

DESIGNING FOR DISTURBANCE: ADAPTING THE  
WILDLAND URBAN INTERFACE TO WILDLAND FIRE

by

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The frequency and severity of wildland fires have been increasing over the past decade, and are will continue to do so at increasing rates as the earth's climate changes. This inevitability has grave implications for the 72,000 communities currently located on the forests edge in the United States.

With fire suppression costs soaring to over \$3 billion annually and an increasing inability to protect life and property from wildland fire, substantial design considerations are necessary to attempt to integrate the built world into a landscape adapted to burn.

The necessary adaption to changing climate will require substantial changes in fire management to cope with increasingly severe fire seasons. The built environment must adjust to accommodate and support these changes, adaptations that must occur on large and small scales. Proactive community planning and ignition resistant construction must be implemented together to fundamentally change the interaction between man and fire in the Wildland Urban Interface.

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## Wildland Fire in the United States

Every fire season<sup>1</sup>, millions of acres of public and private land across the United States are consumed by Wildland Fire. Wildland fires occur to some degree throughout the entirety United States, from the swamplands of Florida to the boreal forests of Alaska. These fires range from a few square feet of smoldering duff to stand-replacing<sup>2</sup> infernos that will engulf hundreds of thousands of acres.

Wildland fire is an integral ecosystem process for much of North America. Prior to European settlement, fire affected approximately 145 million acres a year across what is now the geographic United States. These fires exhibited huge variations in burn severity and fire return interval, characteristics known as fire regimens (Black 1). Historically, these fire regimens affect 94% of the land area of the current United States (Stein et al. 2). Urbanization, agricultural development and active suppression of wildland fire drastically changed the fire regimes in many wildlands. The 2006 fire season is the largest by acre of record, and burned 9,873,745 acres. This figure only represents 6% of the annual acres burned prior to European settlement (National Incident Coordination Center 2014). The historic, regenerative properties of wildland fire are becoming increasingly well known. Continued fire suppression and the influx of non-native species have altered wildlands to be increasingly susceptible to large, high

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<sup>1</sup> “Fire Season” is a term used to describe an approximate period of time in which wildland vegetation is available to burn. The fire seasons in many parts of the United States do not have an absolute correlation with summer months.

<sup>2</sup> A fire propagated in the canopy or crown of the vegetation it burns, with an extremely high mortality rate in the burned area. Differing from fires that kill only a small to moderate percentage of vegetation, stand-replacing fires cause wildlands to be replaced by a new generation of vegetation. Stand-replacing fires are the most violent fire disturbance, yet are the natural fire regime for many ecosystems in the United States.

severity wildfires that exact a larger ecological toll than historically present (Hurteau et al. 280; Stein et al. 1; Stephens et al., 305).

The Wildland Firefighting infrastructure in the United States is the most developed and efficient in the world, composing of 56,000 wildland firefighters and another 100,000 structural firefighters involved in wildland fire suppression. Every year, this group extinguishes an astonishing number of wildland blazes: as high as 97% of the nearly 100,000-wildland fires each year are contained within the first 24-48 hours<sup>3</sup> (Black 1; International Association of Wildland Fire 5). While ecologically unsound, this ability represents an impressive achievement by a highly coordinated and expansive network composed of state, federal, local and private firefighters from every state in the US.

High intensity wildfires, the paradoxical result of this continued fire suppression, are often impossible for firefighters to suppress on their own terms, and often burn substantially unchecked until the weather changes, or in some cases, until winter snow falls. The increasing inability to control violent fires does not bode well for individuals living where the natural and developed world overlap, an area referred to as the Wildland Urban Interface.

Fires in the Wildland Urban Interface (WUI) are well known to firefighters as being complex, dangerous, and expensive. These problems stem from the potential threat to life and property. Between 2000 and 2012, an average of 2970 homes were lost to wildland fire per annum. Civilian deaths in wildland fire burnovers are possible-

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<sup>3</sup> Known as Initial Attack (IA), the vast majority of fires in the US are extinguished by local fire suppression resources. A very small percentage of wildland fires grow complex enough to require “out of district” resources, or fire crews from different agencies, geographic areas and states. These large, complex fires are managed by Incident Management Teams (IMT).

affecting both individuals trying to defend structures and fleeing flame fronts, accounting for roughly 30 civilian and firefighter fatalities annually (International Association of Wildland Fire 5).

Wildland fires burn where fuels<sup>4</sup>, weather and topography allow it-people and buildings have a tendency to be in its way. Historic fires such as the Pesthtigo Fire of 1871 caused over 1000 fatalities in a single event (Hipke). The Great Fires of 1910 are commonly seen as representing the birth of wildland firefighting in the United States, consuming over 3.3 million acres of timber and killing 85 people in Northern Idaho and Montana (Kock). Modern fires in the WUI lack the grand scale of fires past, but it is important to note that fatalities in the WUI are still common and show no signs of abating. The apocalyptic Australian brushfires of 2009 killed 173 people as extreme fire behavior tore through the Wildland Urban Interface with an energy release coefficient equivalent of 1,500 atom bombs (County Fire Authority).

The 2003 Cedar Fire in California killed 13 civilians, 1 firefighter and over 2,800 structures (CalFire 2003). The 2013 death of the 19 members of the Granite Mountain Hotshots<sup>5</sup> are attributed to an attempt to re-engage the fire before it could enter the town of Yarnell, where it eventually destroyed 112 structures (Arizona State Forestry Division, 2013, p. 35). With or without well-publicized deaths in the WUI, it is generally regarded that fires in the WUI are the single largest challenge faced by wildland fire responders (International Association of Wildland Fire 2; Mell et al, 238).

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<sup>4</sup> The vegetation consumed by a wildland fire.

<sup>5</sup> An elite fire crew. Hotshot crews are extremely self-sufficient and operate with a much smaller level of supervision than standard fire crews.

The 2014 fire season was a continuation of these trends. Extensive news coverage of wildland fires such as Washington's Carlton Complex and California's King fire highlighted wildland fires burning through populated areas and destroying numerous structures. While the Carlton and King fires are examples of large forest fires churning through communities, even smaller fires have the ability to spread rapidly through the WUI. Weed California's Boles fire only burned 516 acres, but consumed 165 structures (157 of them being homes) in less than eight hours as flames raced through the WUI in the very center of town (CalFire, 2014). It is worth noting that the 2014 fire season ended as a relatively mild fire season compared to recent years, with 3,168,930 acres burning representing less than half of the 10-year average of 6,601,196 acres burning every summer (National Incident Coordination Center).

## **Wildland Fire and Climate Change**

Settlements in the Wildland Urban Interface must simultaneously adapt to current fire potential and also begin to plan for a future that will be much worse. Wildland fire behavior is derived from fuels (the vegetation a fire consumes), topography (the slope and formation of land masses affect fire behavior and generate local weather), and weather (both drying out fuels and creating conditions more favorable to fire growth).

The increasing severity of wildland fires can potentially be viewed as a canary in the climatic coalmine. Climate change is already causing drastic increases on the fire season. Fire seasons in the 21<sup>st</sup> century have consistently increased the record number of acres burned in the United States (National Interagency Fire center). On average, wildland fires from 2000-2005 burned over 70% more on a yearly acreage than in the 1990's. The increases in fire size produced corresponding increases in yearly fire expenditures, with annual suppression costs growing from \$1.3 billion to \$3.1 billion in the same time period (Mell et al. 238). The fire season of 1963 burned 7 million acres across the United States. This figure remained unmatched until the 2000 fire season. Since 2000, the US has experienced an additional seven fire seasons eclipsing 7 million acres burned, including three fire seasons with an astounding 9 million acres burned (National Interagency Fire center 2014).

## **Predicted Increases in Wildland Fire**

These trends are overwhelmingly expected to continue. In multiple studies, 100% of Global Climate Models predicted trends of increased temperature and decreased precipitation in the American West (Flanagan et al. 57; Rocca et al. 291; Wimberly & Liu 273). These findings have relatively simple implications for fire behavior in the 21<sup>st</sup> century: warmer and drier weather means drier fuels and more volatile fire weather compared to current fire seasons. The length of the fire season in the United States is predicted to increase as well. One of the most prescriptive models of anticipated climate change scenarios forecasts the fire season in most of the United States expected to extend by 20 or more days by 2030 (Flanagan et al. 58).

More specific studies paint a highly nuanced and varied picture as different fire regimes and fuel types are affected in vastly different ways. The modeling of just an average temperature increase of 1 degree centigrade is predicted to double the average area burned in the Northern Rockies of Idaho and Montana. While a 100% increase may seem staggering, this same calculation predicts a 400% increase in average acres burned for the Colorado Plateau, 500% in the Central Rockies of Idaho and Montana, and a staggering six fold increase in annual acres burned in the Southern Rockies of Colorado, Utah and Wyoming (Rocca et al. 294).

Many fire regimes could see a much different, though equally troubling, shift in fire intensity and frequency. In the drier regions of the Southwest United States, climate change modeling predicts an initial increase in fire intensity, as perennial drought initially increases the percentage of fuels available to burn. Multi-decadal modeling reveals a sharp reversal in this trend, as vegetation recovery from fire disturbances

simply proves inadequate to support future fire regimes. This trend will ultimately result in an increase in arid landscapes in the Southwest and parts of California (Hurteau et al. 283-86).

Changes in the prominence of fire on the landscape are not just restricted to the West. Forests in the Southeastern United States are characterized by a much higher human presence compared to the vast open spaces of the West. Currently, the Southeast represents a noteworthy case of active forest management, as land managers in the Southeast conduct more prescribed burns each year than the rest of the United States combined. In 2011 alone, fire managers conducted 2.6 million ha of prescribed burns, representing some 82% of the national total for that year (Mitchell et al. 317). Due to this active management strategy, roughly two thirds of the annual acres burned in the Southeast are from prescribed fire operations, with the remaining one-third the result of natural and human ignitions (319).

The exact nature of how climate change will affect these management practices is somewhat harder to predict than the apparent drying of the West. As opposed to the relative consensus of climate models predicting a warmer, drier West, there is less certainty on whether Southeastern forests will experience more or less precipitation. The fire season in the Southeast is typically seen in the spring, with the summer months experiencing low fire danger while the West is at its most volatile. As with the Western US, the Southeast is predicted to generally experience a warming trend in summer months, which is predicted to increase the general Southeastern fire season by 1-5 months. Because the primary warming period does not correspond with existing peaks

in fire danger, the exact nature of potential increases in fire behavior is less predictable than Western models (Mitchell et al. 321).

The influence of non-fire disturbance associated with climate change could alter Southeastern fire regimes as well. Predicted increases in hurricane frequency may significantly affect Southeastern fire regimes (320). Perhaps contrary to intuition, these violent, extremely wet storms may actually lead to an increase in fire intensity. One of the regions most influential disturbances, a single storm can convert roughly 10% of a forests carbon stock into dead and down fuels, which can then be available to fuel fire behavior years after a storm passes (321). The odd connection between tropical weather and fire trends have already been observed, as the historic 2007 Georgia-Florida Bay Complex Fires were fanned by winds associated with the outskirts of Subtropical Storm Andrew, as an offshore stationary low-pressure system sent strong winds towards the fires without bringing any moisture ashore (321).

The substantial evidence of a drastically increased prevalence of fire across the United States does not bode well for communities exposed to the inevitability of wildland fire. The proposition of developing a Wildland Urban Interface more adapted to fire on the landscape must not only account for the existing threat of fire, but also be proactive in anticipating the radical changes associated with an uncertain future.

## **Fire and the Wildland Urban Interface: Current & Future Status**

The growth in potential fire behavior means more active and more frequent fires for the 22 million square miles of Wildland Urban Interface in the United States (International Association of Wildland Fire 6). Currently, this area represents roughly 9% of the total land area in the US, encompassing 44.8 million housing units in over 72,000 communities under threat from wildland fire. This figure represents 39% of all housing units nationwide (Stewart et al. 3). The suburban nature of American growth in the 20<sup>th</sup> century led to an enormous expansion in the Wildland Urban Interface. Settlement patterns characterized by low-density sprawl radiating away from denser urban centers create a linear relationship between population growth and WUI particularly in the comparatively less populated West. From 1970-2000, the WUI area in the West increased by a staggering 61%. The total number of housing units in the Western WUI increased by 68% in the last decade of the 20<sup>th</sup> century alone (Schoennagel et al. 10706). This fabric of the WUI varies from state to state, as Connecticut holds the largest percentage of WUI land area at 72%. California holds the most housing units threatened by wildland fire at 5.1 million (Radeloff et al. 799; Theobald et al. 340).

The Wildland Urban Interface in the United States is readily identifiable, but the nature and nuance of urban-wild land interactions are as diverse the thousands of differing communities and biomes located in the WUI. Currently, there is no standardized method of comparing broadcast fire risk across the national WUI. Perceived threat from wildland fire is largely determined by local fire managers, using a

combination of fire behavior modeling and individual experience (Mell et al. 239). The lack of a standardized assessment method makes it difficult to produce apples-to-apples comparisons of the differing levels of fire threat facing individual communities.

Perhaps more troubling, the number of structures threatened by wildfires is increasing at an alarming rate, both in number of structures threatened and geographic size. By 2050, the number of houses located in the Wildland Urban Interface is expected to double, with most of the growth in the Intermountain West, a region noted for some of the most severe wildland fire regimes in the country (Theobald et al. 340). In the state of Colorado for instance, the WUI is expected to increase from the 715,500 acres present in 2000 to 2,161,400 acres by 2030, representing an increase of some 300% (340).

The Wildland Urban Interface not only represents the co-mingling of wildland fuel types, but the intermix of numerous political, bureaucratic and social pressures as well. 89% of the WUI is privately owned, mainly in the form of private residences and parcels. 7% of WUI land is under federal ownership, with the remaining land in state, county and city jurisdiction (Theobald et al. 340). The multi-jurisdictional nature of the WUI means prescriptive measures meant to adapt a community to wildland fire encroachment cannot be the sole product of one entity, mandating collaborative efforts of city, county, state and federal land agencies.

These efforts can often be compromised by contradictory land management policy and goals by the vast number of different landowners in the WUI. An excellent example of these issues is the low and mid elevation industrial forests of the West Coast. Private land owners, particularly industrial timber companies, are often in

immediate proximity to public land areas, in many cases sandwiched between developed areas and National Forest lands at higher elevations. Industrial timberlands are generally managed with a sole economic focus. Timber production is prioritized, and ecological goals such as habitat diversity are often counterproductive. As industrial timberlands have a high dollar per acre value, many private timber companies rely on State suppression resources to immediately suppress all human and natural ignitions, creating a culture of aggressive fire suppression goals with the primary goal of preventing timber loss to fire. These goals are understandable, as each tree damaged or killed by fire represents a direct loss to the company's bottom line. Unfortunately, these priorities can often create conflict with Federal and State public lands which may be managed with a less aggressive attitude towards fire suppression, partly in recognition of the critical ecological role of fire.

The differing perspectives on land management often come to a head when managing fires on both private and public land, known as joint-jurisdiction fires. Large, difficult to suppress fires require personnel from multiple organizations from across the United States. In many cases, the Incident Management Team (IMT) is entirely composed of fire managers from Federal Agencies. These teams often bring fire management objectives derived from managing fires on public lands with a stronger priority on ecological and recreational values, diverging from a philosophy that "every acre has value", a point of view generally held by private land managers almost entirely concerned with economic productivity (State of Oregon 2). Diverging viewpoints on suppression strategies and priorities often leave private land owners feeling left out of the decision making process, as their priorities are not recognized by Federal IMTs

(State of Oregon 2-3). These perspectives are often compounded by the fact that the local fire managers have a limited amount of suppression resources available to them, and will inevitably have to rely on substantially more robust Federal resources to manage large, volatile fires.

