LRAs), and notification of the local jurisdiction where Very High Fire Hazard Severity Zones (VHFHSZs) existed. Acceptance of the VHFHSZ maps by local jurisdictions was optional and not mandated by the Bates Bill. If the maps were accepted by the local jurisdiction, this determination would provide a pathway for adoption of wildfire-related requirements applicable to SRAs.[26]

Addressing the Built Environment

The wildfires of the early 1990s were the impetus for statewide regulations addressing the built environment, including construction material type and assembly. In 1993, the Kinneloa, Laguna, and Old Topanga fires all burned in Los Angeles County and resulted in the Federal Emergency Management Agency (FEMA) allocating funds to California in 1997.

Some of the FEMA funding was awarded to the University of California Forest Products Laboratory (UCFPL). Research conducted at the UCFPL, based on this funding, provided foundational knowledge that resulted in testing protocols and prescriptive guidelines for construction materials and assemblies to wildfire ignitions, including roof coverings and assemblies, exterior wall sidings, windows, and attached decks.[27]

Around the same time that California was expanding research and testing protocols for wildfire ignition resistance, the International Fire Code Institute published the first version of the Urban Wildland Interface Code (1995) which was largely prescriptive.

Testing protocols developed by UCFPL would later be issued as State Fire Marshal (SFM) standard test methods and referenced by Chapter 7A. In 2001, when the research at the UCFPL was concluding, an 18-member advisory board chaired by a former state fire marshal was formed. The board consisted of fire and building code officials, plus representatives from CAL FIRE and the research staff from the University of California. The purpose of the advisory board was to translate research findings and the testing protocols into performance-based statements and objectives.

Strengthening the Building Code

By the time of the southern California fires (Old, Simi, Cedar, Grand Prix) in 2003, the foundational activities for the statewide adoption of a wildfire building code were well underway. Passed by the California Building Commission in 2005 and referenced as "Chapter 7A" in the California Building Code, the code addressed building materials and construction methods for the built environment subjected to wildfire exposures.

Chapter 7A was introduced in 2005 and became fully implemented in 2008—the three-year delay was intended to give commercial fire-testing facilities time to develop the capability to conduct the SFM standard test methods and manufacturers time to develop and test products that could comply with requirements. During this time the Office of the State Fire Marshal conducted classes statewide to share information about Chapter 7A with building code and fire officials, manufacturers of exterior-use construction materials, retail outlets, architects, designers, contractors, and other interested stakeholders.

Section 701A.3 states that Chapter 7A provisions are applicable to residential and commercial construction. There are exceptions for smaller accessory buildings and certain agricultural buildings. This section also states that, from the perspective of the State, buildings constructed prior to 2008, the year when Chapter 7A was fully implemented, will never have to comply with the provisions provided in this chapter of the code. Some local jurisdictions have incorporated "significant remodel" language in their adoption process, making Chapter 7A provisions applicable when buildings are remodeled.

Every three years since 2008, Chapter 7A has been reviewed by a committee within the Office of the State Fire Marshal. Further research and post-fire investigations have dramatically improved understanding of the vulnerabilities of buildings threatened by wildfire. Some of these findings have been incorporated in more recent updates to the building code and modifications of standard test methods. The most current version of Chapter 7A is the July 2021 supplement of the 2019 California Building Code.

The 2021 supplemental provisions to Chapter 7A contained four major changes to the previous version of the code, including amendments to the roof, roof edge, vents, and decking.

- **Roof:** Class A fire rating for roof coverings will be required in all FHSZs in the SRA.
- **Roof edge and ridge:** Where the roof covering profile results in an air space between the roof covering and the roof deck, roll-roofing (a mineral-surfaced asphalt fiberglass composition roofing product) will be required to be installed in addition to a bird/fire-stopping product.
- **Vents:** Flame- and ember-resistant vents, approved and listed by the OSFM Building Materials Listing Program, will be required for all attic and crawl space vents.
- **Metal flashing:** Required at attached deck to exterior wall locations; extending up the exterior wall a minimum of six inches.

Recent Legislation and Other Wildfire Resilience Initiatives

On September 29, 2020, California's Governor Newsom signed Assembly Bill 3074 (Fire prevention: wildfire risk: defensible space: ember-resistant zones). This act will result in the amendment of certain sections of the Government Code (51182, 51186, and 51189) and Public Resources Code (PRC) 4291. The amendments to the Government Codes are related to Local Responsibility Areas (LRAs); changes to PRC 4291 pertain to SRAs.

AB 3074 will result in dividing the current "lean, clean and green" zone (0 to 30 feet from the building) into two zones. The first zone, referred to as the "ember-resistant zone," will be the zone immediately adjacent to a building and include the area under the footprint of all attached decks (0 to 5 feet, Fig. 2.2). The second "lean, clean and green" zone will extend outward from 5 to 30 feet from the building (or to the property line).

Modifications to the text of PRC 4291 are being developed by the California Board of Forestry and Fire Protection (CAL FIRE). Legislative language is general in nature, providing intent. The legislation directs the Board of Forestry and Fire Protection to prepare the specific enforcement language. The resulting language may result in a strict "noncombustible zone," but it is possible that certain defined combustible vegetation will be allowed. Once prepared (no later than January 1, 2023), these modifications are anticipated to be required for new construction immediately.

Senate Bill 63 was signed into law in September 2021 expanding areas identified as Moderate and High Fire Hazard Severity Zones (FHSZs) in Local Responsibility Areas (LRAs). For areas designated as High FHSZ, and for Moderate FHSZ when appropriate,

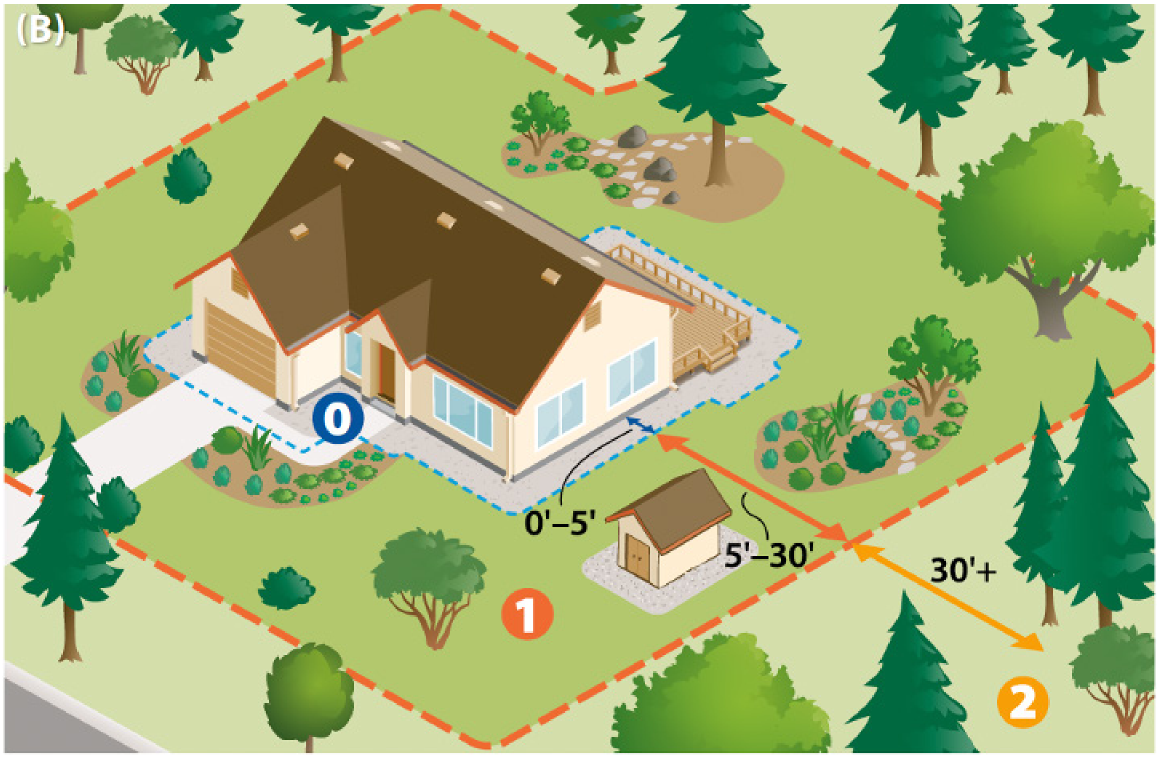


Fig. 2.2: A schematic of the defensible space zones on a property, incorporating the new "near-building" zone (0-5 feet and under the footprint of any attached deck). In this figure, the near-building "ember-resistant zone" is indicated by Zone 0. (Source: Valachovic, Quarles and Swain. 2021. Reducing the Vulnerabilities of Buildings to Wildfire: Vegetation and Landscape Guidance. UC ANR 8695.)

building standards specified in Building Code Chapter 7A or other building standards approved by the California Building Standards Commission are required. The bill also extends vegetation management requirements to newly designated FHSZs as well as expands local assistance grant programs for home mitigation, public outreach, home assessments, and training.

In addition to these legislative changes, *Safer from Wildfires* was launched as a partnership between California's Department of Insurance, the California Office of Emergency Services (Cal OES), CAL FIRE, the Governor's Office of Planning and Research, and the California Public Utilities Commission in 2022. *Safer from Wildfires* provides an approach for homeowners to take action to reduce risk to their homes and properties. In parallel, and outside of state government, the Insurance Institute for Business & Home Safety (IBHS) launched Wildfire Prepared Home™ in 2022, a designation program certifying a home satisfies mitigation requirements.

Efficacy and Costs of Wildfire-Resistant Home Construction

Multiple factors influence home survivability during a wildfire. In addition to building materials and design, housing arrangement, housing and community density, nearby vegetation, topography, response effectiveness, and a variety of climate-related drivers influence wildfire behavior and vulnerability of a home.

In a broad statewide study, Syphard and Keeley (2019) analyzed reports of inspections of more than 40,000 structures between 2013 and 2018.[28] About 90% of these structures were damaged or destroyed in fires that occurred in 36 California counties. The authors determined that building characteristics—primarily the eaves, vents, and windows—were most directly associated with survivability. While factors linked to home survival varied across the state (including firefighting response, specific building materials, and defensible space), building materials highly influenced home survival. Additional determinants influencing home survival included location, topography, and nearby housing arrangements.[29]

In preliminary research conducted by Baylis and Boomhower (2021), the authors examined home survivability factors for nearly 50,000 homes exposed to wildfires between 2007 and 2020 across California.[30] The authors reported that a home built in 2010 or later was nearly 40% less likely to be destroyed by a wildfire compared to a home built in 1985 or before. Home survivability was closely correlated to modern building codes requiring homeowner mitigation measures. Additionally, a home was more likely to survive if its nearest neighbor also complied with recent mitigation regulations resulting in a positive net spillover effect for the larger neighborhood.

In a post-fire analysis of homes damaged and destroyed by the Camp Fire, Knapp et al. (2021) found proximity between destroyed structures, density of development, and tree canopy cover strongly correlated with home survivability.[31] In their analysis of homes damaged, not destroyed, the authors reported that older homes (built prior to 1997) fared poorly compared with newer homes built after 1997. The adoption of Chapter 7A was not a statistically significant factor in determining home survival—rather, radiant heat exposure from nearby burning structures or flame impingement from the ignition of near-home combustible materials were the strongest predictors of survival. Findings suggest homes need to be designed and maintained to minimize the chance of direct flame contact, resist ember ignition, and survive extended radiant heat exposure.

In conjunction with the growing body of work addressing building ignition scenarios and associated vulnerabilities, several recent studies evaluated the costs of wildfire mitigation. In 2016, an Australian study conducted online surveys to evaluate the total costs for local residents to adequately prepare their property for a wildfire.[32] Survey results indicated residents spent an average of $7,500 ($AUD 10,000) on property mitigation with an annual maintenance cost of approximately $750 ($AUD 1,000). The study did not evaluate costs for hardening a home with wildfire-resistant building materials and design features, but rather focused on property mitigation expenses.

In 2004, and as a precursor to California adopting Building Code Chapter 7A, the Office of the State Fire Marshal requested an analysis identifying the costs and benefits associated with proposed regulations in the state's wildfire-prone areas. The study was conducted by Fire Cause Analysis and evaluated economic and construction data within various business sectors to analyze construction costs if proposed regulations were implemented.[33] The study found construction costs for a typical single-family (1,750 square-foot) home would increase approximately $2,000 including developer overhead costs. As an aggregated total at the state level, construction costs would increase approximately $30 million per year for the estimated 14,000 new homes built in areas where regulations would apply. The authors concluded the costs of not implementing regulations, in the form of property losses and suppression costs,

Chapter 2

exceeded the projected costs for regulations and therefore recommended adopting mitigation standards in wildfire-prone areas.

In 2018, a study by Headwaters Economics and the Insurance Institute for Business & Home Safety (IBHS) analyzed the cost of constructing a wildfire-resistant home compared to a home constructed with traditional building materials.[34] Using an actual representative home typical of single-family residential construction in southwest Montana, costs for individual building materials were assessed for the traditional home and a replicated version of the home built to wildfire-resistant standards. The study indicated new construction costs for a wildfire-resistant home were essentially the same as costs for a traditional combustible home. While prices for specific building components varied—for example, the roof, exterior walls, deck, and near-home landscaping—the difference in overall costs were less than 2% when building components were calculated as an aggregated total. The authors of this report acknowledge that selection of certain materials for a given component will influence the cost difference between the two broad categories of "wildfire resistant" and "not wildfire resistant."

