

What is the Wildland Fire Threat to Homes?

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The threat of life and property losses related to wildfires is a significant issue for federal, state, and local fire and planning agencies who consider the mix of residential areas and wildlands. The wildland fire threat is part of the more general consideration of human development encroaching wildlands. The March, 2000 edition of the *Journal of Forestry* reflects this with urban encroachment and wildland fragmentation the principal subject with residential fire one of the specific issues (Cohen 2000). Presently, the wildland fire threat to homes influences fire management and protection policies at national and local levels.

The current national attention to the wildland fire threat to homes was initiated after 1,400 homes were destroyed in 1985 (Laughlin and Page 1987). In 1986 the National Wildland/Urban Interface Fire Protection Program, a multi-agency endeavor, was established. The Program has functioned to the present with sponsorship by the Department of Interior land management agencies, the USDA Forest Service, the National Association of State Foresters, and the National Fire Protection Association. This program also has an advisory committee associated with the multi-agency National Wildfire Coordinating Group. Recent Congressional attention to the wildfire related home fire loss problem indicates its national prominence.

The wildland fire threat to homes is commonly termed the wildland-urban interface (W-UI) fire problem. This and similar terms (e.g., wildland-urban intermix) refer to an area or location where a wildland fire can potentially ignite homes. Although the term "wildland-urban interface" generally defines a context, the term does not indicate the specific nature of the problem.

C.P. Butler (1974), a senior physicist at the Stanford Research Institute, coined the term "urban-wildland interface" and described the fire problem as follows:

In its simplest terms, the fire interface is any point where the fuel feeding a wildfire changes from natural (wildland) fuel to man-made (urban) fuel. ...For this to happen, wildland fire must be close enough for its flying brands or flames to contact the flammable parts of the structure (p.3).

In his definition, Butler provides important references to the characteristics of this problem. He identifies homes ("urban") as potential fuel and indicates that the distance between the wildland fire and the home ("close enough") is an important factor for structure ignition. How close the fire is to a home relates to how much heat the structure will receive.

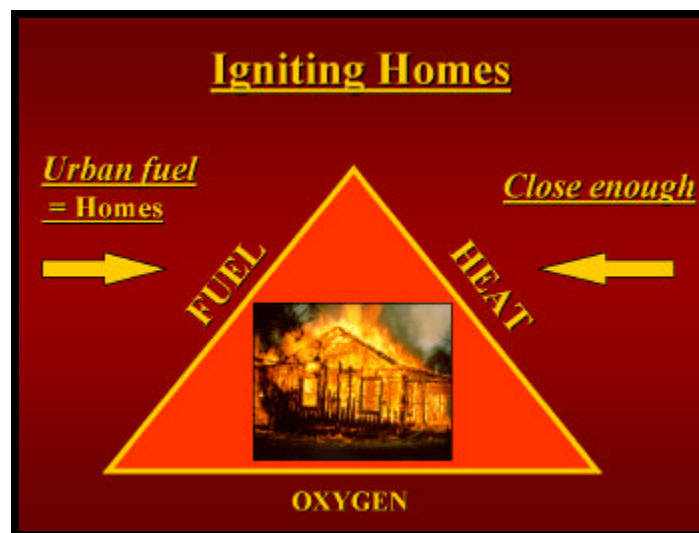


Figure 1— The W-UI context of the requirements for ignition.

These two factors, the homes and fire proximity, represent the fuel and heat "sides" of the fire triangle, respectively (fig. 1). The fire triangle--fuel, heat, and oxygen--represents the critical factors for combustion. Fires burn and ignitions occur only if a sufficient supply of each factor is present. By characterizing the home as fuel and the heat from flames and firebrands, we can describe a home's ignition potential. An understanding of home ignition potential provides a basis for understanding the wildfire threat to homes, and thus leads to reducing potential W-UI fire losses.

Ignition and Fire Spread are a Local Process

Fire spreads as a continually propagating process, not as a moving mass. Unlike a flash flood or an avalanche where a mass engulfs objects in its path, fire spreads because the locations along the path meet the requirements for combustion. For example, C.P. Butler (1974) provides an account from 1848 by Henry Lewis about pioneers being caught on the Great Plains during a fire:

...When the emigrants are surprised by a prairie fire, they mow down the grass on a patch of land large enough for the wagon, horse, etc., to stand on. They then pile up the grass and light it. The same wind which is sweeping the original fire toward them now drives the second fire away from them. Thus, although they are surrounded by a sea of flames, they are relatively safe. Where the grass is cut, the fire has no fuel and goes no further. In this way, experienced people may escape a terrible fate (pp. 1-2).