The multi-jurisdictional nature of the WUI does not by its self represent an overwhelming procedural barrier to more effective wildland fire management. Firefighting efforts in the US currently involve a high amount of cross-agency coordination, and have developed a highly regularized tactical, administrative, and procedural framework to facilitate multijurisdictional collaboration. The patchwork nature of the WUI instead raises more problems by pitting diverging interests and objects against each other. As with many policies, achieving consensus on fire management objectives often represents a greater challenge than policy implementation.

## **Modified Fire Management: Fuel Treatment in the Wildland Urban Interface**

Diverging management perspectives often come to a head when discussing alternative management fire management practices. The understanding that former and current wildland management practices have fundamentally changed the makeup of forests and rangelands in the United States have spurred a wide variety of practices attempting to reverse these harmful trends: a practice known as fuel treatment (Kline 2). Fuel treatment practices have many goals, both ecological and social, and include invasive species eradication, favored species selection and habitat promotion, reducing potential fire activity near structures, and many others (McIver et al. 1-3; Stephens et al. 305). The exact specifications of a prescribed fuel treatment practice are determined by the ecological context it takes place in and the goals of the treatment. While treatment objectives are expansive, fuel treatment methods in the United States are generally comprised of two categories: mechanical treatments, sometimes known as fire surrogate, and fire treatments. These two strategies may be employed together to achieve desired results.

Fuel treatments are proven to reduce fire activity in treated areas (Fitch et al. 6-7; Hessburg et al. 2-3). The simplest, and most beneficial fuels reduction exercise is the creation of “defensible space”. Defensible space is the progressive reduction and eventual complete removal of vegetation around a structure. Defensible space is considered an essential first step in protecting homes from wildland fire (Cohen & Stratton, 5; Quarles et al., *Lessons Learned* 35). Fuel reduction projects generally connote a much larger scale project meant to protect an entire community. The benefits

of using fuel treated areas to protect communities from high intensity fire are well known, with many examples of treated areas being integral in reducing fire severity (Bostwick et al. 10; Quarles et al., *Lessons Learned* 8-9). The Wildland Urban Interface, as a definable area, represents a unique opportunity to focus limited fuel treatment and fire management resources to areas where it can best reduce loss of life and property. Currently, this is not always the case. Study of 11 western states analyzing the use of \$2.7 billion in federally implemented fuel treatments from 2004-2008 reveals only 3% of total land area treated falling within the WUI (McIver et al. 1-3). This figure appears to be staggeringly small, and without a doubt represents a missed opportunity to create a more fire adapted WUI. On the other hand, it is important to remember that many federal funds are applied to federal lands. 90% of the Wildland Urban Interface is privately owned (Theobald et al. 340). Regardless, the need for increased application of fuel treatments to the Wildland Urban Interface is apparent.

The ecological role of fire differs vastly from biome to biome. Different fuel treatments are appropriate for different fuel types. The human context surrounding each potential treatment area also determines the most appropriate fuel treatment techniques. Smoke, recreational value, and potential implications of losing control of a prescribed fire are all primary considerations when planning fuel treatments.

## **Mechanical Treatments**

Mechanical treatments consist of the use of a variety of machinery, ranging from handheld chainsaws (known as “manual treatments”) to industrial logging equipment. Treatment goals usually include a specified crown spacing intended on reducing the likelihood of ground fire moving into the tree canopy. Thinning a timber stand reduces the possibility of the fire propagating in the canopy should individual trees ignite, or “torch”. Mechanical treatments may include removal of a specific species, usually invasive or undesired. Fire surrogate treatments attempt to mimic the ecological effects of a natural fire regime. This practice usually consists of selecting a desired canopy spacing and removing all trees or significant vegetation until the desired vegetative density is achieved. Treatments may also include removing “ladder fuels” or vegetation that facilitates fire on the forest floor climbing into the canopy. This method consists of removing flammable foliage from flame impingement, and is done through pruning low-level tree limbs, removing brush located underneath trees, and reducing the density of small and medium sized trees (North & Hurteau 1119).

Mechanical treatments are more labor intensive than prescribed fire activities, and often are associated with a higher cost per acre (Black 2; Kaval 1866). Enormous variations in vegetation density, topography, technical complexity and worker productivity create a cost range varying from \$200 to \$3,500 an acre (Holl, p. 7-1).

Mechanical treatments are most suited for reducing, or completely removing, the fuels in direct contact with structures. Known as the “home ignition zone”, removing 20-40 feet of brush around a home remains one of the single most effective methods of protecting structures from wild land fire (Jensen 971). The labor-intensive nature of

mechanical treatments makes them unsuitable for the entirety of the 22 million acres of WUI in the United States, but the minimal risks and minor impacts on WUI residents necessitate a place for mechanical treatments where prescribed fire may not be currently appropriate (International Association of Wildland Fire 6).

### **Fire Treatments**

Fire fuel treatments, like mechanical treatments, vary in method and goals. Fire treatments are divided into two different categories: prescribed fires (RX) and fire-use (WFU) fires. Prescribed fires are intentionally ignited in an area located within pre-established control lines. Prescribed fires are implemented when burn conditions are in an ideal range for moderate fire behavior, usually the result of weather that is mild enough that the chances of the fire escaping control lines are minimal, but conducive enough to fire propagation that the treatment will be effective. Prescribed fires are used to mimic a naturally occurring fire in a time and place determined by fire managers. As can be imagined, fire treatments are almost always implemented in the “shoulder seasons”, such as the spring and fall, when conditions allow suitable fire behavior for a short period of time, with little risk of losing control of prescribed burns as milder weather returns soon after the burn window. (Stephens et al., 2009, p. 309) A high level of understanding of the role of fire within that particular ecosystem is required, as failure to understand the specific site and ecosystem can result in fires that threaten biodiversity (Jensen 977).

Fire treatments are able to treat large acreages in a relatively short time. Due to the high discrepancies in complexity of different fire operations, the costs of Prescribed

Fires vary considerably. Low complexity grass and scrubland burns with little risk of escaping control lines can cost as low as ~\$9 an acre (Hinckley 3). RX burns in the WUI run much higher, anywhere from \$400-\$1,500 an acre in extremely complex burn operations with high value assets near by (Holl 7-1). The nationwide average of prescribed fire costs is estimated at roughly \$45 an acre (Black 2).

### **Combined Treatments**

It is also common practice to combine mechanical and fire treatments. Though increased coordination and planning is required, combined treatments are often the most effective means of reaching many fuel treatment goals. Combined treatments consistently show the largest reduction in future fire severity, and are an effective way to accelerate the restoration of a historic fire regimen in a given fuel type (Prichard et al. 1620; Stephens et al. 311). The simplest combination of the two is referred to as “slashing<sup>6</sup> and burning”, or mechanically removing fuels that will help promote fire propagation into the canopy. In the large coniferous stands of much of the Western United States, this practice usually consists of removing low lying limbs and branches, as well as brush underneath the canopy, and then piling the slash nearby. Fire managers will then burn the slash piles outside of the fire season, usually in the spring or fall depending on when the thinning took place. In wetter climates, such as the Pacific Northwest, it is sometimes necessary to cover the slash piles to protect them from the elements, and ensuring they are available to burn when crews arrive.

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<sup>6</sup> Slash is the leftover limbs and branches removed from the trunk of a tree. The term originates in the piles of debris left behind at logging operations, but also applies to the branches removed from a tree that is left standing.

## **Wildland Fire Use**

Land managers have another tool at their disposal to help recreate balanced ecosystems: Fire Use. Wildland Fire Use fires are naturally ignited wildfires that are actively managed (in many cases just monitored) but not actively suppressed.

Occasionally referred to as "let it burn" Wildland Fire Use (WFU) is a fire stewardship method directly derived from the understanding of the natural role of fire in the landscape (Black 1-2).

WFU fires are usually characterized by low to moderate intensity fire activity in particularly fire-adapted landscapes. Often occurring in the low to mid elevations ponderosa pine forests of the Western United States, WFU is currently considered most appropriate in road less areas, Federally designated Wilderness Areas, Wildlife Refuges and other landscapes with minimal human occupancy, particularly the vast Boreal forests of Alaska (Inglesbee 32).

The somewhat specific "wilderness" application of Wildland Fire Use as a management tool is not the manifestation of only "wild" forests and rangelands needing fire disturbance. As previously indicated, virtually all forest and range ecosystems have an ecological need for fire disturbance, regardless of the level of human settlement currently (or historically) present. The currently limited application of WFU is instead the gentlest procedural change allowable in a social climate still wary of the ethics of a "let it burn" approach. The substantial barrier to WFU implementation is not the potential damage of an unsuppressed fire, but a lack of education and institutional understanding of WFU benefits. A 2006 study on the barriers to WFU revealed that the five primary reasons Wildland Fire Use is not implemented are organizational culture,

political boundaries, organizational capacity, policy directives, and public perceptions (Doane et al. 36-37).

Without a doubt, the primary inhibitors toward increase WFU is internal. Fire managers cite the potential political consequences of allocating a natural start to burn under WFU use conditions, and then ultimately suppressing the fire after it has grown exponentially in size (Doane et al. 37).

The historic Yellowstone fires of 1988 are perhaps the best example of the potential political pressures associated with WFU. Yellowstone National Park became one of the earliest areas to recognize the ecological necessity for fire. Natural ignitions in early June were allowed to burn for over a month as the park implemented a Fire Use policy rarely seen at the time. Dozens of fires continued to grow until a concerned public began to voice consternation at the lack of suppression until active suppression efforts began, in the end totaling some \$120 millions with over 25,000 individuals involved in the suppression effort (The Yellowstone Fires of 1988).

Ironically, the substantial public outcry proved misguided. The almost immediate response of the greater Yellowstone ecosystem to the extreme disturbance became one of the greatest tools available to fire science researchers, providing increased understanding of the role of fire disturbance in dozens of different ecosystems across the 793,000 acres ultimately burned. The human impact of the fire was also substantially less than many feared. Instead of foregoing visits to an area many perceived as completely devastated, 1989 actually represented the highest visitation year of the entire decade (The Yellowstone Fires of 1988).

Given the current difficulties in implementing WFU across the US, substantial cultural and policy changes must be implemented before it can be considered a viable tool for WUI fires. Most wildland fires in the United States involve low or moderate fire behavior, a rule that applies to the Wildland Urban Interface as well. As such, it is quite reasonable to “let it burn” in closer proximity with structures. In order for these actions to be viable, more effective implementation of preemptive fuel treatments in immediate proximity to structures must be present. The structures potentially exposed to WFU fires must also be feature ignition resistant construction techniques, to absolutely minimize or eliminate the probability of structure loss and damage to WFU fires. These changes will ultimately contribute to a physical and culture landscape where allowing fire to fulfill a natural role comes with less potential risks for fire managers. Due to the similarities between WFU and RX fires, WFU use costs are estimated at \$40-\$50 an acre, an attractive option compared to the Nationwide average of roughly \$500 an acre for direct suppression (Black 2).

### **Fuel Treatment Options- A Cost/Benefit Analysis**

It is difficult to prescribe broad stroke costs to different fuel treatment approaches. The variables of slope, fuel type, proximity to the WUI, season, labor, material costs and other factors simply make across the board comparisons unrealistic. The ranges in costs per acre of treatment are huge, underscoring the complexity of different treatment methods in different landscapes. Prescribed burning in low risk, coastal grasslands of Florida’s Merritt Island National Wildlife Refuge costs an extremely impressive \$9.08 per acre, an example of low complexity prescribed burn operations in a relatively remote area (Hinckley 3). Mechanical Removal of fuels in the

Wildland Urban Interface of California's Sierra Nevada can cost a staggering \$10,000 per acre- a testament to man-hours and machinery needed to treat plots in the hazard prone WUI areas (Holl 7-1). In some cases, it is possible to offset some of the costs associated with mechanical fuel treatments by selling logs and mulch removed from treated areas, though these treatments will never pay for themselves. Potential income is limited by the fact that the treatment objective is retention of taller, healthy trees- the same merchantable timber that would be most profitable to harvest. Additionally, commercial offset of mechanical fuel treatments are only possible in areas with suitable infrastructure to facilitate the removal and processing of biomass from the treatment area (Holl 7-1).

Considerable evidence exists to support the overall value of fuel treatments in reducing fire management costs. Fuel treatments in the Merrit National Wildlife Refuge were modeled to have saved fire managers \$3.6 million in reduced suppression costs, as naturally started fires within treated areas exhibited mild fire behavior and were easily suppressed (Hinckley 3). A 2013 study estimated that fuel treatments in Northern Arizona's extremely fire prone ponderosa pine forests reduced direct suppression costs from \$706-\$825 per acre to \$287-\$327 per acre, a reduction of roughly 60%. This study did not estimate the indirect costs of rehabilitation and recovery, but did acknowledge that these costs could ultimately be 2-30 times greater than direct suppression costs alone, exponentially increasing the net value of fuel treatments (Fitch et al. 8). In many cases, the largest savings associated with fuel treatments occurred not in direct suppression costs, but the savings in post fire-rehabilitation. Decreased fire severity substantially reduces the need for post fire risk mitigation. A study in California's Sierra

Nevada corroborated these findings, estimating that fuel treatments would save between \$23.6 and \$31.9 million when factoring treatment, suppression and rehabilitation costs (Buckley et al. 89). Fuel treatments yield the highest return on investment when implemented in the Wildland Urban Interface. The extensive fuel reduction performed before the 2012 Waldo Canyon fire in Colorado Springs, CO is estimated to have saved roughly 82% of effected homes from destruction, producing an estimated costs/benefit ratio 1/517 in the most severe areas of the fire (Quarles et al., *Lessons Learned* 23).

The complexity of human interaction substantially increases direct suppression costs, but exponentially affects non-direct fire costs (Western Forestry Leadership Coalition p. 5-6). Complex, high severity WUI fires ultimately costs far more in indirect and rehabilitation costs that in direct suppression costs alone. In many notable cases, the costs to repair or rebuild damaged infrastructure and lost commercial activity dwarfed direct suppression costs. The 2003 Old, Grand Prix and Padua fires<sup>7</sup> cost taxpayers \$61 million in suppression costs. This figure is substantial, but ultimately represents only 5% of the total \$1.2 billion in losses associated with the fire (Western Forestry Leadership Coalition 5-6).

As fire suppression costs continue to increase, the economic payoffs of investing in fuel treatment regimens will become increasingly apparent. The potential for fuel treatments to substantially reduce fire severity will not only lead to a decreased threat to life and property from wildland fire, but also substantially reduce the rehabilitation costs associated with destructive fires.

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<sup>7</sup> Known as the “California Fire Storm”, 2003 was a historically challenging fire season in S. California, and an excellent example of the potentially catastrophic result of severe fires in the Wildland Urban Interface.

## **Adapting the Wildland Urban Interface to Wildland Fire**

The economic costs of the current fire suppression model in the United States are rapidly increasing. The predicted increases in fire behavior associated with a changing climate will almost certainly drive fire suppression costs to much higher levels, potentially doubling, tripling, or even quadrupling the 3.1 billion dollars currently spent on fire suppression. Wildland fire management in the United States must undergo substantial changes in order to minimize costs associated with wildland fire regimes, support the ecological role of fire as a disturbance, and protect communities located in the Wildland Urban Interface. Future wildland fire management must be redirected towards an increased role for WFU and fire and fire surrogate fuel treatments: proven mechanisms to reduce the costs of fire management. Increased use of these alternative fire management techniques will drive down the per acre costs, reducing the substantial fiscal stress that should be expected from the vast increase in fire activity expected in the 21<sup>st</sup> century.