In 2019, the National Institute of Building Sciences (NIBS) released a report identifying the benefit-cost ratio (BCR) of investing in hazard mitigation, including wildfires.[35] The authors found that for every $1 spent on up-front costs for wildfire mitigation, a benefit of $4 was received. In the report, "costs" were determined as the up-front construction cost and long-term maintenance costs to improve existing facilities or the additional up-front cost to build new ones better. "Benefit" referred to the present value of the reduction in future losses that mitigation provides such as property repairs, loss of revenues, fatalities, and other quantifiable variables. Another study by the National Research Council of Canada, discussed in more detail below, similarly calculated a benefit-cost ratio for building and maintaining wildfire-resistant homes.[36]

The National Association of Home Builders commissioned its own study in 2020 that examined the cost of building a house in compliance with Ignition Resistant Construction Class 1 requirements in the International Wildland-Urban Interface Code (IWUIC).[37] In analyzing three different geographic regions, the report indicated additional costs for building to IWUIC standards (International Residential Code) ranged from $1,800 in Los Angeles, CA, to $29,000 in Denver, CO. Including external structural components such as decking, defensible space, and sprinklers added another $2,000 to $10,000 to the total costs.

In 2021, the National Research Council of Canada released a study analyzing the benefit-cost ratio for building new construction to comply with the country's wildland-urban interface (WUI) Guide.[38] In its examination, approximately $12,000 CAD (~$9,500 USD) was added to the overall costs for a new, 2,000-square-foot home to meet the provision of Canada's National WUI Guide. The comprehensive report also examined costs for retrofitting existing structures, as well as transferred costs at the community and national scale. Similar to the NIBS study in 2019, the NRC report found an up-front investment in wildfire-resistant construction and vegetation management yielded benefits that exceeded long-term costs and losses.

This report updates research findings from the original 2018 study conducted by Headwaters Economics and the Insurance Institute for Business & Home Safety (IBHS). Whereas the previous study used a typical home built in southwest Montana as the representative model, this report evaluates new home building costs for wildfire-resistant construction in northern and southern California. Details regarding home selection, building materials, and cost analysis are provided in the methodology and results section.

Chapter 3

Vulnerable Components of a Home

Like the International Wildland-Urban Interface Code (IWUIC) and the National Fire Protection Association's (NFPA) Standard for Reducing Structure Ignition Hazards from Wildland Fire (1140), Chapter 7A in California's Building Code qualifies building materials that comply with referenced standard test methods and certain prescriptive options.

During a wildfire, homes can be ignited by exposure from embers, direct flame contact, and/or radiant heat exposure. The home can be vulnerable as a result of its component materials and design features included in their assembly. The near-home zone, typically considered the five-foot perimeter around the home and under the footprint of any attached decks, can also increase vulnerability of the home depending on the amount of combustible materials in those areas. This report considered wildfire-resistant materials and design features for the following components (Fig. 3.1):

- **Roof –** roof covering, attic vents, and roof edge, including gutter system
- **Under-eave area –** eaves, soffit, and under-eave attic vents
- **Exterior wall –** siding, windows, doors, and foundation (crawl space) vents
- **Attached deck –** walking surface area, rails, and under-the-deck footprint
- **Near-home landscaping –** the immediate five-foot perimeter around the home including mulch and privacy fence

Properly and systematically mitigating individual features of the home reduces ignition potential from embers, near-building fires (radiant heat and direct flame contact), and home-to-home ignitions (which can result from embers, radiant heat, and/or direct flame contact). A brief description of building requirements for Chapter 7A are given in Table 3.1.

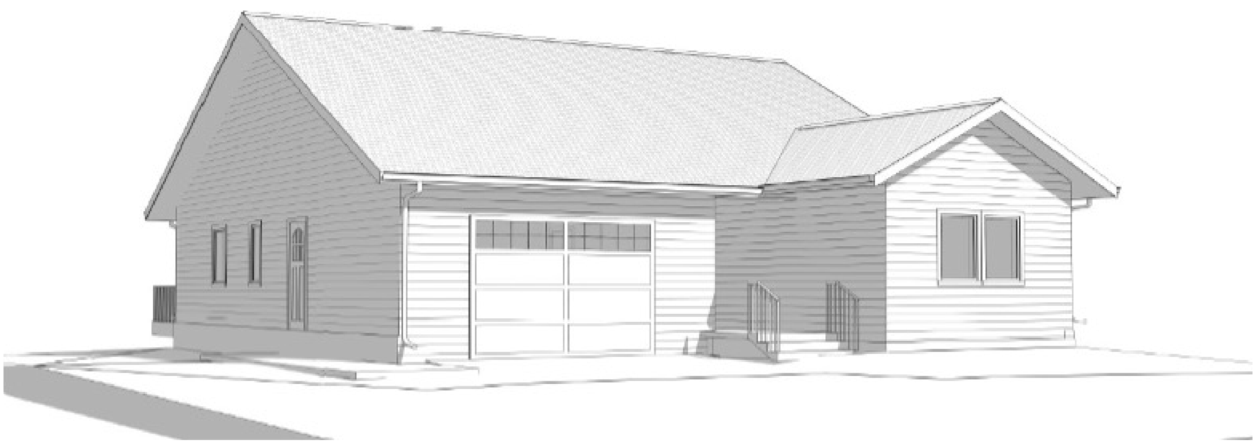


Fig. 3.1: Rendering of the home modeled in this study.

Table 3.1: Building requirements to comply with California Building Code Chapter 7A

Component	Requirements	Section
Roof	Requires a Class A fire-rated roof covering. Plug gaps at ends (i.e., bird-stopped, fire-stopped). A minimum 36-inch-wide mineral-surfaced asphalt fiberglass composition cap sheet must be installed under metal valley flashing. Where the roof profile results in a gap between the covering and the roof deck, a mineral-surfaced asphalt fiberglass composition cap sheet must be installed over the roof surface.	705A
Gutters	Metal and vinyl gutters allowed. Gutter must be equipped with the means to prevent the accumulation of debris. Building code officials have generally interpreted this requirement to mean that a gutter cover device must be installed.	705A4
Under-Eave Area	Soffited or open-eave allowed. If open-eave, nominal 2x material (or greater) is required as blocking and rafters. Exposed roof deck shall be constructed of a material that is noncombustible, or ignition-resistant, or tested for 10-minute direct flame contact, or have a one-hour fire rating on the exterior side of the framing.	707A.4
Vents	Attic and foundation ventilation openings must be Office of State Fire Marshal Building Materials Listing Program (OSFM-BML)-approved and listed Wildland Flame- and Ember-Resistant product.	706A
Exterior Walls	Five options for compliance: 1) noncombustible material, 2) ignition-resistant material, 3) heavy timber construction, 4) log wall assembly, or 5) assembly complying with SFM 12-7A-1.	707A
Windows	Four options for compliance: 1) multipaned glazing with a minimum of one tempered pane, 2) glass block units, 3) fire-resistance rating of not less than 20 minutes, or 4) meeting performance requirements of SFM 12-7A-2.	708A.2
Doors	Four options for compliance: 1) Noncombustible exterior surface or cladding, 2) solid core wood meeting thickness specifications, 3) fire-resistance rating of not less than 20 minutes, or 4) meeting the performance requirements of SFM Standard 12-7A-1.	708A.3
Decking	Only applies to the walking surfaces of the deck. Four options for compliance: 1) ignition-resistant material that complies with SFM Standard 12-7A-54, 2) exterior fire-retardant wood, 3) noncombustible material, or 4) comply with SFM Standard 12-7A-4A. Metal flashing required at attached deck to exterior wall locations and extending vertically up 6 inches.	709A
Near-Home Landscaping	Hazardous vegetation and fuel management required based on different Fire Hazard Severity Zones. Does not explicitly address near-home landscaping.	

Roof

Roofs are highly vulnerable to ignitions due to their relatively large and horizontal surface area. The exposure of roofs to a range of climatic conditions such as wind, rain, and sun means the roof covering will require maintenance and eventually replacement. The roof edge, including gutters and the area where the roof covering meets other materials, can also be vulnerable to ignition from embers. These areas must be properly protected to reduce vulnerability (Fig. 3.2).

Roof Covering

Certified testing facilities conduct a standard fire test to determine the fire rating of the roof covering and other underlying materials in the assembly. This test evaluates the following performance criteria: 1) flame penetration through the roof covering into (what would be) the attic space, 2) flame spread over the surface of the roof covering, and 3) the propensity for the roof covering to become dislodged and generate embers during the course of the fire test (ASTM E108).

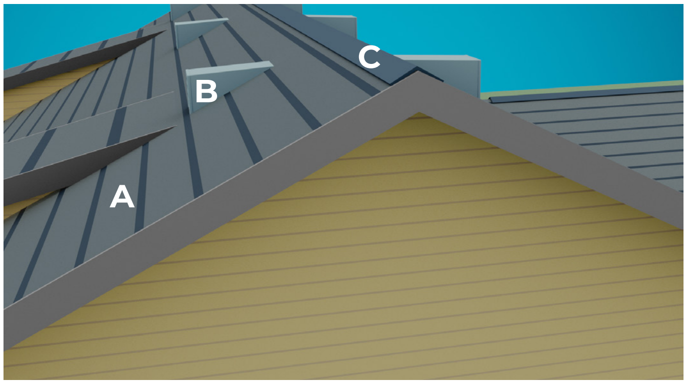


Fig. 3. 2: Roofs are highly vulnerable to wildfires due to the large surface area of the roof covering (A). Roof vents (B, C) circulate air from the inside to outside of the home. During a wildfire, vents provide a potential entry point for embers and flames to enter the attic space.

Roofs are rated as Class A, B, or C based on their response to this test. Class A is the highest rating indicating the highest level of performance. If flame spread is too large, or if fire penetrates through the roof covering and underlying construction material, the covering cannot be considered Class A.[39] Class C is the lowest rate designation. Roofs that do not meet any of the classification requirements are considered unrated. The most common unrated covering material is a non-fire-retardant-treated wood shake or shingle product.

The fire rating of a roof covering can be described as "stand alone" or "by assembly." The fire rating has a "by assembly" rating if an underlying material or special installation technique is required to meet the acceptance criteria associated with the test method. For example, a Class B roof can be rated Class A if an underlying additional fire-resistant material, such as a mineral-surfaced roll roofing product, is used to improve performance. Aluminum roofs can meet Class A requirements if an additional underlying fire-resistant material is used. Although aluminum is considered noncombustible, its relatively low melting point requires incorporation of an additional fire-resistant layer in the assembly to comply with the Class A criteria.

Roof vents are another point of entry for embers and flames into the attic space. Roof vents are important for circulation of air to remove excess moisture from inside the house to outside. Exiting air leaves through vents located on the roof ("ridge vents" or "through-roof vents"), or on the exterior walls ("gable end vents"). Inlet air comes from vents located in the under-eave area at the edge of the roof (see Under-Eave Area section).

Roof Edge

Two vulnerable features of the roof edge can affect the vulnerability of the roof to ignition. These include roof covering profiles where a gap exists between the roof covering and roof sheathing (i.e., the roof deck) and gutters at the roof edge where vegetative debris can accumulate (Fig. 3.3).

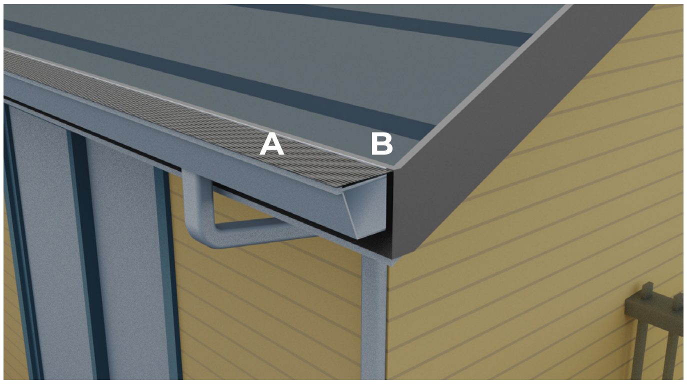


Fig. 3.3: Gutters can collect vegetative debris and ignite by embers during a wildfire. Using a metal (noncombustible) gutter and gutter covers can reduce ignition potential (A). Installing a metal drip edge (B) will also protect the materials at the edge of the roof.

Gaps between the roof edge and the roof sheathing can create opportunities for debris to collect, commonly seen with barrel-shaped tile roof covering. During a wildfire, embers can easily enter the area under the tiles or other roof covering and the roof edge, possibly igniting the debris that has accumulated there.

Gutters can collect vegetative debris (e.g., leaf litter, pine needles, and small twigs). If ignited by embers, these fine fuels expose the edge of the roof to flames. Once debris in a vinyl gutter ignites, the gutter will rapidly melt, detach, and fall to the ground.[40] Alternatively, a metal gutter is noncombustible and will stay in place while allowing the debris to continue to burn at the roof edge.

Under-Eave Area

Eaves, or the overhanging portion of the roof, are either constructed using an open-eave design or enclosed using a soffited-eave design. The former implies an overhang with exposed roof rafters and the latter refers to a boxed-in overhang where the soffit has effectively enclosed the eave. Research suggests eaves are extremely important in structure survivability (Fig. 3.4). One study by Syphard and Keeley (2019) indicated that more than any other home component, enclosed eaves correlated with a reduction in wildfire risk.[41]

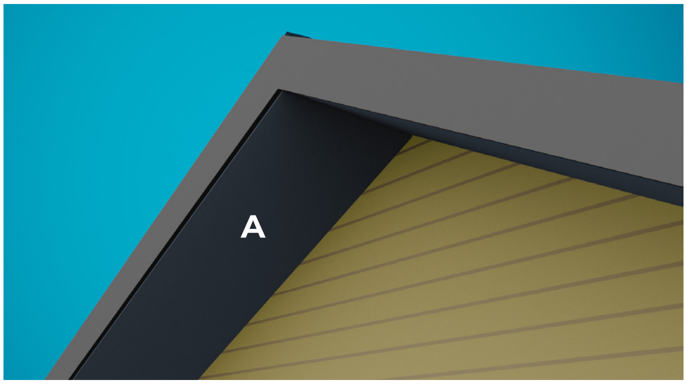


Fig. 3.4: To reduce the vulnerability of eaves, the under-eave area should be enclosed as a soffited eave (A). Chapter 7A requires all vents used in the under-eave area to be flame- and ember-resistant as approved by the California Office of the State Fire Marshal.