It is important to note that the complete success of this technique also relies on their wagons and other goods not igniting and burning from firebrands. This account describes a situation that has similarities with the W-UI fire problem.

A wildland fire does not spread to homes unless the homes meet the fuel and heat requirements sufficient for ignition and continued combustion. In the prairie fire situation, sufficient fuel was removed (by their escape fire) adjacent to the wagons to prevent burning (and injury) and the wagons were ignition resistant enough to not ignite and burn from firebrands. Similarly, the flammables adjacent to a home can be managed with the home's materials and design chosen to minimize potential firebrand ignitions. This can occur regardless of how intensely or fast spreading other fires are burning. Reducing W-UI fire losses must involve a reduction in the flammability of the home (fuel) in relation to its potential severe-case exposure from flames and firebrands (heat). The essential question remains as to how much reduction in flammables (e.g., how much vegetative fuel clearance) must be done relative to the home fuel characteristics to significantly reduce the potential home losses associated with wildland fires.

Insights for Reducing Ignitions from Flames

Recent research provides insights for determining the vegetation clearance required for reducing home ignitions. Structure ignition modeling, fire experiments, and W-UI fire case studies provide a consistent indication of the fuel and heat required for home ignitions.

Modeling. The Structure Ignition Assessment Model (SIAM) (Cohen 1995) assesses the potential ignitability of a structure related to the W-UI fire context. SIAM calculates the amount of heat (radiative and convective) transferred to a structure from a

flame source on the basis of the flame characteristics and the flame distance from a structure. Then, given this thermal exposure, SIAM calculates the amount of time required for the occurrence of piloted wood ignition and flaming (Tran et al. 1992). On the basis of extreme-case assumptions of flame

Piloted ignition: When wood is sufficiently heated, it decomposes to release combustible volatiles. At a sufficient volatile-air mixture, a small flame or hot spark can ignite it to produce flaming; thus, a piloted ignition.

radiation and exposure time, SIAM calculations indicate that large wildland flame fronts (e.g., forest crown fires) will not result in piloted wood ignitions (e.g., the typical variety of exterior wood walls) at distances greater than 40 meters (Cohen and Butler [In press]). For example, the incident radiant heat flux (energy/time/area reaching a surface), the amount of radiant heat a wall would receive from flames, depends on its distance from the fire. That is, the rate of radiant energy per unit wall area decreases as the distance increases (*fig. 2*).

In addition, the time required for a wood wall to ignite depends on its distance from a flame front of the given height and width (*fig. 2*). But the flame's burning time compared to the required ignition time is important. If at some distance the fire front produces a heat flux sufficient to pilot ignite a wood wall, but the flaming duration is less than that required for ignition, then ignition will not occur. At a distance of 40 meters, the radiant heat flux is less than 20 kilowatts per square meter (kW/m^2), which corresponds to a minimum ignition time of greater than 10 minutes (*fig. 2*). Crown fire experiments in forests and shrublands indicate that the burning duration of these large flames is on the order of one minute at a specific location¹. This is because these wildland fires depend on the rapid consumption of the fine dead and live vegetation (e.g., forest crown fires). Thus, a severe but more realistic expectation of a 90 second duration results in a distance estimate of 30 meters to prevent a piloted wood wall ignition.

¹Unpublished data on file, Rocky Mountain Research Station, Fire Sciences Laboratory, Missoula, Montana.