A wildland fire adapted WUI must support the increased roles of low to mid intensity fire, both in the form of prescribed fires and wildland fire use. This accommodation requires holistic design approaches on multiple scales. Effective community planning must regulate and manage the make-up and location of communities exposed to fire, supporting smart growth and consolidation that supports a manageable WUI boundary. Small scale, building-specific construction procedures and codes must account for the inevitability of wildland fire impingement, and recognize

that defending against wildland fire is simply another climate-specific requirement of building envelopes near wildlands.

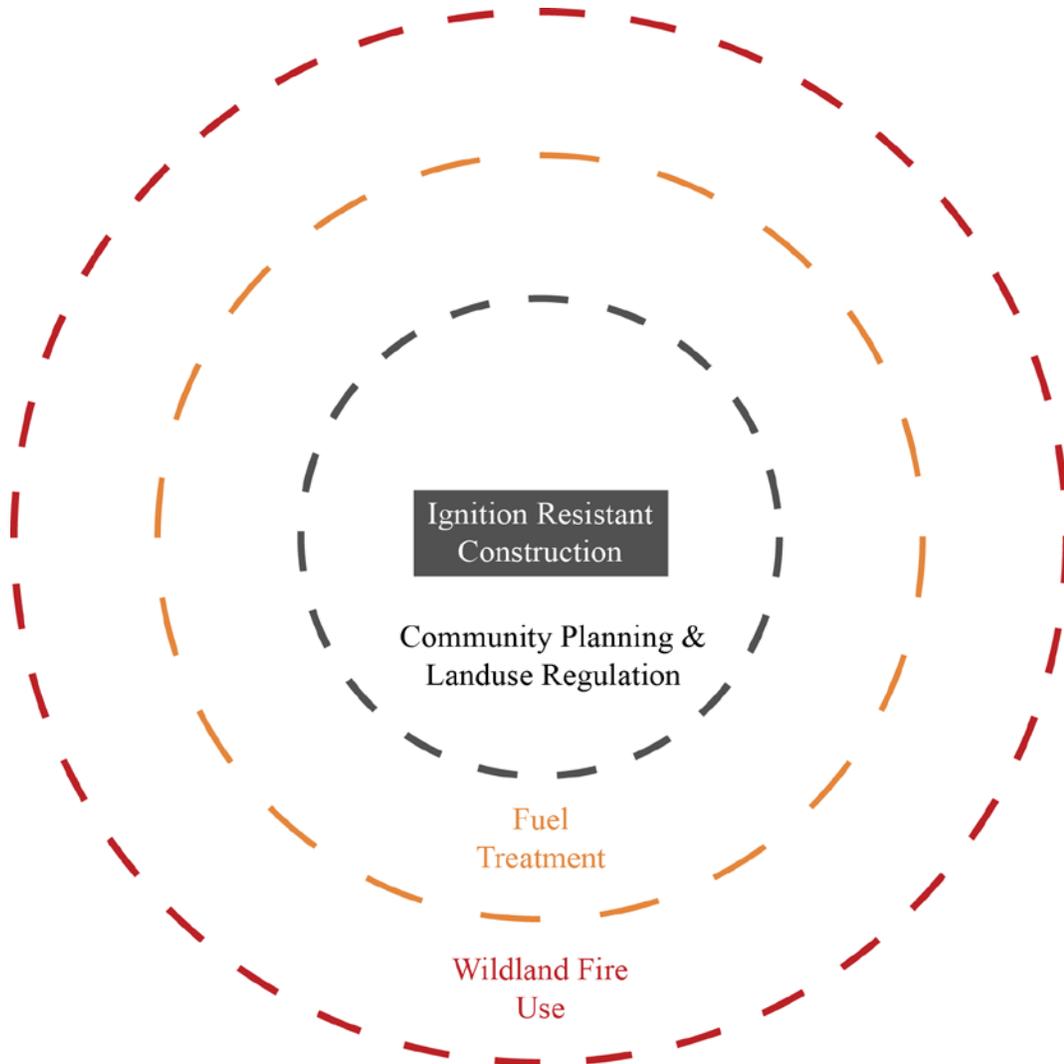


Figure 1: Envisioning a wildland fire adapted Wildland Urban Interface.

A holistic approach to fire integration: Ignition Resistant Construction techniques support defensive fuel treatment around an appropriately planned community. Wildland fire use responsibly manages fires in undeveloped areas. Source: Author

## **Community Planning & Land Use Regulation for the Wildland Urban Interface**

The nature of the interaction between the built environment and the natural area surrounding it is substantially determined by the location of human settlements and the nature of the settlement pattern. As such, a Wildland Urban Interface adapted to wildland fire regimens starts at a large scale. Community planners, developers, policy makers and fire managers have a number of tools at their disposal to design a more fire adapted Wildland Urban Interface.

The necessary preliminary adjustment for large-scale community adaptation is an understanding of the communities overall exposure to wild land fire threat. As previously stated, a natural fire regime exists in some 94% of the United States (Stein et al. 2). For the communities located within the WUI, this threat will not be uniform. Areas settled more densely, as well as many agriculture areas, have been completely removed from availability to wildland fire. Furthermore, the natural effects of topography and fuel type on fire behavior naturally make the elements of a community located in fire prone areas more vulnerable to fire impingement.

There are currently several wildfire preparedness programs, administered by the National Fire Protection Association. Each program is a component of what is called a “Fire Adapted Community” (FAC). The FAC program primarily establishes fire response planning, cooperation and education for communities in the WUI. The FAC certification is the product of several preparation components. The *Firewise* program represents important preliminary adaptation methods. The program’s relatively simple

steps such as assessing community risk, creating a local action plan, promoting fire risk education and investing \$2 per capita in *Firewise* activities, such as fuel reduction exercises or education programs (Firewise).

A slightly more involved element is a *Community Wildfire Protection Plan*, or CWPP. A CWPP is a community prepared strategy to “reduce wildfire risk to communities, municipal water supplies, and other at-risk land through a collaborative process of planning, prioritizing, and implementing hazardous fuels reduction projects” (Smith et al. 2). A CWPP may identify specific areas of elevated fire risk, or identify specific shortfalls in education among residents. Local fire managers can identify not only the areas in a community most exposed to wild land fires, but also the areas in a community that are partially removed from fire danger (Bailey et al. 6-10; Cousineau et al. 15-18; Smith et al.). Analysis and documentation of the differences in threat level facing a community can help lay the groundwork for more fire-friendly development patterns, which will be addressed later.

CWPPs may be united in purpose; they differ greatly on content. There is no prescribed format and very few mandatory deliverables. This allows different communities to tailor their specific CWPP to the needs of their area, with fire regimes, community experience with wildland fire, fuels types, accessibility of resources and jurisdictional structures being unique to each specific community (Smith et al. 2).

The FAC family of programs represents a necessary first step in community coordination, logistical planning, and education between fire managers and WUI residents. These programs were primarily designed to operate within the existing framework of fire suppression, and do little to promote departure from “business as

usual”. Programs like *Firewise* increase firefighter safety, and in many cases contributed to successful structure defense. They are not designed to lower fire suppression costs, and no evidence exists to indicate they do so (Gude et al. *Empirical Investigation* 12).

The 2012 Waldo Canyon fire in Colorado Springs, CO reveals the limitations of programs like *Firewise*. Located in the Colorado front range, Colorado Springs is a community with a substantially above average level of wildland fire preparation, with an annual *Firewise* week, curbside chipping<sup>8</sup> services, active advertisement of *Firewise* principles, a dedicated fuels reduction crew, and a city ordinance mandating ignition resistant, class “A” roofing (Quarles et al., *Lessons Learned* 26). The particularly active Waldo Canyon fire ultimately burned 346 homes. A 2013 case study credited with fuel reduction exercises associated with the city’s *Firewise* program credited for saving 82% of the structures threatened by the fire (23).

An 82% survival rate is helpful, but does not represent an acceptable step towards a more fire adapted WUI. The potential for post fire litigation from 18% of an effected community leaves fire managers little options to pursue more cost-effective, ecologically balanced fire management policies. Programs like *Firewise* represent a step in the right direction, and should be adopted by more communities, but are clearly not adequate in their current form. The promise of a drastically increasing prevalence of wildland fire in the 21<sup>st</sup> century demands a more comprehensive examination of WUI fire adaptations to offset soaring suppression costs, and promote higher survival rates

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<sup>8</sup> A mechanical fuel treatment method.

for structures threatened by wildland fire. Instead, the first step towards a fire integrated built environment is a re-examination of the physical make-up of the WUI.

### **Density in the Wildland Urban Interface**

One of the most nuanced aspects of designing communities to account for wildland fire regime is the essential role of density. Research shows a generally negative correlation between population density and the general population, geographic area, and total number of housing units with wildland fire risk in the Wildland Urban Interface (Paveglio et al. 26-30; Syphard et al., *Land Use Planning*. 7-10). As a general rule this concept is quite simple. Denser settlement patterns concentrates populations in smaller geographic areas. This reduces the sprawled, expansive nature of the Wildland Urban Interface as there are simply less plots of land to support the same amount of population. Furthermore, a denser settlement pattern focuses the removal of vegetation associated with buildings and transportation infrastructure into a more compact area, in some cases removing the built environment from wildland fire regimes all together.

The academic evidence supporting the ecological benefit of denser development patterns provides unwavering evidence that building in, or up, is “green” (Bengston et al. 272). A study of urban cores and suburban areas found net carbon footprints started decreasing as population density exceeded 3,000 per square mile (Jones & Kammen 898-899). The ecological benefit of density is complex and highly nuanced reality, but offers insight into appropriate settlement patterns in the WUI: concentrating development limits the developed area. Conversely, concentrating WUI development limits the WUI area.



Figure 2 Defensible space comparisons

Detached, single family residences in California create a much more complicated WUI boundary than compact, multi family housing in Switzerland. Source: Google Earth.

This trend applies to whole communities as well as individual buildings. The potential for WUI expansion is almost limitless. Only 15% of the available land in the Wildland Urban Interface of the American West is developed (Gude et al., *Potential for Development* 201). Simulated development models show that utilizing settlement patterns that promote density, such as urban infill models, ultimately lead to drastically reduced WUI, both in geographic size and population, than settlement patterns that do not, such as linear expansion and leapfrog development (Paveglio et al. 26-30).

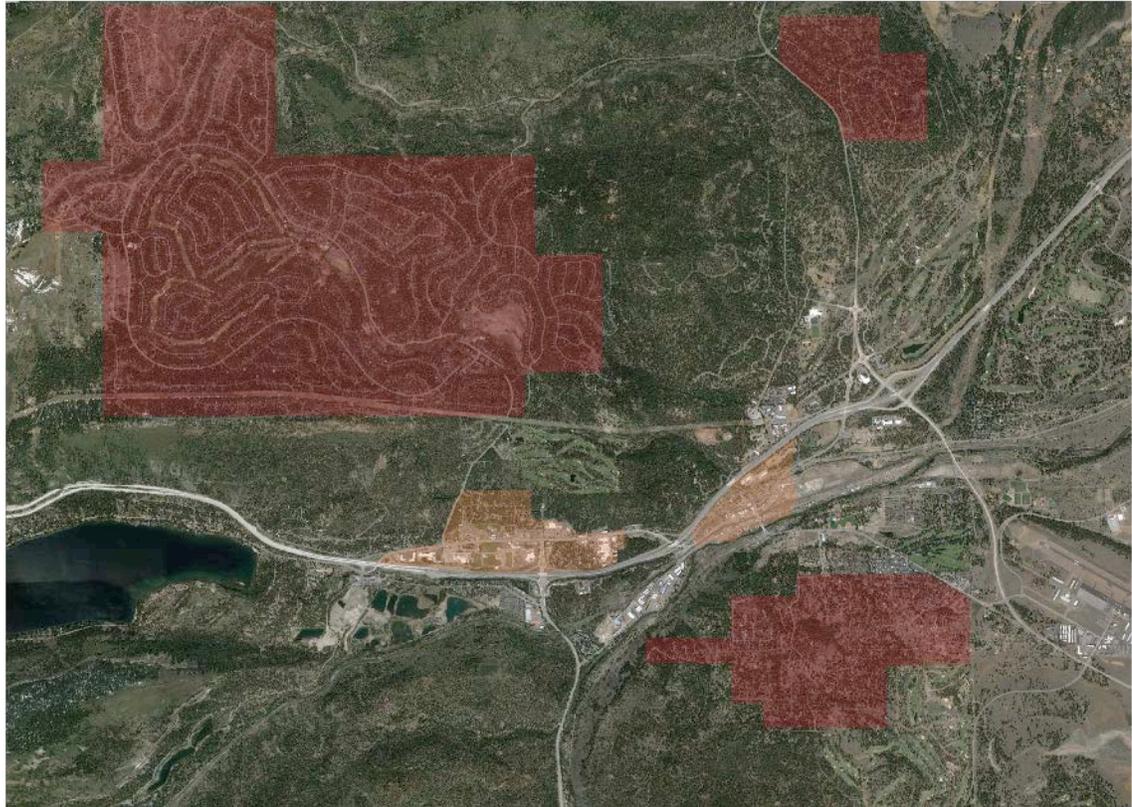


Figure 3 Leap Frog Developments

Leapfrog development (red) in Truckee, CA expanding away from the urban core (orange). This settlement pattern creates an extremely sprawled WUI, with fire impingement potential the continuous edge of each settlement in a highly fire prone, Ponderosa Pine fuel type. Source: Google Earth

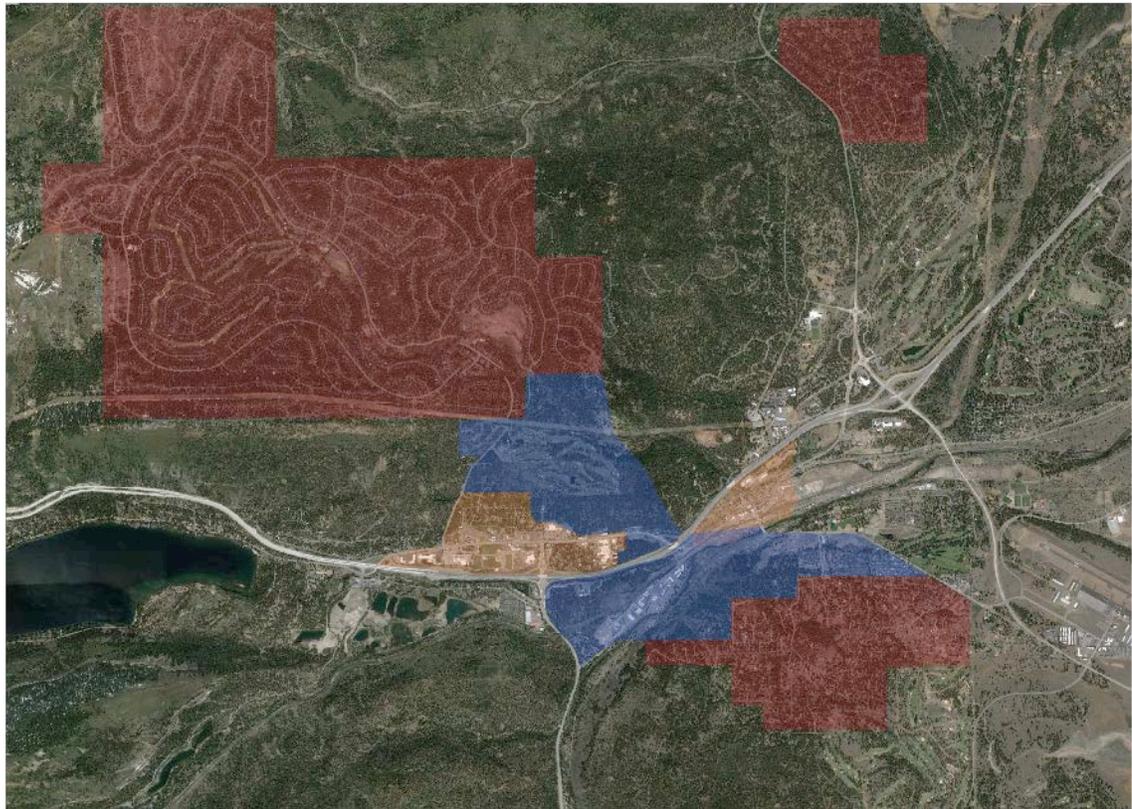


Figure 4 Infill Development

Developing (blue) areas skipped by leap frog (red) development patterns accommodates growth without expanding the size of the Wildland Urban Interface. Source: Google Earth