Eaves are vulnerable to wildfires when embers enter the attic area through vents and other small openings and, with open-eave construction, when they accumulate in gaps between blocking and joists (Fig. 3.5). Open eaves can also trap heat and spread a fire laterally into adjacent rafter bays. In some situations, narrow overhangs can enhance wildfire resistance by reducing the surface area vulnerable to embers and flame entrapment.[42] Alternatively, a wider overhang can protect a portion of the exterior wall from radiant heat.[43] In either case, an eave

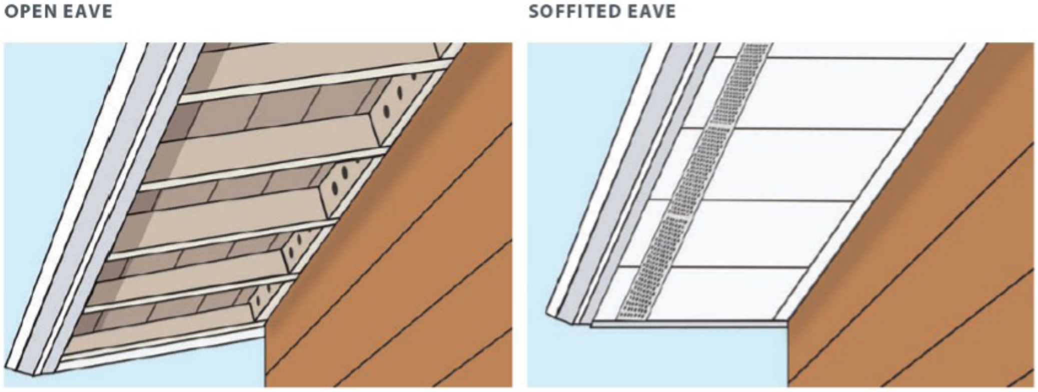


Fig. 3.5: A schematic of open-eave construction (left) and enclosed soffited eave construction (right). (Source: Fig 2(b) Restaino, Kocher, Shaw, Hawks, Murphy, and Quarles. 2020. Univ. of NV Reno Extension SP-20-11.)

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enclosed with a noncombustible soffit material is less vulnerable to flames.[44] Vents in soffited eaves are also less vulnerable to the entry of embers; therefore, enclosed eave design is recommended over open-eave construction.

Vents in the under-eave area are nominal inlet air locations allowing air to enter into the attic space. Under-eave vents are located either:

- In the blocking, in the case of open-eave construction such as frieze block vents, or
- In the soffit material, in the case of soffited-eave construction, often as a "strip vent."

Vents on homes create openings for wind-blown embers. Ember entry through vents can result in ignition of combustible materials in the attic and burning from the inside out.[45] This vulnerability has resulted in the development of commercially available vents designed to resist the intrusion of embers and flame. These vents can be used in new construction or in vents in existing buildings.

Exterior Walls

The exterior wall of a home can be vulnerable to radiant heat, direct flame contact from embers, ignited combustible material that accumulated at the base of the wall, or burning combustible materials located near the home. If combustible siding extends all the way to the ground, it can be ignited directly by embers that accumulate at the base of the wall. Embers can also come from a nearby structure such as a storage shed or a neighboring home. The shape of a home can affect where embers accumulate and influence ignition and fire growth. For example, reentrant corners can result in increased amounts of debris which in turn can increase the potential for ember ignitions. Once ignited, the fire can spread vertically upward on the wall more rapidly. Bay windows can also be more vulnerable when flames impinge on the underside of these bumped-out components.

Chapter 7A distinguishes three different categories of material, including:

- **Noncombustible:** Material that cannot ignite, such as three-coat stucco and metal.
- **Ignition-resistant:** Material that relies on an added treatment to provide a flame spread rating low enough to comply with standard testing methods, such as fire-retardant-treated wood.
- **Combustible:** Material that can ignite, such as solid wood, composite wood products, vinyl, and plastic siding.

Siding

Siding is vulnerable to ignition and flame penetration through lap joints and flame spreading vertically and laterally on the surface, potentially impinging on other wall components such as windows, vents, and the under-eave area (Fig. 3.6).

Research has shown that the siding lap joint is the most vulnerable part of the product. Flame penetration through the siding occurs more readily at less complicated lap joints (an example of which is a plain bevel joint). By contrast, flame penetration was less likely to occur at more complicated siding joints such as a shiplap or tongue-and-groove joint.[46]

Windows and Doors

Doors and windows can be vulnerable to flames or radiant heat when the glass breaks or the door or window frame ignites and fire burns through into the interior of the home. The door can be vulnerable to embers if they accumulate in the area between the door and door frame or door and threshold (at the base of the door). A wood window frame can also be vulnerable to an ember ignition if the outside sill is sufficiently wide.

The heat released by a wildfire or spot fire can break glass because of the temperature difference between the exposed portion of the glass and the glass protected by the framing material. The resulting thermal stresses cause small cracks to develop at the edges and grow inward. Since larger pieces of glass have more edge and therefore more stress cracks, larger windows are more vulnerable to breakage than smaller windows.

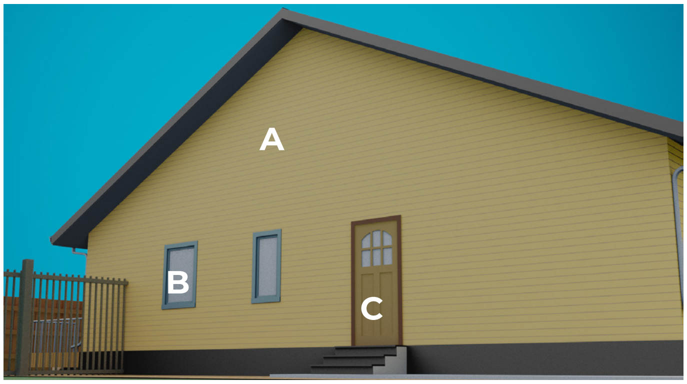

Fig. 3.6: If the exterior wall siding is ignited (A), flames can quickly spread and potentially impinge on the other components of the home, such as windows (B), doors (C), and vents. The glass in windows and doors can break from heat exposure during a wildfire, allowing flames to enter the interior of the home. The lowest six inches of the vertical siding should be constructed with noncombustible material to reduce ignition potential.

There is a wide range of building products and sizes for windows and doors, including different types of glass (annealed, tempered, and laminated) and framing material (e.g., vinyl, wood, aluminum, vinyl- or aluminum-clad wood, and fiberglass). Different combinations of glass, size, and framing material can influence vulnerability of windows to heat. For instance, an insulated glass unit in a vinyl-frame hung window, without reinforcement in the horizontal meeting rails (interlock), can fail at radiant heat exposure lower than that needed to break the glass. In this case, the glass falls out of the frame entirely or creates a gap between the glass and frame, exposing the interior of the home to embers and flames.[47]

Attached Deck and Under-Deck Footprint

The walking surface of decks consists of either a solid surface material such as lightweight concrete or stone, or spaced deck boards. Most solid surface options are made using noncombustible materials. Most spaced deck board options are made using combustible material, such as wood or a plastic composite material, although metal deck boards are now commercially available. In addition to the decking components themselves, combustibles on and under the deck can result in deck ignitions and spread fire to the home.

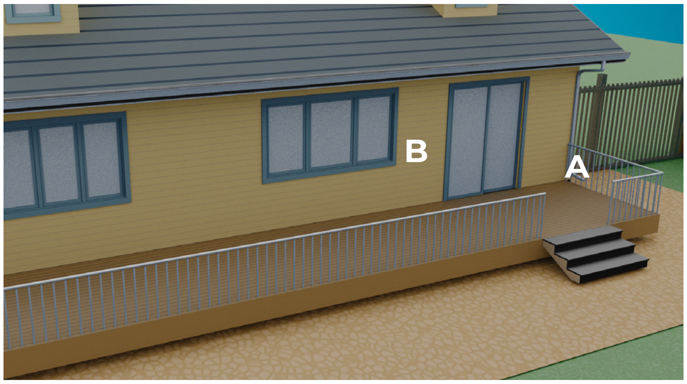

Fig. 3.7: The deck boards (A) as well as what is stored on top, underneath, and around the deck are important considerations in reducing ignition potential. Using noncombustible decking material next to the house and installing metal flashing at the deck-to-wall junction can protect the siding from igniting (B).

Decks can ignite from embers landing on the decking surface as well as from direct flame contact from below (Fig. 3.7). The type of building material used in the deck as well as what is stored on or below the deck can influence its vulnerability to embers and surface fires.

Decks are often constructed with either a single solid surface or with gapped deck boards. If ignited, a deck can threaten the exterior of the home by igniting the siding, with fire possibly spreading vertically into the under-eave area, breaking glass in windows, or exposing doors and other deck-access locations to flames.

Similar to a roof, decks can cover large horizontal surface areas and are therefore highly vulnerable to an ember exposure. Typical home products that are frequently located on top of the deck—such as patio furniture, barbeques with associated lighter fluid and propane tanks, brooms, and door mats—can increase the vulnerability of the deck. Patio furniture cushions, brooms, and door mats can be vulnerable to ignition from embers, as is the deck itself when embers accumulate in the gaps between deck boards. The barbeque grill propane tank would be vulnerable to the flames and radiant heat from these burning items. More important, combustible materials

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stored underneath the deck present a vulnerability. For instance, vegetative debris can easily build up underneath the deck. It is not uncommon to store firewood and other combustible material under the deck, all of which can ignite from burning wind-blown embers that lodge in the materials stored underneath the deck.

Decks can also be open or enclosed underneath. Enclosing a deck can minimize the accumulation of vegetative debris, plants, and combustible materials located underneath the deck. Decks can be enclosed either horizontally by attaching, for example, a sheathing product to the bottom of support joists, or vertically by building a wall or screening around the perimeter of the deck. A horizontal enclosure is not recommended for decks with spaced decking boards. For vertically enclosed decks, using vents to ensure that excessive moisture does not accumulate in the under-deck area is critical to avoid moisture-related degradation (e.g., rotting of the structural support members and corrosion of metal fasteners). Vents used in these areas should be flame- and ember-resistant, similar to roof and under-eave vents.

Near-Home Landscaping

A key component of defensible space is landscaping within 100 feet of the home. This report focuses on the immediate near-home landscaping, also referred to as the “ember-resistant zone,” “noncombustible zone,” and “Zone 0.” This zone nominally includes the area from 0 (i.e., at the house) to five feet from the house (Fig. 3.8). The design and maintenance of materials in this zone are crucial to reducing vulnerability of the home to ignition and, in particular, wind-blown embers and radiant heat exposure from combustibles that would typically be located in this zone.[48]

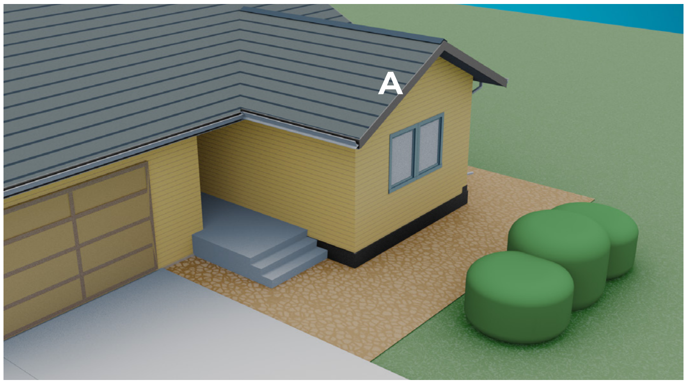


Fig. 3.8: Creating a noncombustible zone within five feet of the home including plants, mulch, trees, and other near-home landscaping materials will reduce exposure to embers, direct flames, and radiant heat (A).

The diverse vulnerabilities of construction materials and designs require a holistic mitigation approach that considers the home in its entirety. While addressing vulnerabilities of each component is critical, mitigation strategies work in unison to reduce overall ignition potential during a wildfire. Mitigating a home should therefore be viewed as a system involving multiple coordinated and maintained efforts.

Further, home and property wildfire mitigation strategies are most effective when every home in the neighborhood participates. One homeowner may incorporate every recommendation to make their house less vulnerable to ignitions, but a neighbor’s inaction can still present a threat to nearby homes. Constructing a wildfire-resistant home will improve the chance of home survival but it is not a guarantee. Complementary mitigation measures such as reducing the continuity of fuels around the home, ensuring broad neighborhood compliance, and continually maintaining the home and property are essential.

Chapter 4
Methodological Approach

This study compared the costs of construction materials for a wildfire-resistant home in northern and southern California. Three different versions of a home were considered:

- Baseline home compliant with the minimum requirements of Building Code Chapter 7A,
- Enhanced home augmenting Chapter 7A requirements with an enclosed under-deck area and noncombustible zone around immediacy of the home (0 to 5 feet); and,
- Optimum home constructed to the most stringent, fire-resistant options (e.g., use of a noncombustible material), or in some cases, a "Code plus" option. Optimum performance levels were selected based on recent research findings and best judgment.