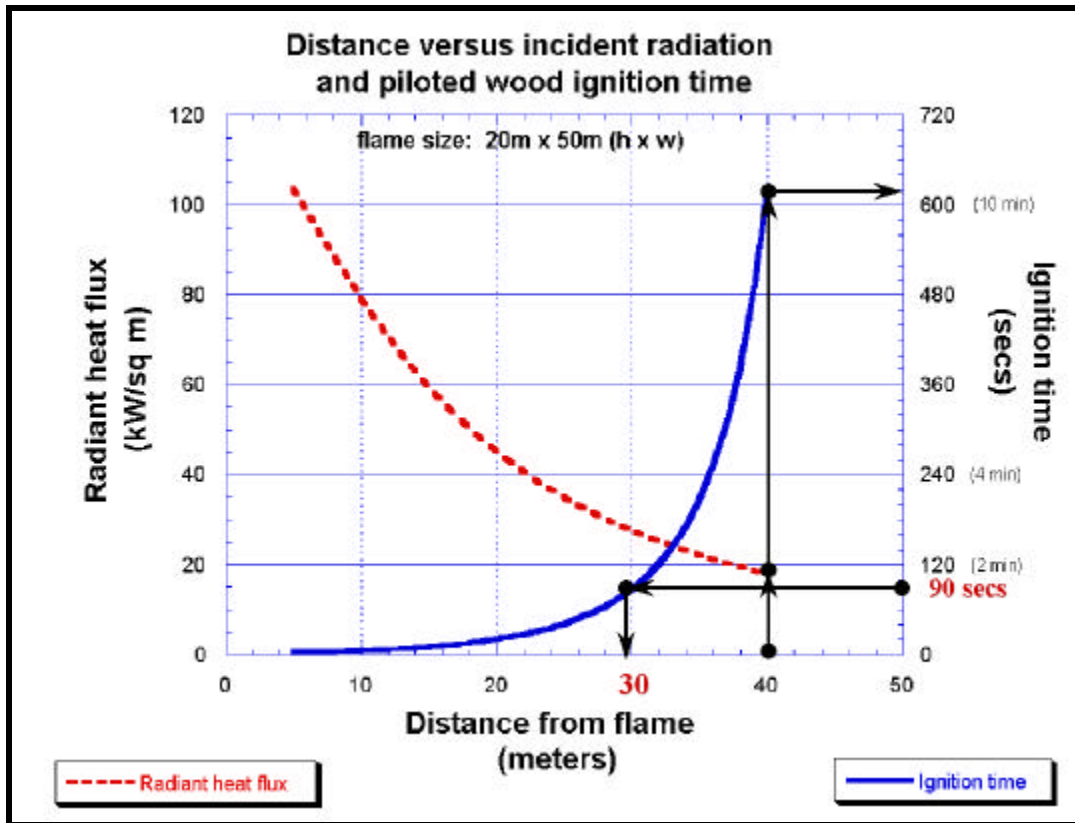


Figure 2-- SIAM calculates the incident radiant heat flux and the minimum time for piloted ignition as a function of distance for the given flame size. The flame is assumed to be a uniform, parallel plane, black body emitter.

The Human Perspective of Radiant Heating	
1 kW/m ²	Maximum for indefinite skin exposure.
10.4 kW/m ²	Pain after 3 seconds of skin exposure.
16.0 kW/m ²	Second-degree burn after 5 seconds of skin exposure
(Drysdale 1985)	

Experiments. Field studies conducted during the International Crown Fire Modeling Experiment (Alexander et al. 1998) provided measured data for comparisons with SIAM model estimates. Total heat transfer (radiation and convection) and ignition data were obtained from heat flux sensors placed in wooden wall sections (fig 3).

The instrumented walls were located on flat, cleared terrain at 10, 20, and 30 meters downwind from the edge of the forested plots. The forest was variably composed of an overstory of jack pine (*Pinus banksiana*) about 13 meters high with an understory of

black spruce (*Picea mariana*). The spreading crown fire produced flames approximately 20 meters high (fig 3).

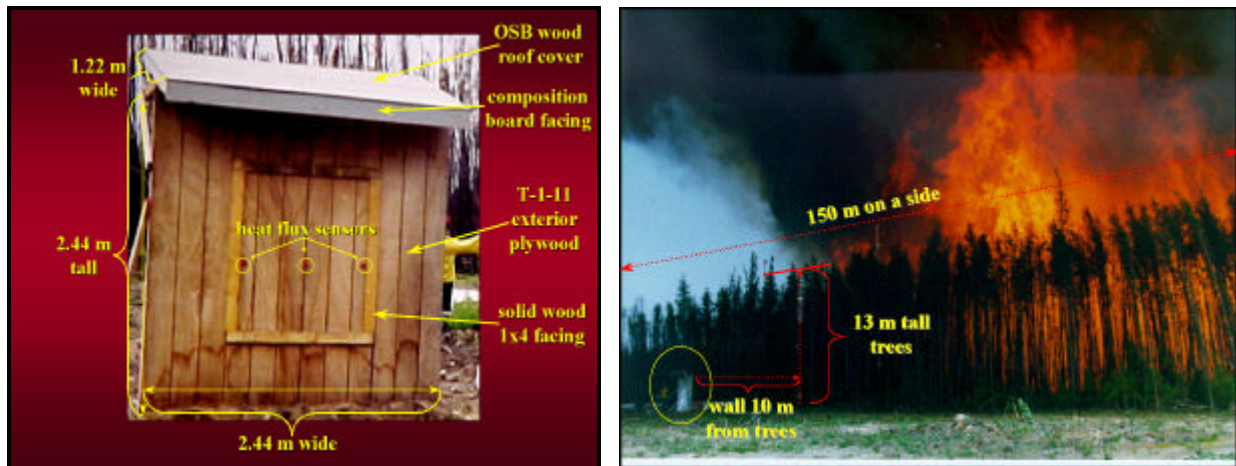


Figure 3— (left) the wall section; (right) the wall section (encircled) placed at 10 meters from the forest edge with an approaching crown fire.