A denser WUI has many potential implications. House-to-house spotting<sup>9</sup> is one of the main causes of structure loss and damage due to Wildland Fire. It stands to reason that increasing distance between structures is an effective tool to reduce structure loss. Case studies of destructive fires have noted structure loss occurring more frequently at houses spaced less than 20 feet apart (Quarles et al., *Home Survival* 1-2; Quarles et al., *Lessons Learned* 10; Cohen & Stratton 1). This assumption naturally

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<sup>9</sup> *Spotting* is when airborne embers and firebrands ignite fires ahead of the main flame front, causing a *spot fire*. The potential for fires to spot is directly related to the climatic conditions favoring fire growth. Frequent spotting is one of the greatest dangers to wildland firefighters, as spot fires can cut off escape routes and grow back towards the main fire edge. Frequent spotting will often cause firefighters to withdraw from an area and re evaluate suppression tactics.

represents a substantial blow to the advantages of denser settlement in the WUI, but a more nuanced interpretation may yield a different big-picture result.

A ten year study of over 4500 structure lost to wild land fire in Southern California did not find a consistent correlation with housing density and structural loss (Syphard et al., *Housing Arrangement* 3-6). In many notable cases, structures ignited from airborne ember intrusion at distances over 1 kilometer from the fire source (Cohen, *Wildland Fire Threat* 192). It is true that the single most statistically advantageous defensive measure is a cleared area in immediate 10-20 meters surrounding a structure, known as the home ignition zone (Cohen, *Wildland Fire Threat* 191; Quarles et al., *Lessons Learned* 9-10). Subsequently, the combustion of a neighboring structure within this area would naturally be more threatening to a structure's survival than burning vegetation, as structures frequently have more potential to ignite other structures than vegetation, a phenomenon known as cluster burning.

The long-term perspective of Syphard et al. (2012) provides an example of the large-scale context necessary to analyze the most suitable settlement patterns in the Wildland Urban Interface. The possibility of cluster burning must be balanced with the negative aspects of a sprawled settlement pattern in the Wildland Urban Interface. Greater distances between structures lend themselves toward increased accessibility challenges for wildland firefighters. This problem is particularly pertinent to firefighters defending structures against an incoming fire front. Crews must work in smaller teams on foot, but have vehicles staged nearby to facilitate a timely retreat should the flame front overrun the area. The increased potential of structures to ignite other structures

associated with denser settlement patterns is substantially offset by the difficulty of protecting even a moderate number of widely spaced structures. Additionally, cost sharing of preventative fuel reduction exercises is necessarily smaller per capita in denser areas: more residents pay less for the same amount of treatment. As such, the advantages widely spaced structures, inconclusive at best, are substantially offset by the implications of increasing sprawl in the Wildland Urban Interface.

Overall, the drawbacks of a less dense WUI are substantial, creating a larger area to cover with fuel treatment programs, a higher ecological impact, and more complex landscape for firefighters to navigate. In current fire suppression practices, a sprawled WUI will additionally lend itself to longer distances to safety zones for residents and responders. These factors, coupled with the somewhat limited advantages of higher structure spacing, ultimately support the advantages of a denser WUI, which should be considered a necessary change for a more fire adapted built environment.

### **The Social Reality of Planning in the Wildland Urban Interface**

The advantages of increasing density in the Wildland Urban Interface are clear, but the path to a denser WUI is not. It is unrealistic to evaluate the possibility of reversing a sprawled settlement pattern without acknowledging the substantial desire for secluded housing away from the city. The ideal of a detached house on a large lot still represents the ideal for many Americans (Bengston et al. 271). As individuals nominally choosing to live outside the confines of more developed urban areas, the importance of what decisions the inhabitants of the Wildland Urban Interface are

willing to support remains one of the most intriguing and potentially frustrating variables in when attempting to adapt to wildland fire regimes (Winter & Fried 34).

Land use ordinances, zoning implementations, and urban growth boundaries are all tools available to focus growth away from extremely fire prone areas (Bengston et al. 271-279). These policies are primarily determined by local governments, and as such, are substantially influenced by the land use attitudes held by elected officials-and their constituents. In many fire threatened communities in the WUI, the attitude towards land use regulation is strained at best, particularly in communities that perceive federal and state regulations as crippling local mining and logging industries. As such, more appropriate WUI land-use regulations will either be the product of a substantial shift in local ideology or a more grassroots movement supported by locals. Either way, increased education and understanding of the relationship between settlement patterns and fire danger is a necessary foundation for building wildland fire integrated communities.

## **Ignition Resistant Construction**

Thoughtfully designed communities are just one tool in the necessary design adaptations for a community in the Wild land Urban Interface. Careful community layout and regular fuel treatment projects are without a doubt necessary tools for the WUI fire adaptations, but are not nearly sufficient fire adaptation tools by themselves.

The smallest scale adaptation of the Wildland Urban Interface is the development and implementation of ignition resistant construction techniques. It is also perhaps the key component for a WUI more adapted to fire. To reduce suppression costs, fire managers must increasingly implement combined fuel treatments and wildland fire use, the cheapest forms of fire management. Adopting a more prescriptive implementation of wildland fire use and combined fuel treatment method in the WUI will rely on a much smaller margin of risk associated with fires burning closer to structures. For homeowners, policy makers, and resource managers, this drastically decreased risk must be equal parts economic and social. This change in perspective will likely only be achieved by a drastically decreased likelihood of structural ignition.

Thoughtful community planning and regular fuel treatments do not guarantee the survival of structures threatened by wildland fire. Furthermore, a homeowner most likely will not have a guarantee that the funding for fuel reduction projects will be available, or that their neighbors have done their part to protect their community from fire impingement. Each individual structure must do its part to reduce the potential damage incurred by fire.

Structures in the WUI must be able to stand on their own against fire impingement. Ordinances promoting water availability and means of ingress for response personnel assume wildland firefighters will be available to suppress a fire, or extinguish sources of ignition near a house. This is simply not the case. The erratic, explosive nature of extreme fire behavior often threatens structures before sufficient suppression resources are in place. Even if firefighters are present, fire activity may be too intense for firefighters to safely suppress structure fires, forcing protection personnel to abandon homes to fare for themselves (Mutch et al. 367).

Forensic analysis of structures destroyed by wild land fire paints a complex and nuanced picture of how and why fires burn homes. Contrary to what one might imagine, most buildings destroyed and damaged by wildland fire are not consumed by the huge flame lengths associated with extreme fire behavior. Fire behavior is commonly significantly reduced once fire enters developed areas, as continuous fuels are broken up and replaced by non-combustible surfaces, such as roads, driveways, and green lawns. Even the most vulnerable structures and landscapes will not burn with the speed or intensity of a running crown fire, as there simply are far less available fuels igniting at a much slower pace (Cohen, *Cerro Grande Fire* 3-6; Cohen & Stratton).

Home ignition and destruction is most often a product of low intensity fires, and in many cases the result of house-to-house spotting (Cohen, *Cerro Grande Fire* 3-6; Cohen & Stratton 1-3; Quarles et al., *Lessons Learned* 10). Many structures destroyed by fires ignite hours after the main flame front passed. In many cases, unburned fuels such as live trees and shrubs can actually be found in immediate proximity next to completely destroyed houses (Cohen & Stratton 16).

Fortunately for designers and homeowners, the palette of fire resistant construction materials is one of the most developed aspects of the building industry. In the United States, buildings are classified by the fire rating of their construction types, based on a rating system of I-V (International Building Codes Section 6). Designs to reduce smoke spread and flame conflagrations represent some of the most substantial driving forces behind the forms and character of much of the built environment. Naturally, life safety remains the unparalleled priority in any construction codes. Failure to obey poorly enforced and potentially underdeveloped thermal codes frequently lead to leaky walls and drafty buildings. Performance in these areas can be so poor that buildings have to be re clad or town down, often resulting in litigation. Buildings that do not meet fire code are not granted the same amount of understanding or disinterest, as code compliance is mandatory and negligence that leads to deaths can result in imprisonment. Not surprisingly, fire codes are some of the most developed, and more importantly, enforced regulatory tools in the building industry. As a result, many of the construction materials used in the United States are specifically developed due to their fire resistance, such as gypsum board sheathing, or drywall.

WUI building codes are not nearly as developed. California is the home to the largest number of houses threatened by wildfire in the United States, and is first state to have developed statewide WUI code (Theobald et al. 340). California WUI codes are currently 3 pages long. To put this in perspective, the total California fire code is 581 pages long (not including the appendix) (California Fire Code). Content is limited, generally specify ignition resistant siding and protecting soffit vents with ¼” mesh. International Building Codes are at a similar level of development, specifying tempered

glass windows, 1 hour rated exterior sheathing, and enclosure of all underfloor areas (International Building Codes Section 5).

Limited data as to the success of these codes is available. The County of San Diego began requiring and progressively updating WUI codes beginning in the early 1980's. The 2003 California Firestorm destroyed 2,137 of 15,000 homes threatened by the fire, destroying some 14% of effected homes. 400 of the homes in the affected area were in compliance with the newest WUI codes. Of these homes, only 17 were destroyed, representing 4% of the code-current structures (San Diego County 1). The County goes on to claim, "homes built under recent codes have a more than three times better chance of survival" (1). This indication may very well be indicative of actual performance benefits associated with the new codes. It could just as easily be caused by deviations in fire severity across the flame front. In reality, there is no way to determine the exact level of exposure each threatened structure.

Ignition resistant construction is without a doubt an effective measure to defend buildings from wildland fire. Some case studies of large loss fires indicate that ignition resistant construction is the most important variable determining a structures chance to survive fire exposure (Cohen, *Wildland Fire Threat* ; Cohen & Stratton). The underdeveloped nature of ignition resistant construction methods requires a careful analysis of the suitability of different possible ignition resistant enclosure systems. This requires a holistic approach that addresses the entirety of the social and environmental factors that determine the suitability of particular building practices.

## **Ignition Resistant Construction: Satisfying Diverging Requirements**

The performance requirements of “traditional” fire codes have created an enormous toolbox of fire resistant materials available to the modern designer. Nominally fireproof construction methods, such as Type I & II assemblies are virtually assured success in resisting ignition from external wildfire impingement. Though constructing concrete and steel “bunkers” may be technically an option, ignition resistant construction must be accessible to the average homeowner, and retain as much of the building techniques typically practiced. Subsequently, ignition resistant construction must be applicable to dimensional wood framing- far and away the most common form of residential and small-scale construction. This acknowledgement represents the culmination of the economic and social realities of the building industry in the United States and an understanding of the diverging requirements of construction assemblies for small-scale residential construction as well.

Fire performance is crucial, but must be balanced with other important considerations determining the total overall value of each component. A structure threatened by the most regular fire return intervals will only be threatened by wildfire a handful of times a decade, and must perform accordingly. The same building will face more traditional environmental stresses every day. Even in times of exceptional drought and dry weather associated with increased wildfire risk, a buildings envelope must still shelter against weather, facilitate drying, provide thermal comfort for the occupants, and protect interior structure and finishes, among other demands. It is inappropriate to justify decreasing thermal performance to increase fire performance, which hasty applications of concrete would virtually assure in most climates. Ignition resistant

construction techniques must also be easily adaptable to retrofit existing structures in the Wildland Urban Interface. This demands a degree of interoperability with the existing envelope systems being used- once again, primarily wood construction.

### **Developing an Ignition Resistant Methodology**

Fortunately, the solution to ignition resistant wood construction may readily be available. Dimensional lumber, or “stick frame” construction typically seen in the majority of stand alone housing in the United States is already designed to be sheltered from damaging forces. Milled wood is not waterproof, pest resistant or particularly resistant to ultra-violet degradation. The durability of wood framed construction is entirely dependant on protecting wood framing from damaging forces. These protections are referred to as “control layers”. A typical wall assembly utilizes several control layers designed to manage the infiltration of liquid water, thermal transfer and moisture/condensation management. Some parts of a building’s assembly, such as an insulated glass unit (IGU) manage each control layer in a single material. For most of the wall, specific materials are applied to manage each control layer. As previously mentioned, the building industry is already well stocked with fire resistance tools. These can easily be applied to a wood framed structure to prevent conflagration due to flame impingement.

## Ignition Resistant Construction: Shedding Surface

The first line of defense against flame and ember infiltration is a durable shedding surface on the exterior of a building's envelope system. For weather infiltration, this is a task accomplished by exterior cladding, such as lapped siding on walls, and roofing shingles. Cladding serves multiple roles in an enclosure. As the exterior an enclosure assembly, cladding provides the aesthetic articulation of a building, such as shingle or lap siding, or asphalt roofing tiles versus terra cotta shingles.

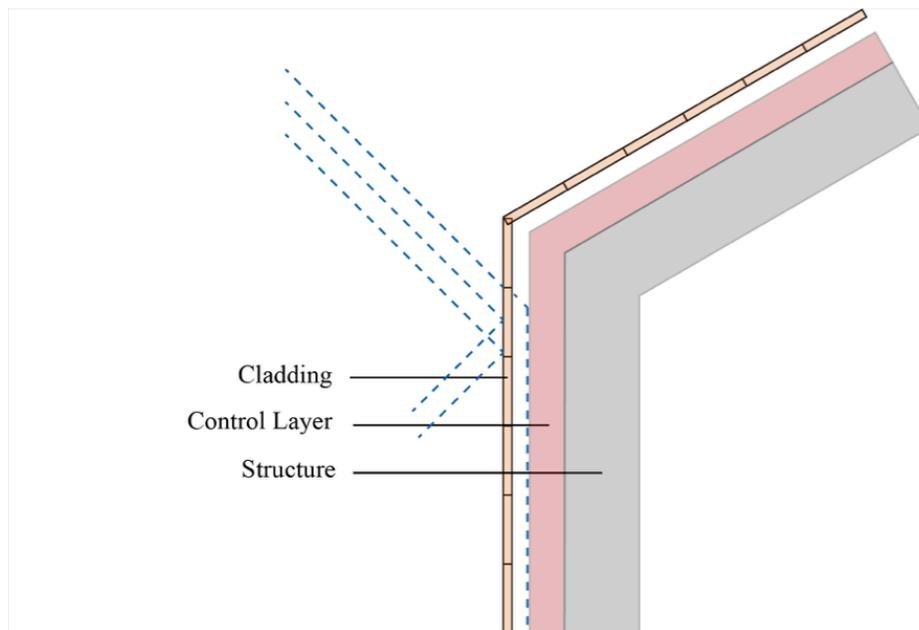


Figure 5 Control Layers.