For the purposes of this study, the Optimum home satisfies: a) Chapter 7A compliance and can include additional building materials and design features beyond what is required in the code ("Code plus"); or b) Chapter 7A compliance by preferentially selecting building materials and design features that meet the most restrictive requirements in the code. All three versions of the home comply with Chapter 7A requirements.

Diverse input from the construction industry and California-based subject matter experts was sought in the review and vetting of building materials and the associated product list. Cost comparisons are referenced as absolute figures for individual assemblies and components of the home.

Data Analysis

California is geographically varied in terms of terrain, land cover, and elevation. Housing designs and construction practices similarly reflect regional context including the availability of building materials, market trends, homeowner aesthetic preferences, geographic constraints, and exposure to wildfire-related hazards.

Data analysis for this study involved three primary phases:

- **Selecting building components and materials.** Using geospatial analysis and query, neighborhoods were sampled in the northern and southern region of California. A representative home was selected to inform the type and quantity of building materials commonly used to meet Chapter 7A code compliance and versions of the same home meeting higher wildfire resistance for both northern and southern California.
- **Building material costs.** Comparative cost calculations were based on cost estimates provided by RSMeans, a national database providing detailed construction costs for material, labor, and contractor overhead. A locator multiplier was factored into the analysis to ensure cost estimates best reflected regional markets in northern and southern California. Costs for products not available in RSMeans were procured from local California-based suppliers or the manufacturer directly. Estimated average labor and overhead expenses were acquired from analogous cost indices from RSMeans.

- **Comparative cost calculations.** The costs for constructing a Baseline home complying with Chapter 7A code requirements, an Enhanced wildfire-resistant version of the same home (i.e., primarily addressing the under-deck area and near-home noncombustible zone), and an Optimum wildfire-resistant version meeting the highest wildfire resistance ("Code plus" or noncombustible options for a given component) were analyzed for the northern and southern regions of California.

Due to the different types of building materials, related labor costs, and other construction expenses specific to the northern and southern regions of California, this study provides a cost comparison of a wildfire-resistant home within the same region and not an evaluation of costs between the regions.

Selecting Building Components and Materials

To capture the variability in building materials found in California, representative neighborhoods in both the northern and southern part of the state were considered. Geospatial analysis was used to refine the neighborhood query and one archetype structural diagram was selected to represent a single residential family structure commonly seen in a northern and southern California community. Demarcation of northern California from southern California was defined by relative location to San Francisco, with areas north of San Francisco considered Northern California, and areas south of San Francisco deemed as Southern California. Specific areas used for comparison were in Shasta (northern) and Los Angeles (southern) counties.

Selected neighborhoods were identified as suburban "tract-built" developments located in Local Responsibility Areas and mapped as Very High Fire Hazard Severity Zone by California's Department of Forestry and Fire Protection (CAL FIRE).[49] Satellite imagery was cross-analyzed with the bounds of the LRA/SRA Very High zones to ensure that these communities were located within the hazard zones.

Once a community was located, the number of different floorplans was identified. Three houses of each floorplan were chosen. The chosen houses' addresses were documented and their square footage was determined. This was completed by using the measuring tool on Google Satellite to take the dimensions of the home. If a home was more than one story, the appropriate factor was multiplied to the square footage. For each floorplan within a given community, the mean square footage of the three homes that were measured was calculated. If a community had more than one type of floorplan, the mean square footage of all selected homes of a community was calculated as well. Four communities were located, and their average square footage was calculated.

Selection of a single archetype home was refined by comparing residential site designs with a California-based construction firm and vetted with a stakeholder group. State-based subject matter expertise confirmed footprint structural design features and measurements aligned with a baseline home model typical of California single-family residential construction.

Supplemental interior and exterior details of the home such as square footage, lot size, and home value were found from real estate websites such as Zillow. Final selection of the archetype home was based on the following criteria:

- **Density –** Tract suburban housing with homes situated 30 feet apart or less, implying overlapping home ignition zones and increased risk of home-to-home ignitions due to radiant heat and flame exposure.
- **Property layout –** Rectangular lots, privacy fence, attached garage unit, no accessory buildings.
- **Structural design –** Simple roof shape, back deck, front entryway, single story, no exterior columns (except for deck supports), single car garage.

- **Topography –** Non-sloped terrain, assumes vegetation management.
- **Interior design –** Total living area not to exceed 2,000 square feet, excluding patios.

While neighborhood sampling informed the type of building materials used in a home compliant with Chapter 7A code, working with one representative home provided consistent structural specifications to inform the quantity of building materials used. In other words, the same home footprint detailing structural dimensions, measures, and surface area was used in the analysis for a home in both the northern and southern regions of California.

For this study, a single-family residential home with a total living area of 1,765 square feet and a front and back total deck area of 385 square feet was used. The home is single-level, mid-range value, two-bedroom, with one attached garage, on a slab-on-grade foundation.

Based on the archetype home, a comprehensive list of building materials for the exterior of the structure was catalogued including the roof, walls, deck, and near-home landscaping. Building materials were then delineated as complying with Baseline Chapter 7A requirement, Enhanced wildfire resistance, or Optimum wildfire-resistant standards in either the northern or southern region of California. With the exception of the attached deck and near-home landscaping, the Enhanced wildfire-resistant home includes the same building materials as the Baseline home. Descriptions of mitigation strategies and associated costs therefore often mutually address both the Baseline and Enhanced version of the home. Mitigation and cost comparisons are more broadly referenced between the Baseline/Enhanced home and the Optimum home meeting the most stringent wildfire-resistant measures per options provided in Chapter 7A. Unless specified in the report, redundant building materials used in all versions of the home for both the north and south region were not included in the analysis (e.g., windows, foundation [crawl space] vents, etc.).

This study focused on the exterior building products. 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. Use of steel studs will not contribute to the fire once ignition occurs nor will use of 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 forms, concrete masonry unit (CMU) block walls, and cross-laminated timber. Once the wildfire moves into the occupied space of the home, many combustible materials—such as furniture, walking surfaces and floor coverings, and other interior contents—will contribute to fire growth and ultimate heat release from the home. However, short of defensive actions, these items would not change the ultimate outcome should the home ignite.

Building Material Cost Data

Cost estimates for individual building materials were provided through RSMeans, a national database of construction costs for residential, commercial, and industrial developments. Cost estimates include building material, 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 wages across 21 building trades. The data used in this study was captured and analyzed from the RSMeans database during the summer and fall of 2021. It includes national averages as well as cost indices to compare regional variability across the country.

A locality multiplier within RSMeans was used for building materials in northern and southern California. Applying the location factor provided a more accurate cost estimate based on market values extrapolated from the nearest city. For representative costs for building materials, labor, and other expenses in northern California, the city of Redding was used as the location multiplier. The city of

Los Angeles was used to approximate regional building costs for a home in southern California.

Several important assumptions were made in building material selection and corresponding calculations provided by RSMeans. When RSMeans provided multiple options for building materials, we used mid-range products typical of construction in the northern and southern region of California. In some instances, wildfire-resistant materials were not available in RSMeans. For these cases, we acquired pricing directly from the manufacturer or received bids from California-based retailers or local distributors and added labor, overhead, and profit rates at California location averages using the appropriate cost indices from RSMeans.

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 expertise was provided by Bechtle Architects[50] in Bozeman, MT. Cost estimates were queried by Aiken Cost Consultants[51] in Greenville, SC, and RSMeans.

While using a national database like RSMeans provided consistency for this study, it also had limitations. The values included in the database were averages, and even with the locality multiplier it was difficult to accurately capture market adjustments specific to community conditions. Nuances in supply and demand, contractor availability, managerial efficiency, competition, or local building or union requirements were not included in RSMeans and therefore were not factored into this analysis.

RSMeans did not provide detailed enough information to accurately price differences in costs for the window options needed for this study and analysis. As a result, window cost comparisons are not discussed in the same way as other components. Cost information was obtained from two manufacturers. Chapter 7A does not restrict frame type. One of the prescriptive options is for windows to have tempered glass in one pane of a dual-paned window—location of the tempered glass pane is not specified. Most window manufacturers use this option for compliance. One of the manufacturers indicated that they only supplied windows with both glass panes tempered and that tempered glass was approximately $7 per square foot more expensive than annealed glass. The other manufacturer supplied glass in the multipaned unit as specified in the order (i.e., both panes tempered, inner-pane-only tempered, or outer-pane-only tempered). Both panes tempered cost approximately 15% to 18% more than annealed.

Importantly, recent economic shocks, shortages, and fluctuations in the supply chain and market value of certain products due to the coronavirus pandemic were not reflected in this study. Cost estimates provided by recent RSMeans indices were likely conservative given inflated costs for certain materials such as lumber, shipping and freight fees, and contractor rates.

The monetized values include only the immediate costs of construction and did not account for long-term maintenance and replacement costs of the features. In some cases, wildfire-resistant materials have added benefits such as reduced maintenance, longer lifespan, and energy efficiency.

Comparative Cost Analysis

Data analysis compared the costs for constructing three versions of a wildfire-resistant home: 1) Baseline home compliant with minimum requirements in Chapter 7A in the California Building Code, 2) Enhanced home (deck enclosure and incorporation of a near-home noncombustible zone) providing an improved level of wildfire resistance, and 3) Optimum home built to the most stringent wildfire resistance by use of the most restrictive code options and in some cases, “Code plus” options. Due to California’s diverse homeowner preferences and building materials, analysis was performed for a home located in the northern part of the state as well as a home located in the southern part of the state.

For both the northern and southern California case studies, a home complying with Chapter 7A was used as the Baseline model. The same floor plan was used in all wildfire-resistant versions of the home for both the north and south region. While the floor plan provided consistent home dimensions and structural measurements throughout, building materials and in some cases the associated quantities specific to that building material differ between the Baseline, Enhanced, and Optimum wildfire-resistant homes, and with respect to the northern and southern region of the state.

Building materials were individually priced for the Baseline home and a version of the same home constructed to an Enhanced and Optimum level of wildfire resistance. The Baseline and Enhanced homes are similar with the exception of the latter addressing the under-deck area and near-home noncombustible zone. The Optimum home meets the most stringent and restrictive interpretation of wildfire resistance such as using noncombustible materials over ignition-resistant or combustible materials.

Included in the pricing index was an indication of regional geography and whether the building material was part of the northern or southern California case study. Additionally included in the estimated market value were costs associated with labor and contractor overhead and profit because installation of some wildfire-resistant components and assemblies require more labor. Features not considered vulnerable to wildfire exposures that were equally incorporated in both the northern and southern California Baseline home were not included in the analysis, such as the cost of the foundation and materials used on the interior walls of the home. Landscaping beyond the immediate five-foot perimeter of the home (including the perimeter of the attached deck) was also not included.

Only new home construction costs were analyzed in this report. Details specific to retrofitting existing structures with building materials required by Chapter 7A or to a higher wildfire-resistant level were not determined. Costs related to purchasing building materials for retrofitting can be quantified with RSMeans data, but information does not include costs for demolition, removal, or additional labor needed for retrofitting an existing home.

This report did not analyze the total cost to construct an entire new home. Construction costs using RSMeans and other data sources were calculated for wildfire-resistant building materials and assemblies only. It is therefore not possible to extrapolate precisely what percentage of the total costs for a new home were a result of added wildfire-resistant building materials. However, to estimate the additive cost of wildfire-resistant construction to the cost of an entire home, the Zillow Home Value Index (ZHVI) was used. The ZHVI is a seasonally adjusted measure of typical home values in the 35th to 65th percentile range. Data from May 2022 was used for Los Angeles (to represent southern California) and Redding (to represent northern California).

In southern California, the mean cost of a typical home is between $1,215,000 and $1,395,000. In northern California, the mean cost of a typical home is between $328,000 and $414,000. The total costs for wildfire-resistant building materials for the Baseline, Enhanced, and Optimum home were calculated as a proportional increase to the mean range values for a home in northern and southern California.

Chapter 5
Results

This report shows an increase or decrease in building material costs for constructing: 1) a home compliant with the minimum requirements of Chapter 7A, 2) an enhanced version of the same home addressing the under-deck area and near-home noncombustible zone, and 3) a home meeting an optimal level of wildfire resistance per performance testing and best judgment. This analysis does not reflect a proportional value as related to the entire cost associated with constructing a new home. The assemblies and components included in this report represent a small portion of the total building materials and costs associated with constructing an entire home.

Our analysis indicates that overall, building a home in northern California to enhanced wildfire resistance increased construction costs by $2,770, while building a home for optimal wildfire resistance increased costs by $18,180 compared to building a Baseline home compliant to the state's minimum Chapter 7A building code requirements.

For a home built in southern California, enhanced wildfire-resistant building materials and assemblies increased costs by approximately $2,780, and for optimal wildfire resistance, costs increased by $27,100 over building materials and assemblies used in the Baseline home (Table 5.1).

Differences in building materials and components between the Baseline, Enhanced, and Optimum wildfire-resistant homes are summarized in Table 5.2. With the exception of the attached deck and near-home landscaping, building materials are the same for the Baseline and Enhanced homes. The increase in costs from the Baseline to Enhanced home reflects additional wildfire-resistant measures to the under-deck area and noncombustible area around the Enhanced home. Optimum building materials meet the most stringent wildfire-resistant and noncombustible rating per current testing practices and best judgment.

The importance of a near-home noncombustible zone and its inclusion in both the Enhanced and Optimum wildfire-resistant home has been underscored with recent state legislation. In 2020, California's Assembly Bill No. 3074 was adopted requiring an "ember-resistant" zone (0 to 5 feet from the home) including the area under the footprint of all attached decks. While the resulting legislative language may result in a strict "noncombustible zone," it is possible that certain defined combustible vegetation will be allowed.