Figure 4— (left) the experimental crown fire with flame heights about 20 meters; (right) wall section after the crown fire exposure--scorch but no ignition. Note the lack of scorch under the eave due to "shading" of the flame radiation.

Five burns were conducted where wall sections were exposed to a spreading crown fire. As the crown fires reached the downwind edge of the plot, turbulent flames extended into the clearing beyond the forest edge. In two of the five burns, flames extended beyond 10 meters to make contact with the wall section

placed at 10 meters from the forest edge. When flame contact occurred, the walls ignited; however, without flame contact, only scorch occurred, as shown in *figure 4*. The wooden panels at 20 and 30 meters never ignited and the panel at 30 meters never scorched.

Case studies. Case studies of actual W-UI fires provide an independent comparison with SIAM and the crown fire experiments. The actual fires incorporate a wide range of fire exposures. The case studies chosen examine significant factors related to home survival for two fires that destroyed hundreds of homes. The Bel Air fire resulted in 484 homes destroyed (Howard et al. 1973) and the Painted Cave fire destroyed 479 homes (Foote 1994).

Analyses of both fires indicate that home ignitions depend on the characteristics of a home and its immediate surroundings. Howard et al. (1973) observed 95 percent survival for homes with nonflammable roofs and a vegetation clearance of 10 to 18 meters. Foote (1994) observed 86 percent survival for homes with nonflammable roofs and a clearance of 10 meters or more.

Discussion

Comparisons between SIAM calculations and the crown fire experiments indicate that modeling overestimates the flame-to-wall distance required to prevent piloted ignition. Using the flame heights from the experimental crown fires, SIAM estimates a flame-to-wall distance of around 30 meters. During the crown fire experiments when the flames remained at about 10 meters the wood walls did not ignite and walls at 30 meters never scorched during any burn. Cohen (2000) reports that this is expected since SIAM assumes a uniform and constant heat source when actual flames are neither uniform nor constant. Thus, the SIAM calculations for an actual flame front represent severe-case estimates of the heat received and the potential for ignition. The model calculated distances represent a high estimate of the flame-wall separation distance required to prevent ignitions (*fig. 2*).

Firebrands are also a principal W-UI ignition factor. Highly ignitable homes can ignite during wildland fires without fire spreading near the structure. This occurs when firebrands are lofted downwind from fires. The firebrands subsequently collect on and ignite flammable home materials and adjacent flammables. Firebrands that result in ignitions can originate from distant wildfires. For example, during the 1980 Panorama Fire (San Bernardino, California), the initial firebrand ignitions to homes occurred when the wildfire was burning in low shrubs about one kilometer from the neighborhood. Although firebrands capable of ignition can originate from a fire several kilometers away, homes can only be threatened if the firebrands ignite the home directly or ignite adjacent flammable materials that then ignite the home.

The analyses using modeling, experiments, and case studies

did not explicitly address firebrand ignitions. However, firebrand ignitions were implicitly considered because of the firebrand exposures that occurred during the crown fire experiments and the case studies. The experimental crown fires provided a firebrand exposure that resulted in spot ignitions in the dead wood and duff around the wall sections but not directly on the wall sections. In the case studies, firebrand ignitions occurred throughout the areas affected by the Bel Air and Painted Cave fires. The high survival rate for homes with nonflammable roofs and 10-20 meter vegetation clearances included firebrands as an ignition factor, thus indicating that firebrand ignitions also depend on the ignition characteristics of the home and the adjacent flammable materials.

Research Conclusions

SIAM modeling, crown fire experiments, and case studies indicate that the characteristics of a home and its immediate surroundings determine a home's ignition potential during wildland fires. For this context, we can refer to the home and its immediate surroundings as the home ignition zone (*fig. 5*). And we can refer to the ignition potential within the home ignition zone as home ignitability. The home ignition zone extends to a few tens of meters around a home not hundreds of meters or beyond. Home ignitions and thus, the W-UI fire loss problem principally depend on home ignitability.