Exterior Cladding deflects the majority of rain, but weather management is ultimately handled by a barrier inside the wall envelope. Graphic by Author.

Cladding also provides durability for an assembly, protecting the more sensitive control layers underneath from abrasion and ultra-violet degradation. Known as a shedding surface, the cladding of a building will provide deflection against the vast majority of moisture infiltration, deflecting rain and snow before it can penetrate deeper into a wall assembly. Cladding can easily serve the same role in ignition resistant construction. Ignition resistant cladding is not only available, but also comparatively economical. Products such as fiber cement siding are sometimes more prevalent than natural wood siding, extremely durable, and generally aesthetically acceptable as an alternative to more ignition prone substances. Roof cladding, such as terra cotta shingles, and asphalt shingles are extremely fire resistant, and both can be integral parts of Class A, or noncombustible assemblies, achieving a high degree of ignition resistant with proper installation.

### **Ignition Resistant Construction: Ember Control Layer**

An effective shedding surface is the first line of defense against ember intrusion in ignition resistant construction. Similar to a weather-shedding layer, an ember-shedding surface alone does not adequately guarantee a wall assembly will survive ember intrusion. A secondary control layer must be present to protect flammable material further inside the wall assembly, in what will be the final ember control layer.

This second control layer must act as an ember control layer as opposed to the shedding surface. It will act as the final barrier for ember infiltration, stopping potential ignition sources before they come in contact with flammable materials. Traditionally,

the final barrier for weather intrusion is thin wrapping substance—often called a paper or wrap.

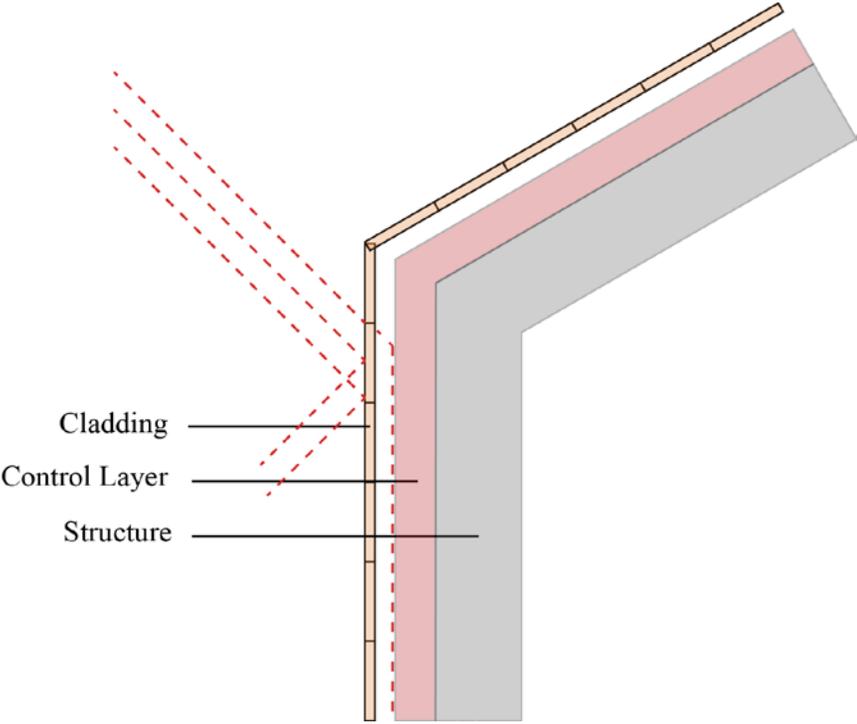


Figure 6 Ember Control layer

Ember control acts just like water control. Exterior (ignition proof) cladding deflects the vast majority of embers, but an interior control layer provides the critical last point of defense. Graphic by Author.

As building sciences develop, the options for weather barriers have become abundant. Waterproof membranes have evolved from simple wraps to a myriad of other forms, such as peel-and-stick, spray and roller applied liquids, and a variety of other options. Whether traditional barriers, such as building felt, or cutting edge products, the role of the weather barrier remains the same: to be the final control layer against weather intrusion.

Controlling ember intrusion does not have nearly the same amount of specifically designed products to complete the exact task. That being said, the development of fire-resistant building materials previously outlined provides a number of options that are capable of stopping embers from advancing further into a wall assembly.

## **Testing the Perfect Wall: Adapting Best Practice Construction to Exterior Fire Impingement**

Building envelopes in the Wildland Urban Interface must perform traditional (non-fire) assembly requirements to the fullest extent. As such, it is necessary to explore the suitability of a drainage cavity wall, known as the “perfect wall” for fire-adapted construction. Advancement of building science and an increasing understanding of the thermal realities of wall assemblies led to the development of what is colloquially known as “The Perfect Wall” (Lstiburek, “The Perfect Wall”).

The Perfect Wall, also known as a rainscreen, or drainage cavity wall, is a general wall assembly schematic designed with the understanding that control layers should be removed from the structure of an enclosure. Traditionally constructed walls present in the overwhelming majority 20<sup>th</sup> century stand alone houses, place insulation in between the studs in a wall cavity. A layer of sheathing is then applied to both sides of the cavity, with the WRB occurring on the outside layer of the external sheathing, and then covered with a siding for protection.

While almost ubiquitous in many parts of the United States, this assembly has notable weaknesses. Placing insulation inside of the WRB means that the first cold surface, and the condensation that comes with it, will occur inside the wall cavity itself. In some climates, this mandates a moisture control layer specifically placed to remove the moisture from the air as it passes into an opaque wall. This usually requires a vapor barrier, such as a visqueen sheet located on the inside of a wall. The Perfect Wall also utilizes the potential for continuous exterior insulation, providing substantially increased whole-wall thermal performance over wall with similar components.

Determining the suitability of the Perfect Wall for the Wildland Urban Interface reveals one potential weakness: the drainage cavity itself. The drainage cavity, a continuous shaft of vertical air, is extremely useful for drying out an enclosure assembly, allowing free air movement up and down an exterior cavity. Fire needs three ingredients: fuel, heat and air. Continuous air movement, excellent for drying, is also extremely conducive for fire growth. This is not surprising, as air supply is one of the determining factors for combustion. Limited research, as well as common sense, reveals that continuous air cavities lead to an increased flame spread through exterior cladding, as well inside the air cavity, when compared to traditional enclosure assemblies with no air gap present (Quarles, “Conflicting Issues” 6).

Though continuous drainage cavities allow free movement of air, and therefore embers (and potentially flame) the obvious advantages of drainage cavity construction are too substantial to be written off. Instead, designing ignition resistant construction in the Wildland Urban Interface must utilize the tools available to negate the inherent fire disadvantage of a drainage cavity.

Fortunately, designers and homeowners in the WUI can simply repurpose the existing control layer strategies in drainage cavity construction to negate the potential for flame spread. Similar to weather barriers in a drainage cavity wall, the exterior cladding only acts as a shedding surface. Though the majority of exterior water infiltration is deflected, the assembly assumes that a significant amount of water will enter the wall beyond the shedding surface, to be blocked by the actual weather barrier further inside the wall assembly. Designing for ember intrusion can very much follow the same strategy. Embers will progress past the exterior cladding, and must be

met with a control layer on the interior side of the drainage cavity. This necessitates that every material on the exterior side of the final ember control layer must be nominally ignition proof, which is a relatively simple demand with a number of economical options available for each layer.

### **Testing the Perfect Wall for Wildland Fire Performance**

In order to prescribe the suitability of “The Perfect Wall” for the WUI, testing must be done to corroborate the performance of the whole wall system in simulated fire exposure scenarios. There is currently limited publication on whole wall performance under simulated wildland fire conditions. One simple test, modeled after the CA SFM Standard 12-7A-4 and ASTM E 108 is a simple “burning brand” test, using a 12” x 12” simulated fire brand burned in direct contact with the wall (Calfire 2009). A Class “A” brand is a relatively simple test method meant to replicate the possible exposure to large firebrands that can very easily be deposited on a structure in an event of considerable fire activity, an event that any structure located near a very active flame front could be exposed to, even if the defensible space surrounding the building is in immaculate condition.

Semi-rigid stone wool insulation was selected as the tested ember control layer. Stone wool is a commercially available insulation product, seeing increasing use due to a high level of durability, high r-value per inch, and non-combustible nature (Lstiburek, “Rocks Don’t Burn”).

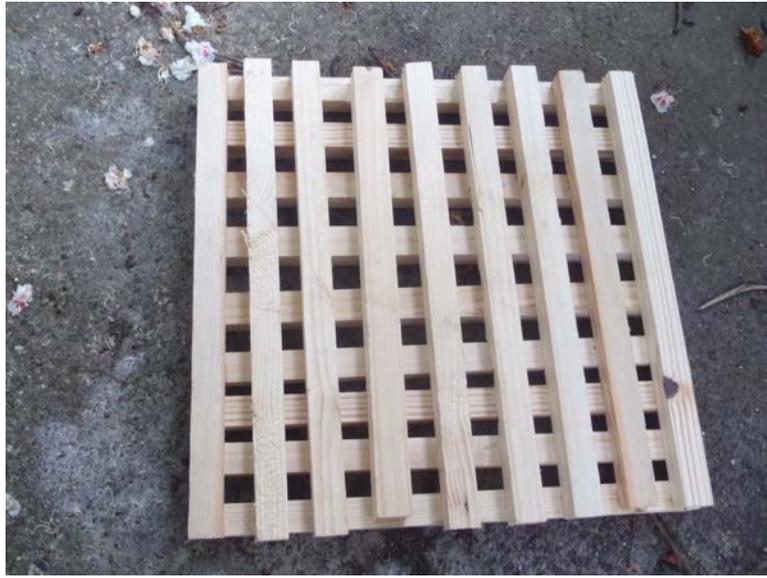


Figure 7 Class "A" Firebrand. Photo By Author

## **Methodology**

Two 2' x 4' section of traditionally framed, 24" on center 2"x4" wall were constructed for both wall assemblies being tested. Both walls used identical, non-combustible lap siding to compare wall performance when exposed to flame and embers that have penetrated the exterior shedding surface. The control wall (Figure 8), meant to simulate traditionally assembly techniques, was constructed with exterior fiber cement siding over a layer of plywood sheathing. The test wall (Figure 9) was constructed with exterior fiber cement siding, 1" x 3" furring strips, and a 1" thick continuous layer of semi-rigid stone wool insulation. Both brands were ignited and allowed to burn out, and did so in roughly 20 minutes. The test was conducted twice, outside in Portland, Oregon. Temperature and relative humidity (RH) recorded were 64 degrees and 61%

RH for the first experiment, and 66 degrees and 56% RH for the second experiment.<sup>10</sup>

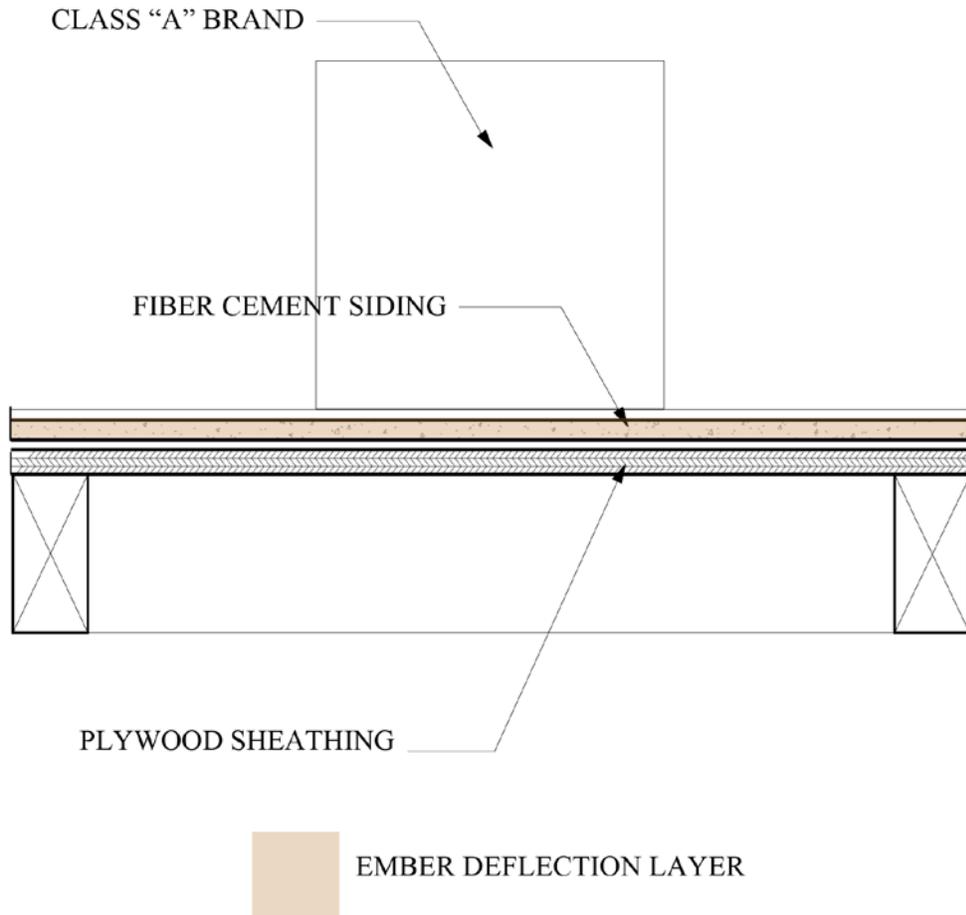


Figure 8 Control Wall Diagram. Graphic by Author.

<sup>10</sup> Temperature and relative humidity are the two factors with the most direct correlation to fire behavior, as well as how “available” fuels are to burning.