Building material costs within individual components of the home varied. For instance, using steel roofing product and associated roof assembly materials for the optimal wildfire resistance option cost approximately $10,200 more than Class A fire-rated asphalt fiberglass composition shingles. Similarly, enclosing open eaves with fiber-cement or stucco material increased building material costs. Landscaping with gravel mulch instead of bark mulch and specifying a metal privacy fence in place of a wooden fence also increased the overall construction costs.

Wildfire-resistant building materials added approximately 2% to 13% to the total cost of a new home. Using recent data from the Zillow Home Value Index, it is estimated that wildfire-resistant building materials for a Baseline and Enhanced home increase total home costs by 2%-8%. For the Optimum home, wildfire-resistant building materials added 4%-13% to total home costs.

It is important to note, however, that many improved wildfire-resistant features when properly installed provide the additional benefits of durability, low-maintenance, and in some cases energy efficiency.[52]

Table 5.1: Cost and proportional difference of assemblies in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

	Northern California			Southern California		
	Baseline	Enhanced	Optimum	Baseline	Enhanced	Optimum
Assembly						
Roof	$7,270	$7,270	$17,720	$7,310	$7,310	$19,670
Under-Eave Area	$1,180	$1,180	$3,180	$1,180	$1,180	$1,900
Exterior Wall	$12,210	$12,210	$12,860	$12,250	$12,250	$15,760
Attached Deck	$3,500	$3,700	$6,010	$4,680	$4,880	$12,590
Near-Home Landscaping	$680	$3,250	$3,250	$690	$3,270	$3,270
Total	**$24,840**	**$27,610**	**$43,020**	**$26,110**	**$28,890**	**$53,190**
Difference from Baseline		$2,770	$18,180		$2,780	$27,080
% Difference from Baseline		11%	73%		11%	104%

Chapter 5

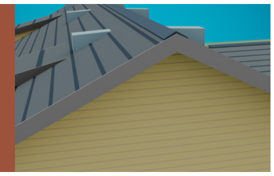
Table 5.2. Building materials and components in the Baseline, Enhanced, and Optimum scenarios.

	BASELINE		ENHANCED		OPTIMUM	
	Northern California	**Southern California**	**Northern California**	**Southern California**	**Northern California**	**Southern California**
Roof						
Fascia	Wood	Wood	Wood	Wood	Fiber-cement	None
Gutter	Vinyl	Vinyl	Vinyl	Vinyl	Metal with metal gutter guards	Metal with metal gutter guards
Roof surface	Asphalt composition shingle	Asphalt composition shingle	Asphalt composition shingle	Asphalt composition shingle	Steel roof panels, metal drip edge	Clay tiles, noncombustible end caps, metal drip edge
Underlayment	None	None	None	None	Synthetic, fire-resistant	Mineral-surfaced roll roofing
Under-Eave Area						
Soffit	Open eaves (no soffit)	Open eaves (no soffit)	Open eaves (no soffit)	Open eaves (no soffit)	Fiber-cement	Stucco
Under-eave vent	Circular metal vents between rafters	Circular metal vents between rafters	Circular metal vents between rafters	Circular metal vents between rafters	Metal strip vents	Metal strip vents
Exterior Walls						
Door	Solid-core birch wood; vinyl-clad wood-framed sliding glass door; fiberglass garage door	Solid-core birch wood; vinyl-clad wood-framed sliding glass door; fiberglass garage door	Solid-core birch wood; vinyl-clad wood-framed sliding glass door; fiberglass garage door	Solid-core birch wood; vinyl-clad wood-framed sliding glass door; fiberglass garage door	Galvanized steel with insulated glass panel; aluminum-framed tempered-insulated-glass sliding door; metal garage door	Galvanized steel with insulated glass panel; aluminum-framed tempered-insulated-glass sliding door; metal garage door
Dryer vent	Plastic, louvered	Plastic, louvered	Plastic, louvered	Plastic, louvered	Metal	Metal
Siding	Wood composite cladding, gypsum wallboard (ending six inches above grade)	Wood composite cladding, gypsum wallboard (ending six inches above grade)	Wood composite cladding, gypsum wallboard (ending six inches above grade)	Wood composite cladding, gypsum wallboard (ending six inches above grade)	Fiber-cement lap siding	Stucco
Trim	Wood composite	Wood composite	Wood composite	Wood composite	Fiber-cement	Stucco
Attached Deck						
Deck surface	Redwood (non-fire-retardant-treated)	Plastic composite, uncapped	Redwood (non-fire-retardant-treated)	Plastic composite, uncapped	Plastic composite, capped; metal grate at deck-to-wall junction	Metal decking; metal grate at deck-to-wall junction
Fascia	Redwood	Plastic composite	Redwood	Plastic composite	Plastic composite, capped	Metal
Railing	Redwood	Plastic composite	Redwood	Plastic composite	Plastic composite	Metal
Structural support system	Preservative-treated wood	Preservative-treated wood	Preservative-treated wood	Preservative-treated wood	Foil-faced bitumen tape on top and sides of supporting joists	Metal
Underdeck area	Not enclosed	Not enclosed	Enclosed with 1/8 inch metal mesh	Enclosed with 1/8 inch metal mesh	Enclosed with 1/8 inch metal mesh	Enclosed with 1/8 inch metal mesh
Near-Home Landscaping						
Fencing and gate	Cedar	Cedar	Metal chain-link	Metal chain-link	Metal chain-link	Metal chain-link
Mulch	Bark mulch	Bark mulch	Pea gravel and landscaping fabric	Pea gravel and landscaping fabric	Pea gravel and landscaping fabric	Pea gravel and landscaping fabric

Chapter 5

Roof Mitigation and Costs

The peak of the roof ridgeline to the edge of the roof including roof covering and underlayment, roof edge (fascia), vents, gutters, and drip edge.



Mitigation

Chapter 7A Code Compliance

The most current version of Chapter 7A requires all new roof coverings, regardless of Fire Hazard Severity Zone, to have a Class A fire rating. Wood shakes and shingles treated with a fire retardant are permissible if they pass the fire test used to establish the fire rating after being subjected to a natural weathering exposure protocol approved by the Office of the State Fire Marshal. These installations must include an additional fire-resistant material to obtain the required Class A fire rating. However, local jurisdictions (like Los Angeles County[53]) may have adopted additional code measures prohibiting the use of fire-retardant wood shakes and shingles. Many jurisdictions throughout the state do not allow any new installations of fire-retardant treated shakes or shingles used as a roof covering.

Depending on the roof covering, an additional fire-resistant material used as an underlayment may be needed to attain a Class A fire rating. At roof-to-wall junctions, like dormers and other intersections with exposed siding, an underlayment can increase the resistance of the siding to the penetration of flames.

Mitigating vulnerabilities at the roof edge can be addressed through the use of a "bird-stop" material at the edge and ridge(s), use of a gutter cover device on gutters, and use of metal flashing where the gutter meets the roof (commonly referred to as a "drip edge"). Both bird-stop and gutter cover devices are required by Chapter 7A. A bird-stop is attained by installing a noncombustible material to plug gaps between roof coverings and the roof deck (e.g., barrel tile and some metal roof coverings) to minimize the accumulation of debris and flammable material. During a wildfire, bird-stops will also minimize the entry of embers.

Similarly, installing gutter cover devices will reduce the amount of vegetative debris (e.g., needle and leaf litter) that can be easily ignited by embers. If fascia is being used, a noncombustible or fire-resistant material will reduce ignition vulnerability to the roof and eaves. Chapter 7A does not restrict the type of material for gutters, allowing for both plastic (typically vinyl) and metal. The most effective mitigation strategy for gutters is ensuring they are clear of vegetative debris.

In 2021, Chapter 7A prohibited the use of all vents except those approved by the Office of the State Fire Marshal as resistant to flame and ember intrusion. This directive applies to all vents including roof, under-eave, and foundation (crawl space).

Optimal Wildfire Resistance

Because of the typical one- to two-inch clearance between the roof covering and start of siding, use of metal flashing at roof-to-wall intersections will reduce the vulnerability of the siding to ignition from embers. Installing noncombustible siding at roof-to-wall intersections also improves resistance to ignition from embers that can accumulate at these locations. Installing metal flashing at these locations improves wildfire resistance but is not required in Chapter 7A. Where roof design results in the creation of a valley, and where a metal flashing material is used in the valley, Chapter 7A requires that an underlying mineral-surfaced cap sheet be installed under the metal flashing. When asphalt composition fiberglass shingles are installed, use of metal flashing can be avoided by interweaving the shingles in the valley.

Additional features such as noncombustible gutters and gutter covers can reduce ignition potential of the (usually combustible) components at the roof edge. Installing a metal drip edge will also protect the materials at the edge of the roof, and with a soffited eave will minimize ember entry into the attic space by covering the fascia-to-sheathing gap that can occur.

New Construction Cost Comparison

For the home in northern California, using optimal wildfire-resistant materials for the roof covering (including surface material and underlayment) and roof edge (including fascia, gutters, gutter guards, and drip edge) cost approximately $10,450 more than the Class A asphalt composition shingle roof covering selected for the Baseline/Enhanced homes. Constructing an Optimum wildfire-resistant home in the south added approximately $12,360 compared to the Baseline/Enhanced homes.

Because of its large surface area, the roofing material is the most expensive feature of the roof. For the Baseline/Enhanced homes, roof coverings were assumed to be Class A fire-rated asphalt fiberglass composition shingles, a very popular and commonly used material across the state. However, for the Optimum home, differences in homeowner preferences are reflected in the types of building materials used in the northern and southern regions. For instance, a standing seam steel roof was selected for the Optimum home in the north and clay barrel-style tiles were selected as the roof covering for the Optimum home in the south. Ridge vents were not considered in the Baseline, Enhanced, or Optimum homes because the ASTM standard test method used to evaluate performance of vents technically does not apply to vents in this location.

For the home in northern California, the use of standing seam steel roofing panels in the Optimum home increased costs by $7,840 in comparison to using Class A asphalt shingles in the Baseline/Enhanced homes. No underlayment materials were assumed for the Baseline/Enhanced homes with an asphalt composition shingle roof covering. A fire-resistant underlayment and a synthetic underlayment were applied underneath the standing seam steel roofing panels for the Optimum home, increasing the costs by $2,400. Because through-roof metal vents and metal flashing were used in the Baseline, Enhanced, and Optimum homes, they were not included in the cost analysis.

Additional expenses for Optimum wildfire-resistant roofing materials for the home in northern California included fiber-cement fascia, metal drip edge, metal gutters, and metal mesh gutter guards. For the Baseline/Enhanced homes, wooden fascia, vinyl gutters, and vinyl gutter guards were selected; no drip edge was specified. Selecting fiber-cement fascia instead of wood fascia decreased costs by $110, while specifying an all-metal gutter system added approximately $320. In total, roof covering and assemblies for an Optimum wildfire-resistant home in northern California cost $10,450 more than the Class A asphalt composition shingle roof covering on the Baseline/Enhanced homes.

For the Optimum wildfire-resistant home in southern California, barrel-style tiles were more expensive than the Class A asphalt composition shingle roof covering used in the Baseline/Enhanced homes. When installing barrel-style tiles instead of traditional asphalt composition shingles, noncombustible end caps ("bird-stops") are required at the edge of the roof and other locations (e.g., at the ridge) where there is a gap between the tile and roof sheathing. Barrel-style tiles, noncombustible end caps, and mineral-surfaced roll roofing added $12,870 to the roof cost.

For the roof edge of the Optimum home in the south, a metal drip edge, metal gutters, and metal gutter guards were selected, adding approximately $310 to the overall costs. In contrast to the Baseline/Enhanced homes, no fascia was assumed in the Optimum home in the south, resulting in a savings of approximately $820. In total, constructing an Optimum wildfire-resistant barrel-style tile roof in southern California cost approximately $12,870 more than a Class A asphalt composition shingled roof.