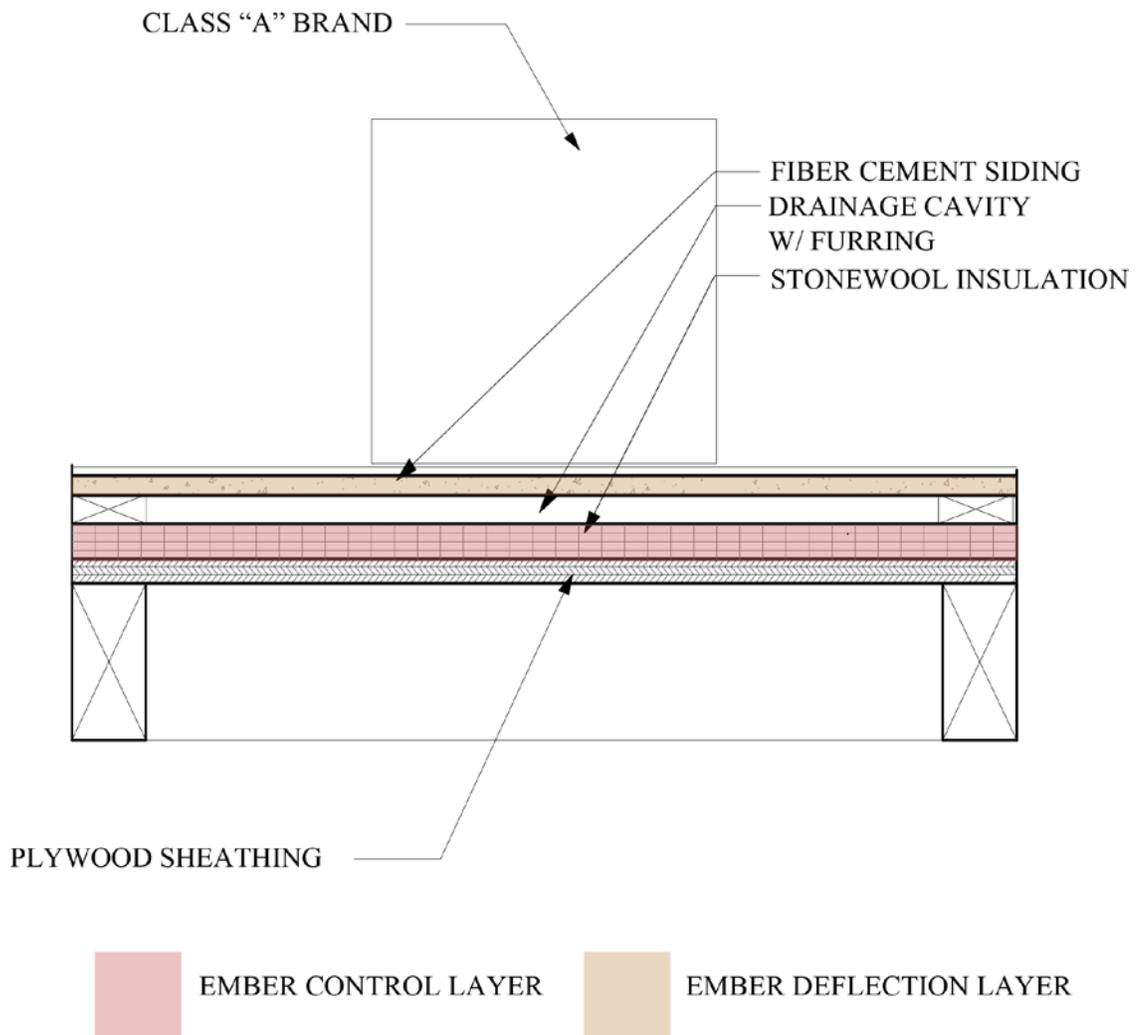


Figure 9 Perfect Wall Test Diagram

The furring strips used in the experiment were untreated lumber. In real world application, non combustibile materials like metal or fire retardant treated wood are much more appropriate, as furring members are outside of the ember control layer.

Graphic by. Author.

## Results

Both walls performed as anticipated. The ignition resistant cladding (a very commonly used fiber cement lap board) did not ignite, but did not act as a barrier to flame and ember impingement on its own. Both wall assemblies showed signs of fire impingement past the exterior cladding. The control wall experienced damage to the

exterior sheathing layer, (Figure 11) which smoldered for approximately 4 minutes before going out on its own. The test wall showed no signs of flame impingement, indicating the success of the ember control layer. (Figure 12)

## **Discussion**

The success of the rain screen wall in these conditions represents an interesting starting point suggesting the improved fire performance of fire-resistant rainscreen construction. The considerable differences in performance of the two wall assemblies demonstrates a substantial difference in wildland fire performance, with stone wool/rain screen construction showing considerably superior resistance to external fire sources. The indicated ability of protecting flammable construction components with non-combustible materials that simultaneously increase traditional performance is extremely applicable to the millions of wood framed houses in the Wildland Urban Interface. It is also important to note the conditions the test was conducted in are substantially less conducive to flame propagation that would be encountered in a wildfire environment. The relative humidity and temperature recorded represent enormous departures from the conditions present in fire environments. The damage to the control wall in the experiment conditions would have been much worse in hot, dry fire conditions, and could have very likely led to complete building destruction.

Only 1” of exterior rock wool insulation was used, with the intent of increasing thickness if damage to the siding occurred behind the rock wool layer. The testing of additional thicknesses were not required, as the 1” thick insulation proved sufficient in the testing circumstances.

Rain screen construction, or the “Perfect Wall” represents the current best practices for building construction, providing superior performance to cavity walls of comparable materials. These advantages may be negated by failure to perform in a wildland fire context, as the potential for ember intrusion represents another environmental stressor that a buildings enclosure system must account for. Few enclosure failures jeopardize envelope integrity as completely as combustion. Evidence that rain screen construction of the correct materials could increase the ignition resistance of an enclosure system, while at the same time additionally increasing the enclosures performance in more traditional categories, is extremely compelling. No building ordinances are enforced as successfully as fire codes, and the potential for inclusion of rain screen construction in mandatory construction practices represents a rare, compulsory implementation of high performance construction techniques.

Though evidence in favor of fire-resistant wall cavity construction is compelling, the extremely limited scope of this particular study is certainly not enough data to mandate any changes to construction ordinances. The substantially qualitative nature of this study merely represents an intriguing foray into a complex issue. A series of much more concise and controlled tests, and eventual real world observation are in order to deliver a final verdict. Regardless, the finding that exterior rock wool insulation may in fact increase an assembly’s resistance to ember intrusion is extremely promising.



Figure 10 Class "A" Brand Burning

The white outline indicates the damaged area behind the sheathing. Photo by Author.



Figure 11 Control wall Sheathing (left) and rainscreen sheathing (right)

The control wall experienced damage to its exterior sheathing where the building wrap would be located in traditional construction. Assuming the fire was extinguished, this damage to the building's envelope would have caused potential mold and decomposition on the effected wall. The rainscreen wall showed no damage. Graphic by Author.

## **Applying Lessons Learned: Detailing Ignition Resistant Construction**

One of the most promising applications of an ember control layer is the versatility with which it can be applied. New construction can utilize this approach from the beginning of construction, establishing the specific envelope goals for fire defense. Retro-fitting existing structures naturally presents more constraints, but still leaves designers and homeowners a number of options to drastically reduce the ignition potential of a structure. The application of an ember control layer can take place in many different wall assemblies, and is possible in virtually every scenario. All wall assemblies analyzed will assume ignition resistant siding, the necessary first steps towards ignition resistant design.

## Existing Condition: Standard Residential Wall Assembly

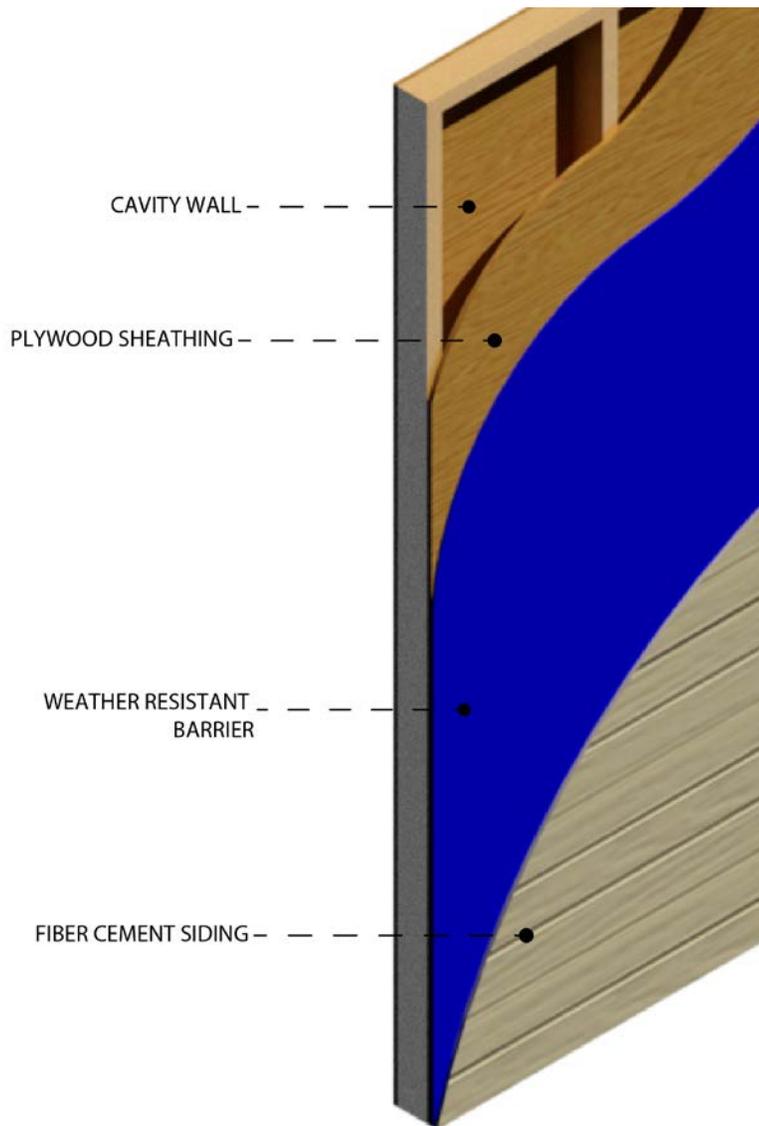


Figure 12 Standard Residential Assembly

Standard dimension lumber framing with cavity insulation. This assembly will be used as the standard assembly in need of an ignition resistant retrofit, assuming the presence of non combustible siding (a condition that would be the first step toward ignition resistance). Graphic by Author.

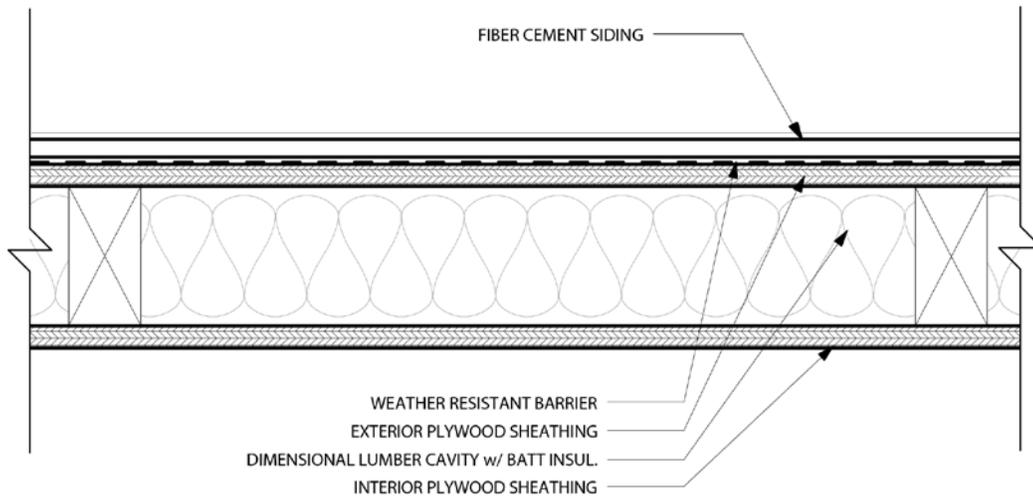


Figure 13 Existing condition wall assembly

The standard wall assembly in the majority of homes in the WUI. The exterior fiber cement siding will repel a majority of embers, but will not ensure home survival.

Graphic by. Author.

## Standard Residential Wall Assembly: Fire Rated Sheathing

Cost: \$\$

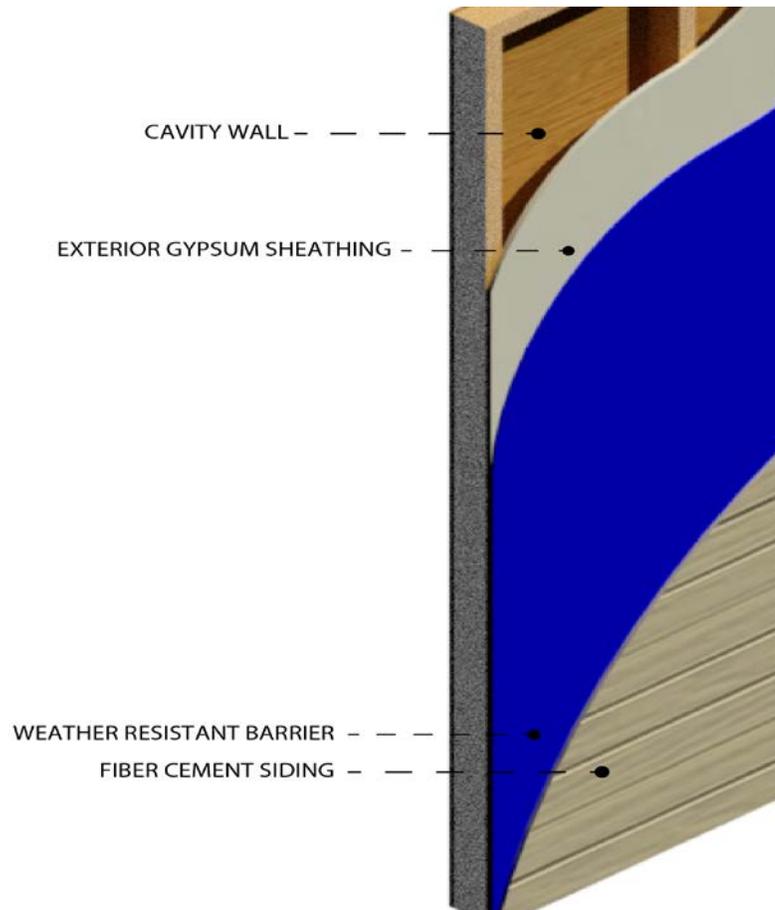


Figure 14 Standard wall assembly with fire rated exterior siding

This wall represents an increase in ignition resistance from the standard wall assembly. It is also the assembly prescribed by existing building codes. Unfortunately, the ember control layer, the exterior gypsum board sheathing, will not protect the Weather Resistant Barrier, potentially jeopardizing the enclosure with fire impingement. The limited advantages of only adding exterior gypsum sheathing do not justify the effort and cost to retrofit a structure with this assembly. Construction requirements involve stripping the cladding, building wrap, flashings and potentially windows. (depending on construction) just to replace the sheathing- adding no non-fire performance increases and probably mandating complete replacement of all affected materials. This assembly meets existing WUI codes. Graphic by. Author.