Table 5.2: Cost and proportional difference of roofing assembly in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

Roof							
		Northern California			**Southern California**		
Component	**Material**	**Baseline**	**Enhanced**	**Optimum**	**Baseline**	**Enhanced**	**Optimum**
Fascia	Fiber-cement			$710			
	Wood	$820	$820		$820	$820	
Gutter	Gutter guard: aluminum mesh			$310			$310
	Gutter guard: vinyl	$180	$180		$190	$190	
	Gutter: metal			$600			$600
	Gutter: vinyl	$580	$580		$580	$580	
	Metal drip edge			$170			$170
Roof Surface	Asphalt shingles, Architectural	$5,690	$5,690		$5,720	$5,720	
	Cap roll roofing						$1,210
	Clay tiles						$15,040
	Noncombustible end cap (i.e. bird stopping)						$2,340
	Steel Roofing Panels			$13,530			
Underlayment	Fire-resistant underlayment			$1,770			
	Synthetic underlayment			$630			
Total		**$7,270**	**$7,270**	**$17,720**	**$7,310**	**$7,310**	**$19,670**
Difference from Baseline			$0	$10,450		$0	$12,360
% Difference from Baseline			0%	144%		0%	169%

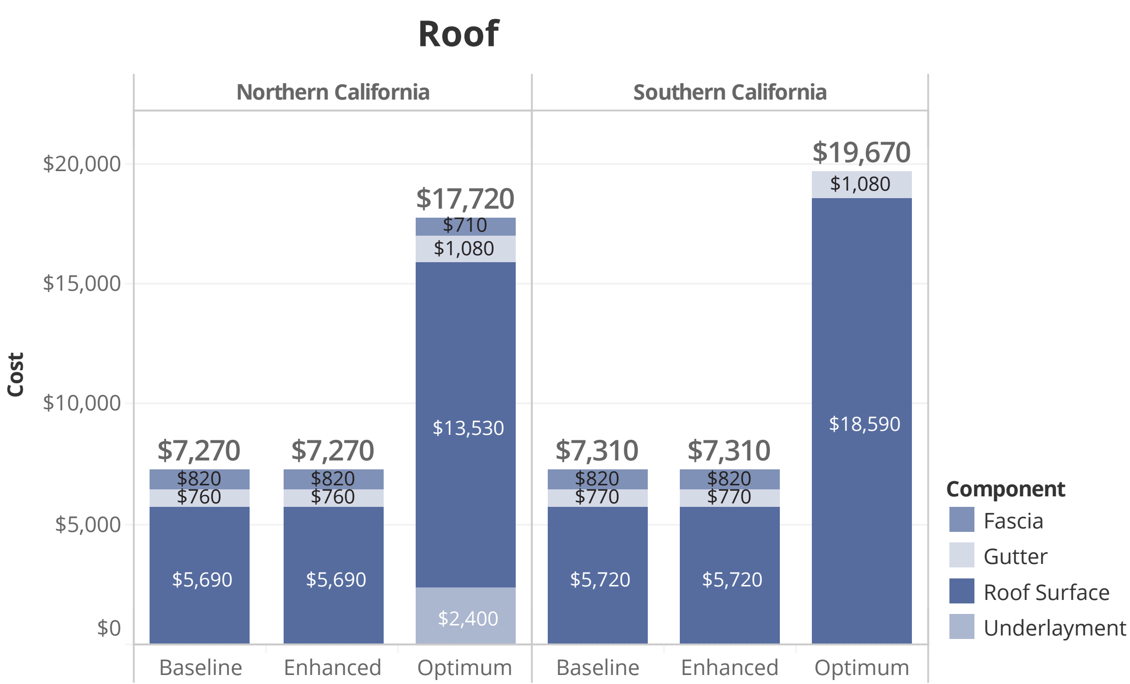
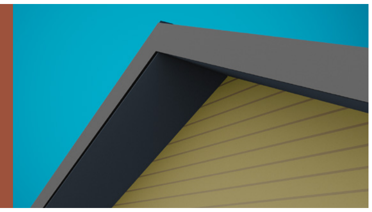


Fig. 5.1: Roofing assembly costs for Baseline, Enhanced, and Optimum homes in northern and southern California.

Under-Eave Area Mitigation and Costs

The lower portion of a sloping roof assembly that projects beyond and overhangs an exterior wall. Roof eaves may be either open or enclosed (soffited) and include vents to allow airflow.



Mitigation

Chapter 7A Code Compliance

Chapter 7A allows for both open and enclosed (soffited) eaves. For the former, the exposed roof decking is required to be constructed with ignition-resistant materials or noncombustible materials or must pass a 10-minute direct flame exposure test. Alternatively, a 5/8-inch Type X gypsum wallboard, or the exterior portion of a one-hour fire-rated assembly can be installed. Nominal 2x lumber can be used for blocking and rafters. The implication of these requirements is that the construction in the roof overhang (under-eave) area will be different than the typical wood-based sheathing (e.g., plywood or oriented strand board) used on the balance of the roof deck. There are several ways to address the under-eave material issue, all of which result in an increased cost of construction for the open-eave area compared to a non-Chapter 7A-compliant home. In non-Chapter 7A-compliant homes, for aesthetic reasons, the sheathing in the exposed under-eave area is often a higher grade of plywood (e.g., ACX instead of CDX). This report did not evaluate the cost of these potential differences.

If an enclosed, soffited eave design is used, the material must either be a noncombustible or ignition-resistant material or the assembly must pass the SFM standard test for the soffit.

Chapter 7A requires all ventilation openings to be flame- and ember-resistant according to procedures set forth in an ASTM standard test method. As of July 2021, finer mesh screens covering vent openings are not allowed as a means of compliance. Only vents reviewed and approved by the California Office of the State Fire Marshal can be installed. At the time of adoption, approved vents included Vulcan, Brandguard, and Embers Out.

One option to eliminate venting vulnerabilities is to install an unvented attic. Although removing vents eliminates the opportunity for ember entry, an unvented attic design can result in moisture-related performance issues if improperly installed.[54] An unvented attic design was not included in this evaluation.

Optimal Wildfire Resistance

To reduce the vulnerability of eaves, the under-eave area should be enclosed as a soffited eave. The authors of this report consider a soffit eave to be less vulnerable to flames and embers and therefore the preferable option.

New Construction Cost Comparison

For the Baseline/Enhanced homes in the northern and southern regions, open-eave design with circular noncombustible (metal) cut-outs in between rafter blockings were assumed. SFM-approved flame- and ember-resistant vents were selected in the circular openings.

For the Optimum home in northern California, an enclosed soffited eave design using a fiber-cement material was assumed. Flame- and ember-resistant metal strip vents were selected. The fiber-cement soffit covering cost approximately $2,570 more than an open-eave construction design. Using flame- and ember-resistant strip vents instead of flame- and ember-resistant circular vents saved approximately $570. In total, Optimum under-eave construction added approximately $2,000 to open-eave construction.

For the Optimum home in southern California, the soffit covering included a three-coat stucco application and flame- and ember-resistant metal strip vents. The enclosed eave design with stucco and vents added approximately $720 to the cost of the open-eave design used in the Baseline/Enhanced homes.

Table 5.3: Cost and proportional difference of under-eave assembly in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

Under-Eave Area							
		Northern California			**Southern California**		
Component	**Material**	**Baseline**	**Enhanced**	**Optimum**	**Baseline**	**Enhanced**	**Optimum**
Soffit covering	Fiber-cement			$2,570			
	Stucco (3-coat)						$1,290
Under-eave vents	Open eave: circular metal flame- and ember-resistant vent	$1,180	$1,180		$1,180	$1,180	
	Soffited eave: metal flame- and ember-resistant strip vent			$610			$610
Total		**$1,180**	**$1,180**	**$3,180**	**$1,180**	**$1,180**	**$1,900**
Difference from Baseline			$0	$2,000		$0	$720
% Difference from Baseline			0%	169%		0%	61%

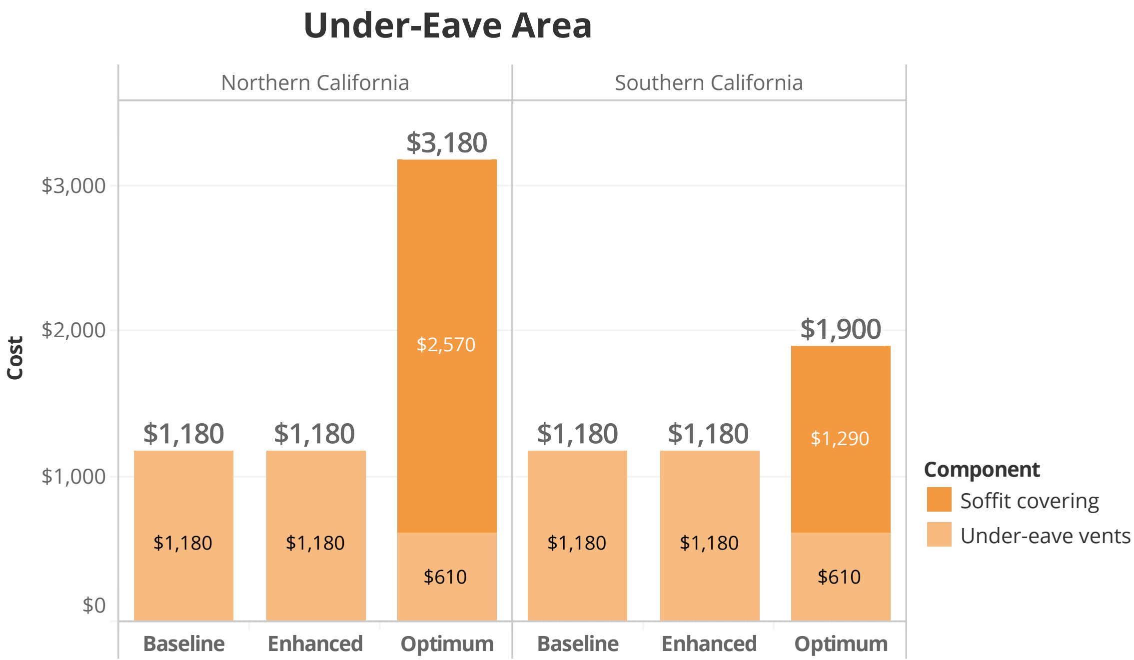


Fig. 5.2: Under-eave assembly costs for Baseline, Enhanced, and Optimum homes in northern and southern California.

Exterior Wall Mitigation and Costs

Siding, trim, windows, and doors on the exterior walls.

Mitigation

Chapter 7A Code Compliance

Several options for exterior wall covering or wall assemblies comply with Chapter 7A:

- Noncombustible
- Ignition-resistant
- Heavy timber construction or log wall assembly
- The exterior portion of a one-hour fire resistive wall assembly
- Wall assemblies complying with the Office of the State Fire Marshal (SFM) 12-7A-1 for Exterior Wall Siding and Sheathing (ASTM E2707) for a 10-minute direct flame contact exposure test

Materials and assemblies considered noncombustible and ignition-resistant are determined in accordance with SFM Standard 12-7A-5 and the acceptance criteria provided in Section 704A.3 (Ignition-Resistant Material).

The use of heavy timber construction or log wall assembly is a prescriptive option. If the siding is made from timbers that are large enough to comply with the definition of "heavy timber," then that siding complies. Similarly, round logs used in a log home also comply prescriptively.

Alternative materials and assemblies that pass SFM 12-7A-1 standard testing methods also comply with Chapter 7A— for example, combustible siding products such as untreated wood lap and panelized siding, vinyl, or other plastic or wood-plastic composite product. The SFM exterior wall test evaluates the ability of the siding product (and assembly) to resist the penetration of a flame into the stud cavity but not vertical flame spread on the wall. Similarly, the exterior portion of a one-hour wall assembly can be used.

Using structural sheathing such as plywood or oriented strand board can add another layer of protection and reduce flame penetration into the stud cavity. Sheathing can be installed underneath the siding in the siding assembly to comply with Chapter 7A and is commonly found across California.

The type of glass used in a window or exterior door can also be a critical determinant of ignition vulnerability. While not addressing window framing, Chapter 7A requires the glass in windows to meet one of the following requirements:

- Multipaned glazing with a minimum of one tempered pane (can be either the inner or outer pane),
- Glass block units,
- Fire-resistance rating of not less than 20 minutes, or
- Meeting performance requirements of SFM 12-7A-2.

Studies have shown that tempered glass is three to four times more resistant to a radiant heat exposure than annealed glass.[55] Currently, the building code requires tempered glass for windows in or immediately adjacent to doors, and in windows that are 18 inches or less from a floor. In specifically addressing new development in wildfire severity zones, Chapter 7A extends this requirement to all other windows in the home.

A fire-resistant rating for a glass window requires testing in a vertical furnace following a specified time-temperature regime. This test results in a largely radiant exposure. After 20 minutes, the exposure temperature is about 1,300 degrees F.

Glass materials that pass the SFM standard test for fire penetration (SFM 12-7A-2) comply with Chapter 7A. During this test, a window is subjected to a flame impingement exposure. For the window to comply, the window or framing material cannot allow any fire penetration.

For exterior doors, Chapter 7A requires compliance in one of the following ways:

- Noncombustible or ignition-resistant exterior surface or siding,
- Solid-core wood meeting thickness specifications,
- Fire-resistance rating of not less than 20 minutes, or
- Meeting the performance requirements of SFM Standard 12-7A-1.

To meet compliance under the solid-core wood definition, the stiles and rails of the exterior door must be no less than 1 3/8 inches and the door panels must not be less than 1 1/4 inches thick (Section 708.A.3). Exterior doors can also meet fire-resistance ratings in accordance with National Fire Protection Association (NFPA) 252 or meet performance criteria required in SFM Standard 12-7A-1 (ASTM E2707).

For exterior garage doors, Chapter 7A requires weather stripping to resist the intrusion of embers from entering through gaps between doors and door openings when visible gaps exceed 1/8 inch (Section 708A.3.1). Weather stripping or seals have to be installed on the bottom, sides, and tops of doors to reduce gaps between doors and door openings to 1/8 inch or less.

Optimal Wildfire Resistance

For optimal wildfire-resistant construction, noncombustible materials are recommended. This is particularly important at the base of the exterior wall and the first vertical six inches. A six-inch vertical noncombustible zone is crucial because even if noncombustible siding is used, combustible sheathing, still commonly used behind the siding, can extend over the foundation where it is exposed and vulnerable to ignition from embers and flames from ember-ignited vegetative debris that can accumulate at the base of the wall.[56]

Installing two panes of tempered glass in windows reduces their vulnerability to radiant heat during a wildfire. In California, most windows available on the market include tempered glass in both panes. Metal-clad wood-framed windows are less susceptible than vinyl frames to damage from radiant heat. The horizontal interlock member in a vinyl-framed single- or double-hung window can be vulnerable to radiant heat or direct flame contact if a reinforcement member isn't included. Aluminum or other metal window screens can help protect against ember entry if the glass breaks or if a window is inadvertently left open. When home-to-home spacing is less than 30 feet, metal shutters can provide additional protection from radiant heat exposures.

Using fire-resistant exterior and garage doors such as steel or aluminum can reduce vulnerability to ignition. Weather stripping around pedestrian and vehicle access doors can reduce the ability of embers to pass through openings between door and jamb but can also be vulnerable if embers accumulate against it and cause it to ignite or melt. The location of weather stripping on outswing doors is more vulnerable than inswing doors. Weather stripping containing fire retardants can reduce the vulnerability of this component.