## Retrofit with Rain Screen Assembly

Cost: \$\$

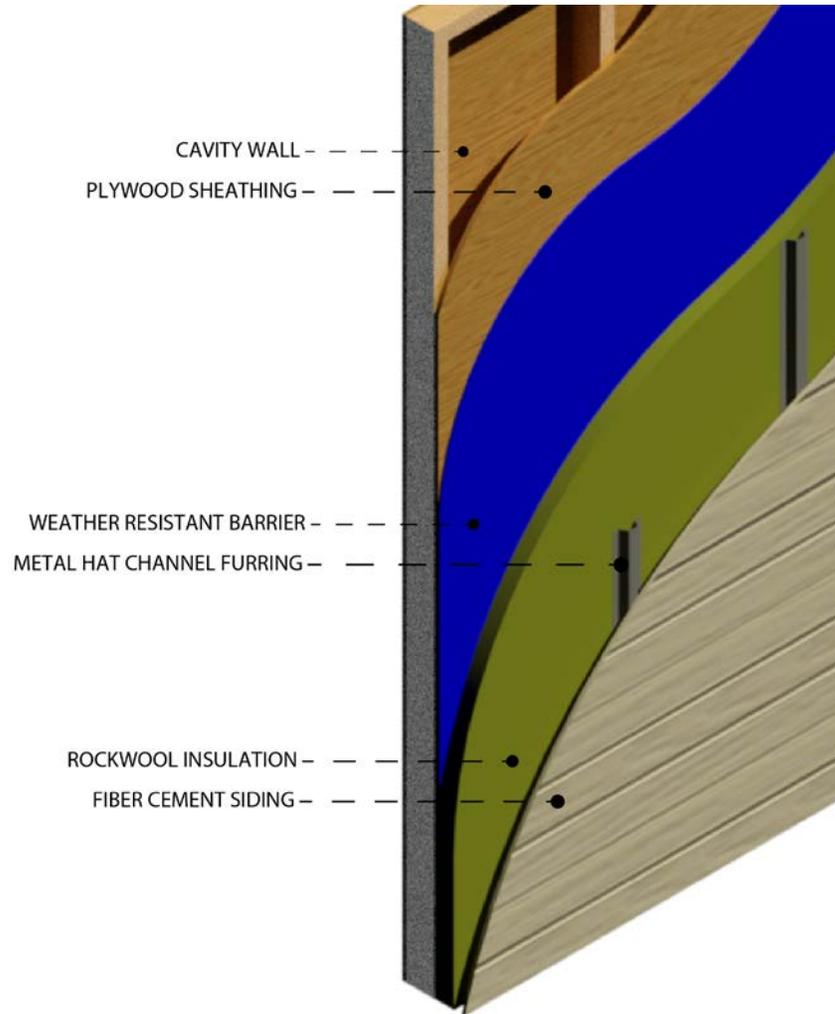


Figure 15 Retrofit with rainscreen assembly

Continuous external stone wool insulation provides both increased fire protection as an ember control layer and substantially increased insulation. Applying 2" stone wool will effectively double the walls insulation. Metal furring is used since they are located outside the stone wool, and will be exposed to fire. Metal furring can potentially be substituted with fire retardant treated dimensional lumber. A substantial advantage of adding a Rain Screen Wall is the potential to save the existing sheathing and building wrap, substantially reducing labor and material costs. Graphic by. Author.

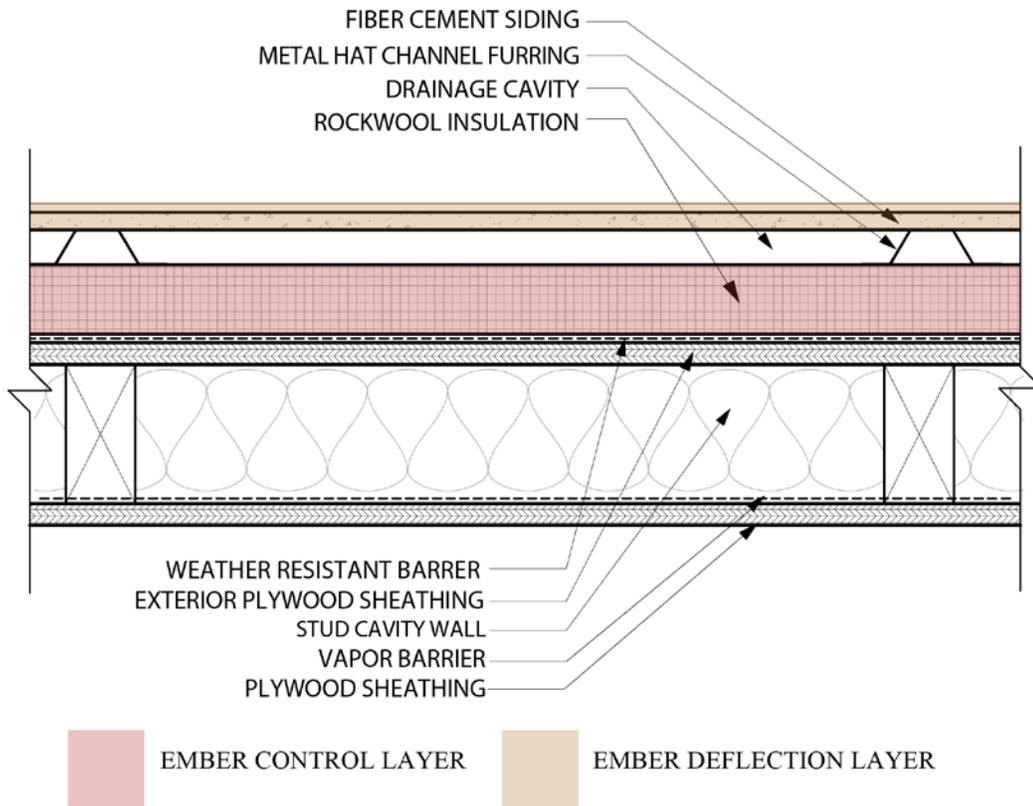


Figure 16 Retrofit with rainscreen assembly

Adding a continuous stone wool insulation layer greatly improves the walls thermal performance, as well providing an ember control layer. If the existing wall is in good condition, every layer interior of the continuous stone wool can remain from the original wall assembly. Graphic by. Author.

# Retrofit with Rain Screen Assembly With Fluid Applied Silicon Membrane

Price \$\$\$\$

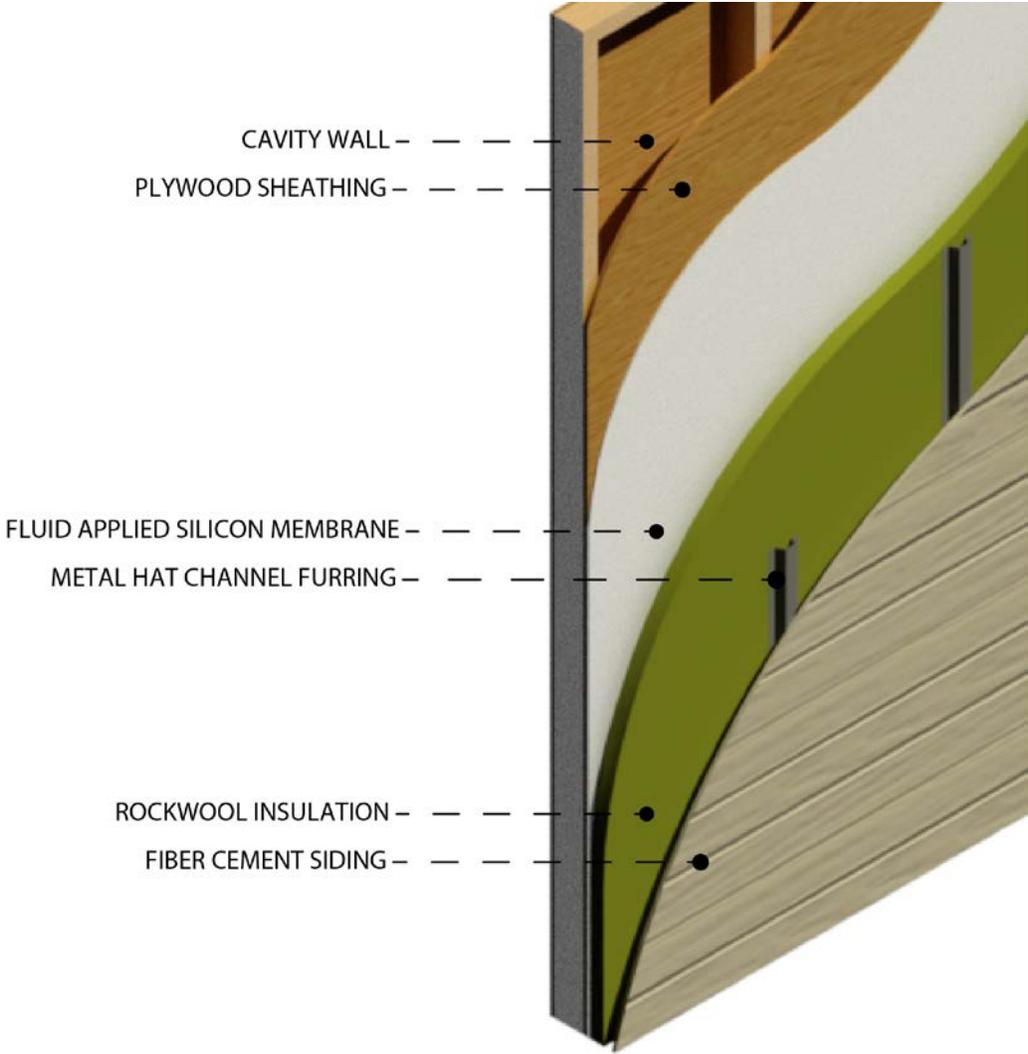


Figure 17 Rainscreen retrofit with liquid applied silicon membrane

Application of a liquid applied silicone membrane adds a secondary ember control barrier. Liquid applied silicon membrane is a class “A” rated fire resistant air and water barrier, offering top of the line air and water barrier performance, while also stopping flame spread. As one could expect, it is prohibitively expensive for many homeowners. Graphic by. Author.

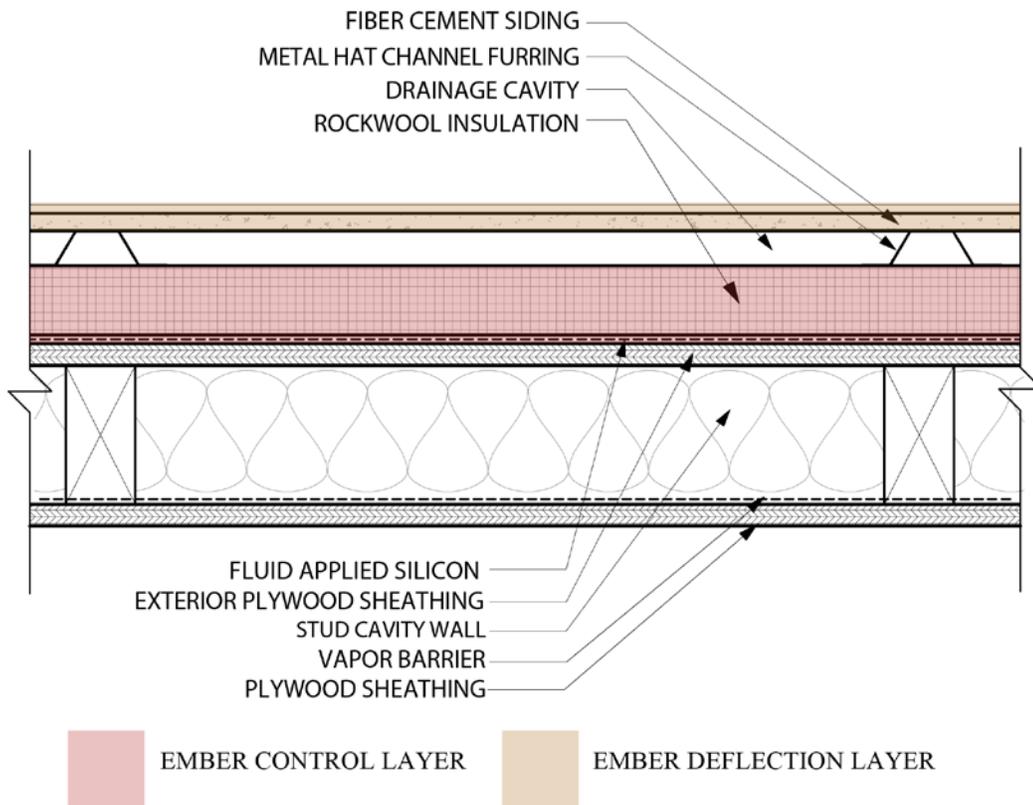


Figure 18 Rainscreen retrofit with fluid applied silicon

The addition of a fluid applied silicon membrane provides a continuous back up to the mineral wool insulation. When installed correctly, a class “A” rated fire control layer would cover the entirety of the wooden structure. It also represents one of the most high performance products available, providing unmatched air and water barrier performance. Unfortunately, the addition of a fluid applied membrane substantially drives up material costs and requires a higher degree of technical knowledge, further decreasing the potential consumer group for this assembly. Graphic by. Author.

## The Ideal Ignition Resistant Wall

Cost \$\$\$\$\$

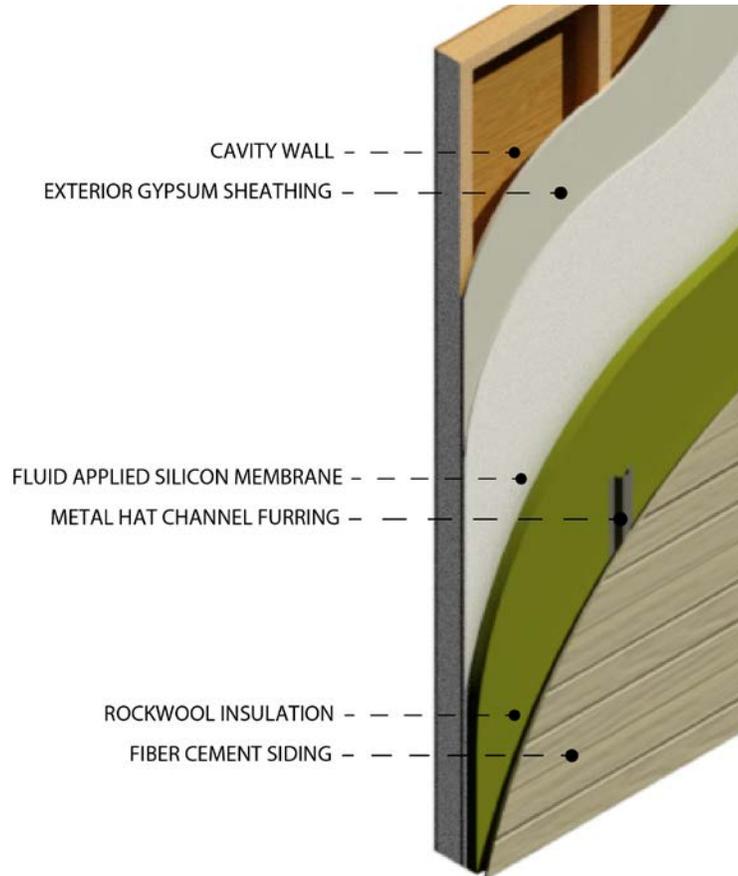


Figure 19 The ideal ignition resistant wall assembly.

The ideal WUI enclosure adds fire rated gypsum for exterior sheathing, adding another redundant protection against flame impingement. This enclosure strategy features a total of 3 defenses against ember and flame intrusion. It is the most expensive option, and the increased difficulty in replacing the original plywood sheathing with fire rated gypsum board may not be justified for a redundant layer. Overall, the assembly achieves an ideal level of fire performance. Graphic by. Author.