Beyond building materials and assembly, mitigation strategies for exterior walls include creation and maintenance of an effective defensible space to reduce the chance of extended radiant heat or flame contact exposure to the siding, including creation of a zero- to five-foot noncombustible zone.

New Construction Cost Comparison

For the Baseline/Enhanced homes in northern California, siding and trim assumed a wood composite siding (and associated trim product). Based on installation instruction from the manufacturer, gypsum wallboard was included underneath the siding as a fire-resistant layer. For enhanced wildfire resistance, ending the siding six inches above the grade results in a vertical noncombustible zone. A plastic louvered dryer vent was assumed on the exterior of the Baseline/Enhanced homes. Foundation (crawl space) vents for all versions of the home—Baseline, Enhanced, and Optimum wildfire-resistant homes in northern and southern California—were OSFM-approved and listed as flame- and ember-resistant.

For an Optimum home in the north, siding and trim were fiber-cement lap siding with a wood-grain texture. For the Optimum home in the south, siding was a three-coat stucco application over a wire mesh on wood frame and sheathing system (although, as previously stated, the cost of the framing system was not part of this analysis). The dryer vent on the exterior of the Optimum home in both regions was noncombustible galvanized metal. For the home in northern California, optimal exterior wall components including the siding, trim, and dryer vent cost approximately $1,240 more than the exterior wall features used in the Baseline/Enhanced homes.

The Baseline/Enhanced homes in southern California also had a wood composite siding and accompanying trim. A gypsum wallboard and plastic louvered dryer vent was assumed on the exterior of the Baseline/Enhanced homes in southern California. By contrast, the Optimum home in the south had exterior walls of three-coat stucco. As noted above, all versions of the home included an OSFM-approved and listed flame- and ember-resistant foundation (crawl space) vent. Using stucco instead of wood composite siding and a noncombustible dryer vent added approximately $4,110 to the cost of the exterior walls for an Optimum wildfire-resistant home in southern California.

As noted in Chapter 4, price differences in costs for window options between Baseline, Enhanced, and Optimum wildfire resistance were not included in this report due to manufacturing preferences in California. Most windows on the market in California come with both panes tempered and meet recommendations for wildfire resistance. While tempered glass will be more expensive than annealed glass, cost comparisons are not included here.

For the Baseline/Enhanced homes in northern and southern California, exterior pedestrian doors on the side of the home and front entrance were solid-core birch wood. The back sliding door onto the patio was a vinyl-clad wood-framed glass door, and the garage door was standard fiberglass.

The front and side pedestrian doors for the Optimum home in the north and south were prehung galvanized steel with an insulated glass panel. The patio sliding door was aluminum and contained tempered insulated glass, and the garage door was fire-resistant metal. Optimal wildfire-resistant doors and assemblies cost approximately $590 less than the pedestrian and garage doors used in the Baseline/ Enhanced homes.

Overall, building exterior walls to Optimum wildfire-resistance—including siding, dryer vents, trim, and doors—increased construction costs by approximately $650 over the Baseline/Enhanced homes in northern California. Exterior wall construction costs for the Optimum home in southern California increased costs by approximately $3,510 over the Baseline/Enhanced homes.

Table 5.4: Cost and proportional difference of exterior wall assembly in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

Exterior Wall							
		Northern California			Southern California		
Component	**Material**	**Baseline**	**Enhanced**	**Optimum**	**Baseline**	**Enhanced**	**Optimum**
Doors	Garage door	$2,360	$2,360	$1,070	$2,380	$2,380	$1,080
	Pedestrian doors	$3,160	$3,160	$3,860	$3,190	$3,190	$3,890
Dryer vent	Metal			$60			$60
	Vinyl	$40	$40		$40	$40	
Siding	Fiber-cement			$6,900			
	Gypsum wallboard	$1,200	$1,200		$1,200	$1,200	
	Stucco (3-coat)						$10,730
	Wood composite cladding	$4,690	$4,690		$4,680	$4,680	
Trim	Fiber-cement			$970			
	Wood composite cladding	$760	$760		$760	$760	
Total		**$12,210**	**$12,210**	**$12,860**	**$12,250**	**$12,250**	**$15,760**
Difference from Baseline			$0	$650		$0	$3,510
% Difference from Baseline			0%	5%		0%	29%

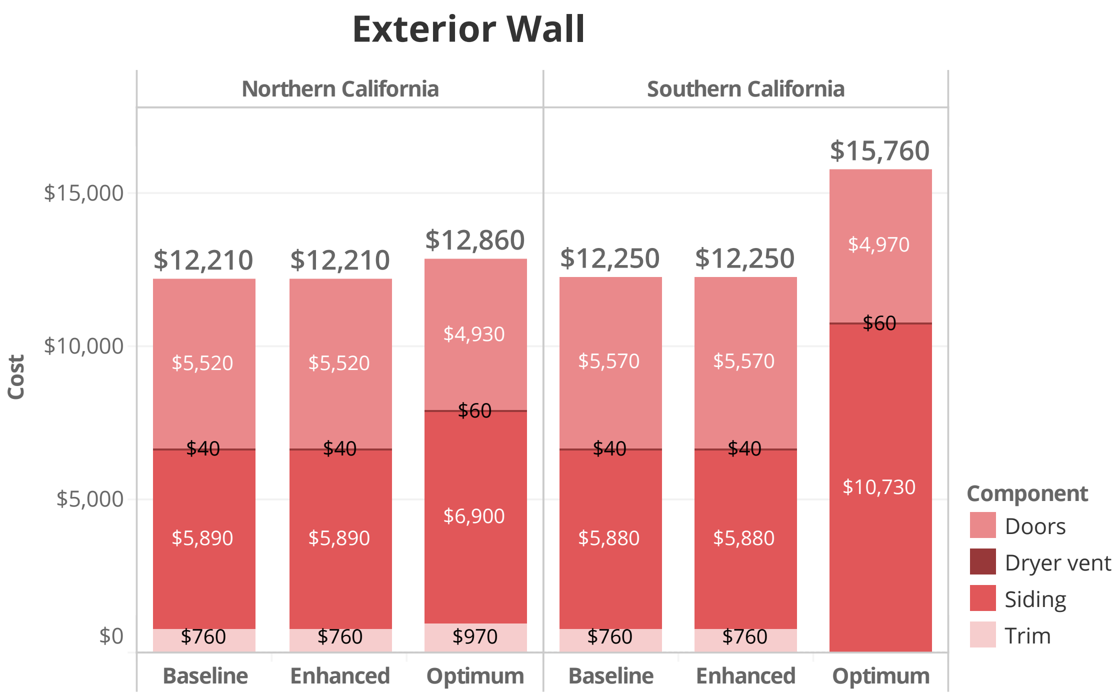
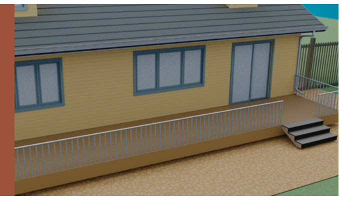


Fig. 5.3: Exterior wall assembly costs for Baseline, Enhanced, and Optimum homes in northern and southern California.

Chapter 5

Attached Deck Mitigation and Costs

Horizontal surface area of the deck and under-the-deck footprint, including walking surface, framing, and rails.



Mitigation

Chapter 7A Code Compliance

Chapter 7A restricts the use of combustible decking products based on the heat release rate, which is the amount of energy released after the deck is ignited by an under-deck flame from a gas burner. The code only considers the decking surface and not the structural support system.

There are three options for a decking material to comply with Chapter 7A. The most restrictive requires compliance with standard testing methods within Parts A and B in SFM 12-7A-4 (ASTM 2632 and ASTM E2626). Part A is an under-deck flame impingement exposure test and Part B is an exposure from a burning brand (wood crib) placed on top of the deck surface. The deck boards must also meet the criteria to be classified as ignition-resistant material. Although products can use this pathway for compliance, a less restrictive path is available. This less restrictive path is used by all decking products that cannot meet the requirements for being classified as an ignition-resistant material. This less restrictive pathway is used by all of the commonly used wood and plastic composite deck board products.

Other options for decking material compliant with Chapter 7A include heavy timber, fire-retardant-treated lumber, or an approved noncombustible material. "Heavy timber" is defined as decking boards that are a minimum of three inches thick.

The most common option for compliance is the least restrictive method. Under this provision, a decking material only needs to meet the minimum heat release rate as stipulated by SFM (SFM 12-7A-4, Part A). Decking that complies with this option must consider the flame spread index, which is classified as either Class A (the best rating), Class B, or Class C. Class C decking materials require adjacent siding to be rated as either noncombustible or ignition-resistant. The burning brand exposure test included in Part B of SFM 12-7A-4 is not required.

Higher-density deck board products, including plastic composites and the tropical hardwood products such as ipe, 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.[57]

In July 2021, Chapter 7A was amended to require a minimum of a six-inch metal flashing to be applied vertically on the exterior of the wall at all deck-to-wall intersections. The required metal flashing provides a six-inch noncombustible vertical surface and reduces ignition exposure from embers and debris that can accumulate at the deck-to-wall junctions.

Enhanced wildfire resistance measures address the under-deck area to minimize ignition potential from embers igniting combustible materials located below the decking surface such as accumulated vegetative debris, plants, and other combustible materials. Using a metal mesh screen with openings 1/8 inch or less will minimize the size of embers and amount of debris that enter the under-deck area.

Optimal Wildfire Resistance

Optimal wildfire mitigation measures of the attached deck and under-deck footprint consider building materials and design together with the presence of combustible materials on top and underneath the deck.

Use of a foil-faced bitumen product, applied to the top surface of the support joists, has been shown to reduce the vulnerability of combustible decking products to ember exposures, particularly the non-fire-retardant-treated, medium-density, solid wood products such as redwood and cedar. The tape should extend about halfway down the side of the joist. The tape is not a mitigation strategy for under-deck flames.

Other optimal mitigation strategies for decks include increasing the gap between deck boards (e.g., from 1/8 inch to 1/4 inch) and increasing between-joist spacing from 16-inch on-center to 24-inch on-center. Structural and safety requirements should be confirmed before changing deck board or joist spacing. In addition, noncombustible deck boards can be used as the walking surface. If an existing deck already has a wood walking surface, a more affordable mitigation strategy would be to remove a near-home deck board and replace it with a noncombustible option. This strategy is easier to implement if the deck boards are parallel to the house.

To minimize the potential for a flame contact exposure to the underside of the deck, the near-home noncombustible zone should extend under the entire footprint of the attached deck (see "near-home landscaping"). When a home is located on a slope and an attached deck extends out over that slope, vegetation should be selected, planted, and maintained in such a way as to reduce the opportunity for flames to impinge on the underside of the deck.

Enclosing the deck with a metal mesh screen with 1/8-inch openings can reduce the vulnerability of decks by minimizing embers entering the under-deck area and igniting combustible material. Enclosing a deck with non-mesh materials such as fiber-cement can reduce the vulnerability of decks to wildfire but caution should be used with certain enclosure techniques that can result in water-related degradation of the deck (e.g., fungal decay and insect damage). Such enclosure techniques restrict the ability of wet deck boards and framing members to dry out and can also result in corroded fasteners.

New Construction Cost Comparison

For the Baseline and Enhanced homes located in northern California, the attached horizontal decking surface was non-fire-retardant-treated redwood. The structural support for the deck was framed with 2-by-10-inch preservative-treated lumber. The decking fascia including the rails and trim were also made of redwood.

The Enhanced home in northern California also had a 1/8-inch metal mesh screen enclosing the under-deck area. Applying a metal mesh screen added $200 to the costs for constructing an Enhanced wildfire-resistant home in northern California.

The decking used in the Optimum home in the north was a plastic composite, wood-grained, capped product. The horizontal deck board at the deck-to-wall junction was replaced with a metal grate to create a narrow noncombustible zone at the base of the exterior siding. Foil-faced bitumen tape for the top and sides of the joist supporting the deck was used. The fascia was plastic composite capped boards and the railing was also plastic composite decking board. The deck was enclosed with 1/8-inch metal mesh screening to minimize ember intrusion to the under-deck area. Using plastic composite capped decking (for the surface, fascia, and railing), a metal grate decking board, foil-faced bitumen tape on the joists, and a metal mesh screen cost approximately $2,510 more than a redwood deck in northern California.

For the Baseline and Enhanced homes in southern California, the attached horizontal decking surface was a plastic uncapped composite (wood-grain textured) decking material framed with 2-by-10-inch preservative-treated lumber. The fascia and railings were similarly assumed to be plastic composite decking board. For the Enhanced home, the deck was also enclosed with 1/8-inch metal mesh screen which added $200 to the overall decking costs.

Metal decking including horizontal surface and rails were assumed for the Optimum home in southern California. A steel grate was selected at the deck-to-wall junction and a metal structural support system, including the framing and posts, was used. A metal mesh screen with 1/8-inch openings was used to enclose the under-deck area. An attached metal deck increased construction costs by $7,910 over a deck built with plastic composite boards, framing, fascia, and rails.

Table 5.5: Cost and proportional difference of deck assembly in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

Attached Deck							
		Northern California			**Southern California**		
Component	**Material**	**Baseline**	**Enhanced**	**Optimum**	**Baseline**	**Enhanced**	**Optimum**
Decking Surface	Composite capped, metal grate			$3,250			$1,180
	Metal decking						$2,190
	Plastic composite decking				$1,370	$1,370	
	Redwood (not fire-retardant-treated)	$1,310	$1,310				
Enclosed Underdeck	Metal		$200	$200		$200	$200
Fascia	Composite capped			$650			
	Plastic composite				$460	$460	
	Redwood	$1,220	$1,220				
Railing	Metal			$620			$620
	Plastic composite				$2,080	$2,080	
	Redwood	$210	$210				
Structural Support System	Foil-faced bitumen tape for joist top and sides			$530			
	Pressure-treated lumber structural support	$640	$640	$640	$650	$650	
	Steel horizontal framing						$5,780
	Steel vertical column						$2,620
	Wood vertical column	$120	$120	$120	$120	$120	
Total		**$3,500**	**$3,700**	**$6,010**	**$4,680**	**$4,880**	**$12,590**
Difference from Baseline			$200	$2,510		$200	$7,910
% Difference from Baseline			6%	72%		4%	169%

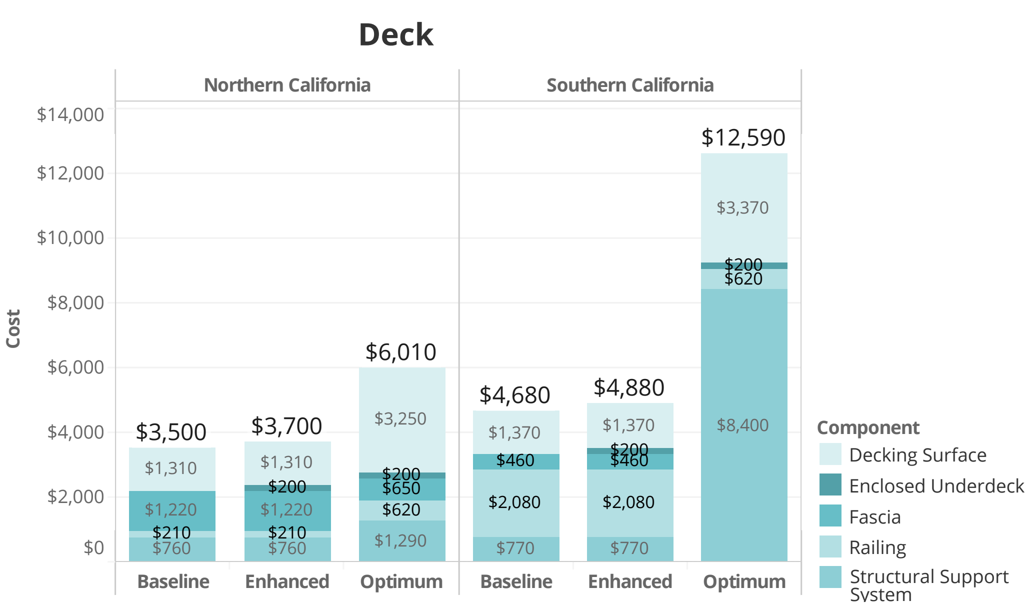
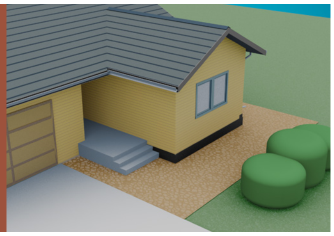


Fig. 5.4: Deck assembly costs for Baseline, Enhanced, and Optimum homes in northern and southern California.

Near-Home Landscaping Mitigation and Costs

A "noncombustible zone" within five feet of the home including the mulch, landscaping fabric, and privacy fence.



Mitigation

Chapter 7A Code Compliance

Chapter 7A references Public Resources Code (PRC) 4291 and an appropriate government code for defensible space requirements for a given property. PRC 4291 divides a property into two zones (0-30 and 30-100 ft, or to the property line). California Assembly Bill 3074 (2020) required the State Board of Forestry and Fire Protection to develop regulations for a zero to five-foot "ember-resistant zone."[58] Recommendations for an ember-resistant zone developed by the State Board of Forestry and Fire Protection are expected to go into effect by January 1, 2023.

Optimal Wildfire Resistance

Removing all combustible materials within five feet of the home such as bark mulch, vegetation, and stored materials such as firewood minimizes the chance of ignition by embers.[59] The noncombustible zone should include the area underneath the deck, bay windows, and other overhanging or attached components of the home.

All plants are susceptible to burning under certain wildfire conditions. To effectively maintain a noncombustible zone and reduce ignition vulnerabilities, particularly from embers, it is recommended that no vegetation is planted within five feet of the home. A strict interpretation of the ember-resistant (i.e., noncombustible) zone was used in this report.

Mulch is commonly used in flowerbeds and around the perimeter of the home. Due to the horizontal spread of mulch and its proximity to the side of a structure, mulch can be a significant source of vulnerability to wildfire, especially from embers.[60] Using noncombustible materials for mulch, such as pea gravel and rocks rather than organic mulch such as wood chips, can reduce the threat from embers.

Fencing extending from the home and around the property can be vulnerable to ignitions and must be considered as part of the near-home landscaping. If ignited, fencing can serve as a wick during a wildfire and threaten the home with direct flame contact or embers. Using noncombustible fencing material within the near-home landscaping zone reduces opportunities for ignition. Studies by the National Institute of Standards and Technology (NIST) also indicate the design of the fence can greatly influence the spread and intensity of ignitions and can serve as a pathway for fire to burn to a building.[61]

New Construction Cost Comparison

Until the guidelines for maintaining an ember-resistant zone are established by the State Board of Forestry and Fire Protection, there are no requirements for near-home landscaping (0 to 5 feet) in California code. Typical landscaping practices for mulch and fencing were assumed for the Baseline homes in northern and southern California. No plants or vegetation were included in the cost analysis for this report.

For the Baseline homes, bark mulch at a depth of three inches and extending five feet from the home was assumed. The privacy fence was constructed with cedar fence boards (1-by-4-inch) at a height of six feet and included an entry gate of the same material. The fence was assembled with 4-by-4-inch posts and three 2-by-4-inch rails.

For the Enhanced and Optimum homes in northern and southern California, the bark mulch was replaced with pea gravel and included landscape fabric (polypropylene mesh erosion control fabric) underneath the pea gravel. The privacy fence was six feet high and made with galvanized metal chain links. A metal gate, concrete, and hardware were included in the cost analysis.

Enhanced/Optimum wildfire-resistant features within the near-home landscaping, including gravel mulch, weed barrier, and a noncombustible privacy fence, cost approximately $2,570 more than using the bark mulch and a wood privacy fence of the Baseline home.

Table 5.6: Cost and proportional difference of near-home landscaping in new construction for Baseline, Enhanced, and Optimum homes in northern and southern California.

Near-Home Landscaping							
		Northern California			Southern California		
Component	Material	Baseline	Enhanced	Optimum	Baseline	Enhanced	Optimum
Fence	Metal		$360	$360		$360	$360
	Wood	$160			$160		
Mulch System	Bark mulch	$520			$530		
	Pea gravel		$2,790	$2,790		$2,810	$2,810
	Weed barrier		$100	$100		$100	$100
Total		**$680**	**$3,250**	**$3,250**	**$690**	**$3,270**	**$3,270**
Difference from Baseline			$2,570	$2,570		$2,580	$2,580
% Difference from Baseline			378%	378%		374%	374%

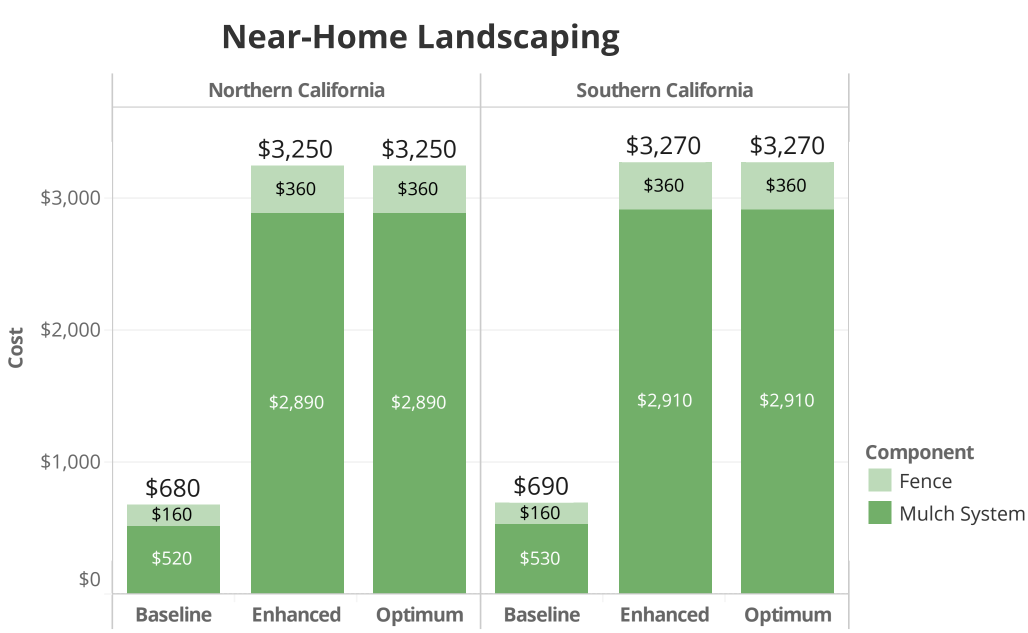


Fig. 5.5: Near-home landscaping costs for Baseline, Enhanced, and Optimum homes in northern and southern California.

Chapter 6
Conclusion

As wildfires become more damaging, we cannot afford to wait to build wildfire-resistant homes. Rising trends in wildfire severity, frequency, and duration increase the risk to people and homes. At the same time, more development in wildfire-prone areas exacerbates wildfire impacts. Building and investing in wildfire-resistant homes now will increase overall community resilience for generations to come.

This study fills a key information gap for California homeowners, builders, and policymakers: the cost differential to a level of wildfire resilience beyond the requirements set forth in California's Building Code Chapter 7A. To this end, this study analyzed the costs for constructing (1) a Baseline home in compliance with California's Building Code Chapter 7A compared to (2) an Enhanced wildfire-resistant home that also addressed the under-deck area and near-home landscaping, and (3) an Optimum home built to high wildfire-resistant measures, the most stringent evaluated in this report.

Research findings suggest that the cost of constructing an Enhanced wildfire-resistant home is not significantly higher than a Baseline home compliant with Chapter 7A. Differences between a Baseline and an Enhanced wildfire-resistant home included an enclosed under-deck area and a noncombustible zone from zero to five feet from the home, adding approximately $2,800 to the overall price of an Enhanced wildfire-resistant home.

Constructing an Optimum wildfire-resistant home increased overall costs by $18,200 to $27,100, but that investment will return greater long-term benefits in energy efficiency and building material durability. Wildfire-resistant construction adds approximately 2%-13% to the entire cost of a new home. (Baseline/Enhanced building materials add 2%-8%; Optimum building materials add 4%-13%).

It is important to note that building an Optimum wildfire-resistant home assumed premium construction materials and products often associated with higher costs. For many of these building materials, there are less expensive alternatives that still provide improved wildfire resistance.

Additionally, some mitigation measures taken with the Optimum wildfire-resistant home may not be necessary if ignition potential has been addressed throughout the entirety of the home and property. For example, a metal structural support system for a deck may not be needed if adequate defensible space around the home and a noncombustible zone below the deck are created and maintained.

Findings from this study are intended to inform dialogue and policy regarding wildfire mitigation to the home and property. While identifying the costs for wildfire-resistant construction is important, it is only part of a broad and multifaceted approach for reducing risk of wildfire to homes. Two additional areas requiring attention include assessing retrofitting needs for existing construction in California and across all wildfire-prone areas in the country, and analyzing the effects of housing arrangements and building-to-building proximities.

Retrofitting California's Existing Housing Stock

While building new construction to elevated levels of wildfire resistance will help the next generation of California homes, risk remains for millions of existing homes across the state. Given California's substantial housing stock and high wildfire risk, retrofitting the fleet of existing homes in wildfire hazard areas must also be addressed.[63] In an important first step, California's Assembly Bill 38 (2019) required the State Fire Marshal to develop a list of low-cost retrofits to reduce risk to structures by July 2025. As part of this, the Department of Forestry and Fire Protection (CAL FIRE) will create a plan of retrofitting activities that a resident could implement given specific information regarding the building, location of buildings on the property, and neighboring properties.

Supporting the cost of retrofitting California's existing housing stock in wildfire hazard areas will require resources and funding from the state and federal government. Providing subsidies to homeowners to offset the costs for retrofitting activities and new construction requirements is crucial in ensuring mitigation compliance across entire neighborhoods, which is necessary to drive down risk for individual homes as well as across communities.

Risk of High-Density Developments

A second area of concern and complexity is high-density developments within wildfire hazard areas. With growing pressure from state policymakers to increase housing, many communities are left with few options but to build in high-hazard areas. In higher-density development where homes are close together, incorporating wildfire-resistant, near-building details is critical. Because there is limited information regarding radiant heat and potential for flame contact exposure as a function of building separation distances (in conjunction with elevated wind, also common during wildfires), it is challenging to develop material and design specifications.

A series of CAL FIRE-funded "structure separation experiments" is being conducted by the National Institute of Standards and Technology (NIST) and IBHS. These experiments will lead to better guidance regarding home-to-home spacing (and other smaller building-to-home distances) in wildfire-prone areas. Outcomes from this research may ultimately influence building code amendments and understanding regarding high-density developments alongside increasing wildfire risks. The NIST and IBHS experiments are scheduled to be completed in 2024.

For decades, researchers have argued for a reframing of the wildfire crisis as a home-ignition problem and not a wildland fire problem.[64] Reducing impacts to communities and increasing home survivability requires a multipronged approach that considers ignition vulnerabilities to the home, neighborhood, and community. Success requires deliberate consideration and planning of housing arrangements, property vegetation management, nearby wildland fuels, and the materials, design, and near-home landscaping of the home itself. With ever-increasing wildfire risks, we cannot wait to invest in wildfire-resistant homes and communities.

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