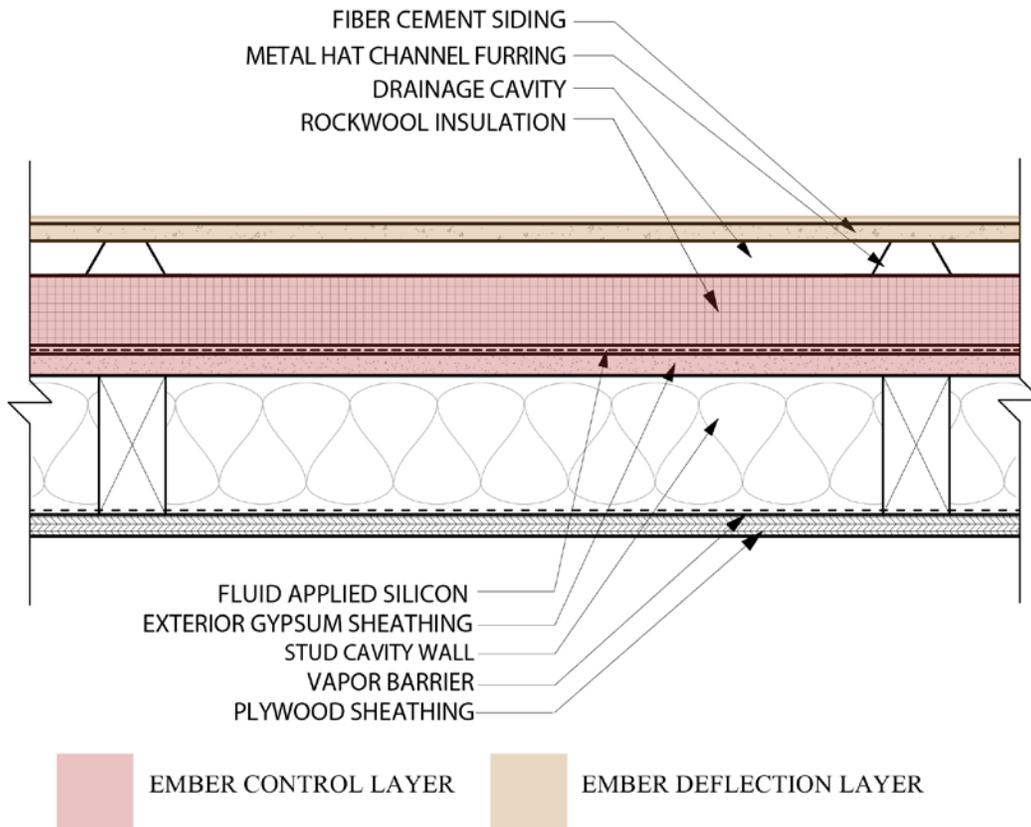


Figure 20 The ideal ignition resistant wall assembly.

Utilizing three potential ember control layers behind noncombustible cladding delivers an extremely fire resistant wall. The addition of exterior gypsum board sheathing has limited value as a retrofit option, but represents an excellent assembly for new construction. Graphic by. Author.

### **Ignition Resistant Construction: Ember Control Layer for Eave Walls**

Once an effective palette of ignition resistant construction techniques have been developed, designers must locate the most vulnerable areas in an enclosure system, and adjust the building assembly accordingly. One of the most vulnerable areas of an enclosure system exposed to ember intrusion is the vented soffit, located on the

underside of a roof overhang. Roof overhangs are one of the most effective climate management tools in available to designers, and provide effective climatic protection in virtually every climate. Roof overhangs simultaneously shelter the vertical façade from rain and snow, as well shade glazing from high sun angles, limiting solar heat gain (Gerner 23).

Venting at roof overhangs facilitates moisture management in the roof cavity. Effective airflow is also essential for preventing ice damming in cold climates, a very real challenge to much of the Wildland Urban Interface (Lstiburek, “Attic Ventilation” 50). Airflow from soffit venting is critical in hot climates as well. In wildland fire scenarios, the free flow of air into a building’s roof cavity means the threat of ember intrusion. Ember intrusion through soffit vents is one of the leading causes of ember related ignition, and installation of soffit vents will not stop all embers (Cohen & Stratton 2-3; Quarles, *Ignition Resistant* 4).

The application of ignition resistant construction techniques must recognize the substantial advantages of soffit ventilation. Unvented roofs are currently available, would require extensive retrofit for many typical 20<sup>th</sup> century houses. In many typical residential houses in the WUI, sealing off an attic designed for soffit venting virtually ensures moisture damage. If sealing off soffit venting is not an option, designers must plan for ember intrusion. The application of the ember control layer technique should help “catch” any ember intrusion through soffit vents, and protect flammable structural members further within the roof cavity, while still supporting air flow and ventilation.

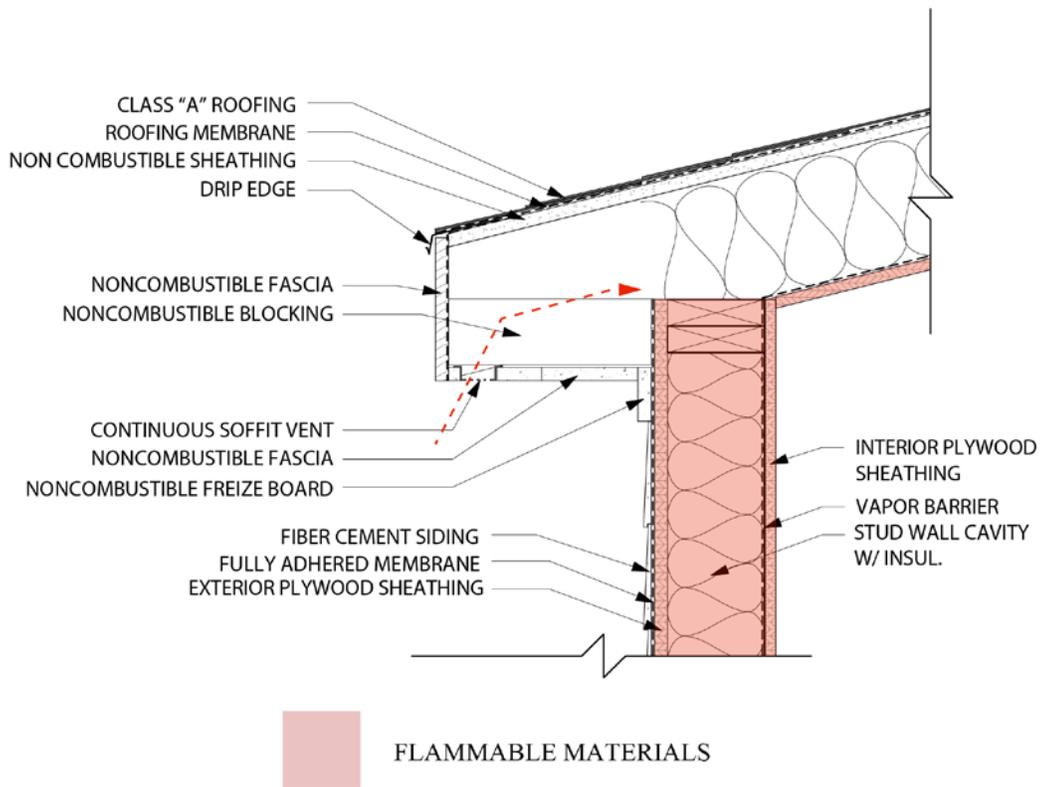


Figure 21 Ember intrusion through soffit vents.

Even though this assembly utilizes fire resistant components for every part of its exterior cladding, interior combustible members are still exposed to ember intrusion through soffit venting (seen as the red arrow). Graphic by. Author.

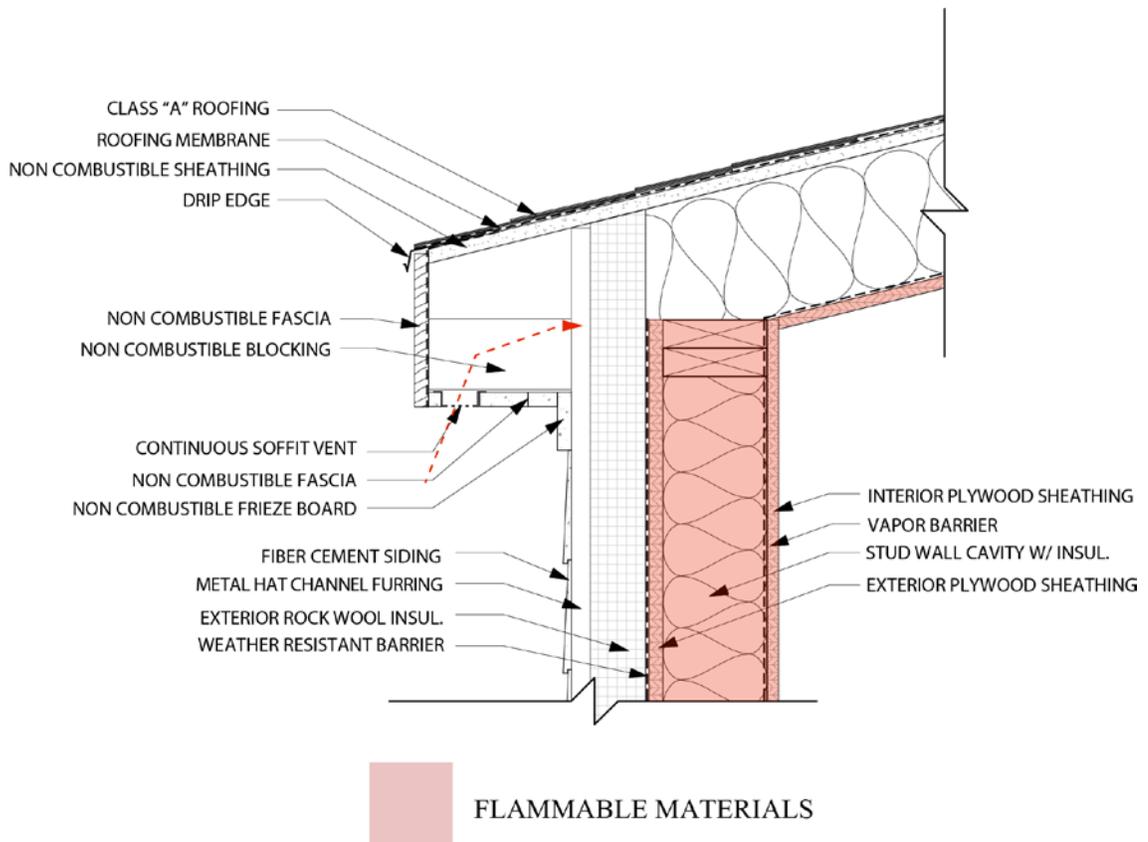


Figure 22 Utilizing the perfect wall to protect the roof cavity

Adding rain screen construction with continuous semi rigid rock wool insulation extended into the roof cavity acts as an ember control layer on the interior of the soffit vent. Careful construction must assure a “press fit” for the rock wool in contact with roof sheathing to minimize the chances of embers traveling past the rock wool and settling on flammable materials. Graphic by. Author.

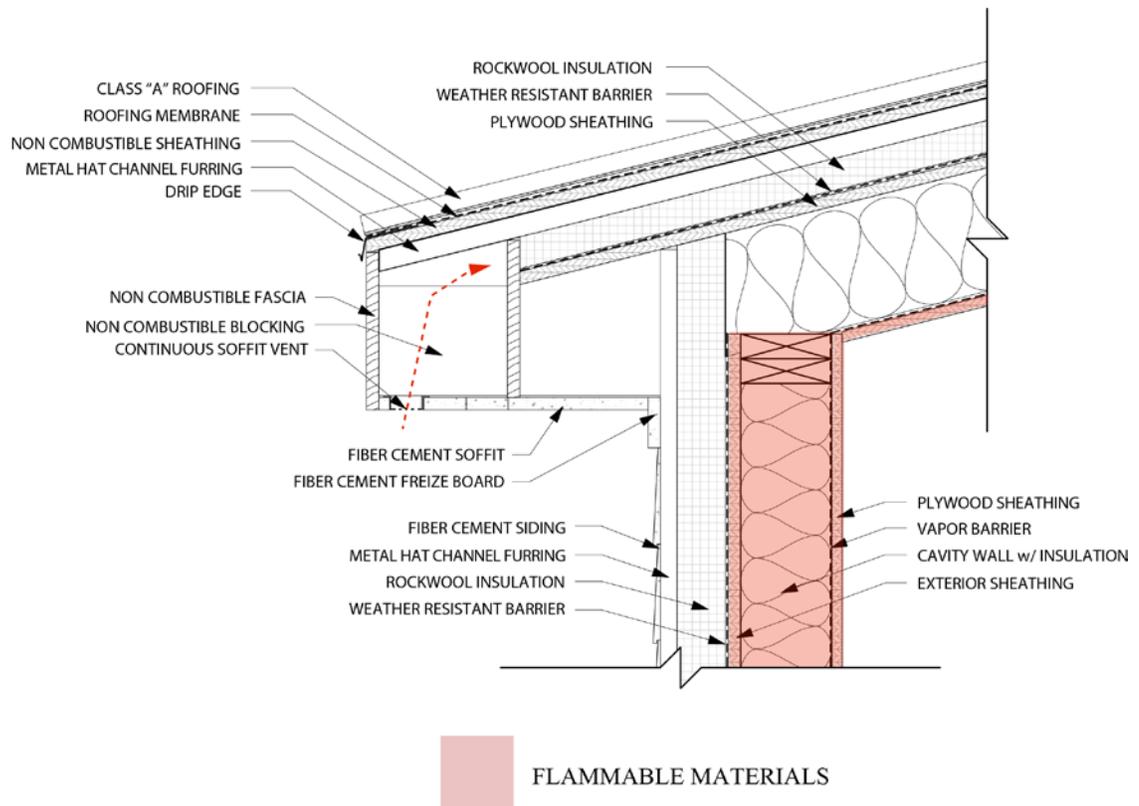


Figure 23 The ideal soffit assembly

Exterior continuous rock wool insulation is added to the roofing as well, facilitating continuous airflow through the furred air space, providing increased thermal and moisture performance while simultaneously sheltering all potentially flammable materials with several layers of fire protection. Graphic by. Author.

### Ignition Resistant Construction: Conclusions

The methods and approaches for ignition resistant construction included above are not comprehensive. In the building industry, there are many different ways to achieve a goal. The designer always has options. Designing building enclosures most suited to defend interior spaces and materials from external elements is often a practice

of identifying the specific challenges a building will face, and utilizing a kit of parts up to the task.

Wildland fire impingement merely represents another climatic pressure on the building envelope. The large variety of ignition resistant options for designers and homeowners assures that cost effective, ecologically responsible options are available to the millions of structures threatened by wildland fire regimes. The solution simply requires analyzing the specific threats posed by wildland fire impingement, and addressing them with the appropriate measures. Faced with the certainty of increased exposure to wildland fire, ignition resistant construction techniques may become as commonplace as seismic design in many cities in the United States. Until then, designers and homeowners will be most rewarded by a developed understanding of the threats posed by wildland fire, and be proactive in responsible mitigation.

## Conclusions

Climate change will be one of the greatest challenges of the 21<sup>st</sup> century. The built environment is tasked with simultaneously reducing its own ecological footprint and adapting to the changes in the natural world. For the 72,000 communities in the Wildland Urban Interface, the increased threat from wildland fire will provide physical, economic and social challenges that may fundamentally change the make-up of settlement located on the interstitial zone.

As wildland fire seasons get progressively more destructive, the need to fundamentally re-evaluate the fabric of communities in the WUI will become increasingly more apparent. Increasing destruction of homes and properties will play a larger role in the national discourse on adaptations to climate change. The increasing academic evidence supporting a departure from sprawling, hazard prone settlement patterns will become more pertinent as increasing wildfires run their course.

Substantial evidence confirms that a more appropriately designed Wildland Urban Interface is possible. Forest restoration practices, growth management and ignition resistant construction are individually effective in reducing the susceptibility of the built environment to destruction from wildland fire. Evidence supporting these trends will continue to emerge.

Academics and researchers can play an increasing role in the national discourse on fire management. Unfortunately, researchers are rarely policy makers or firefighters. Substantive shifts away from current WUI trajectories will require a fundamental change in consumer and voter understanding of appropriate ways to interact with wild

landscapes. Change in management perspectives must occur fire managers and firefighters. Climate change in the 21<sup>st</sup> century will substantially change the relation between wildlands and fire. For the communities exposed to these changes, adaption remains the only option.

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