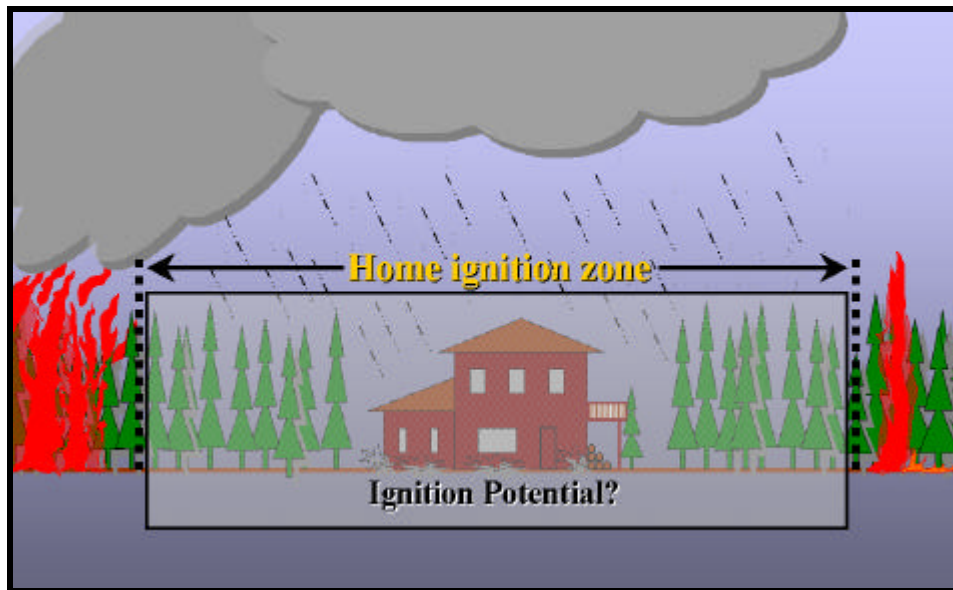


Figure 5— The ignition characteristics of a home and the burning characteristics of the surrounding flammable materials within the ignition zone determine a home's W-UI ignition potential.

Wildland fuel reduction beyond the home ignition zone does not necessarily change home ignitability; therefore, wildland fuel reduction does not necessarily mitigate the W-UI fire loss problem. Consequently, if home ignitability is not considered for reducing W-UI fire losses, extensive wildland fuel reduction must eliminate a home's exposure to flames and particularly

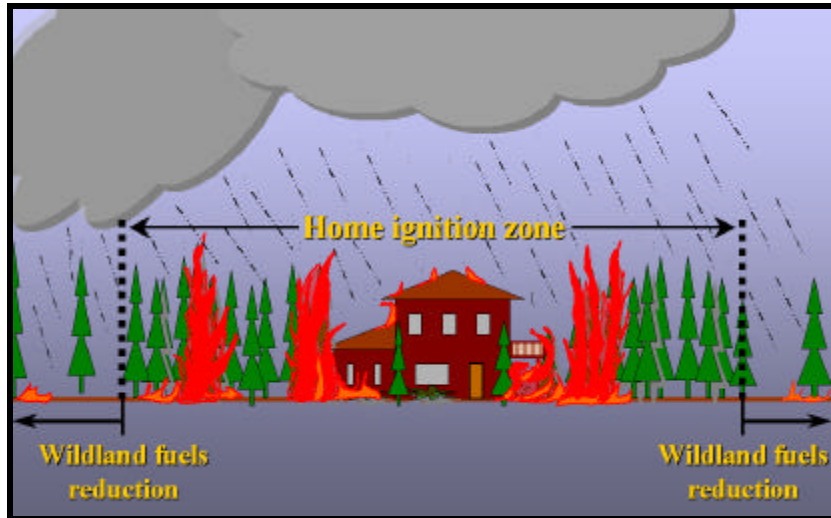


Figure 6— Even with wildland fuel reduction that keeps flames from spreading to the home ignition zone, a highly ignitable home can ignite from firebrands.



Figure 7— A low ignition potential home ignition zone reduces potential fire destruction even if no vegetation fuel reduction occurs in the surrounding wildlands.

firebrands. Thus, wildland fuel reduction that is effective for reducing the wildland fire intensity might be insufficient for reducing the destruction of highly ignitable homes (*fig. 6*). In contrast, a low home ignition potential reduces the chances of fire destruction without extensive wildland fuel reduction (*fig. 7*). These findings indicate that the W-UI home fire loss problem is a home ignitability issue largely independent of landscape fuel reduction issues.

Management Implications

Fire losses depend on home ignitions and home ignitions depend on home ignitability. Thus, home ignitability, being limited to a home and its immediate surroundings, offers us the opportunity to separate the W-UI structure fire loss problem from other landscape-scale fire management issues. This conclusion has significant implications for the actions and responsibilities of homeowners and fire agencies, such as identifying and mapping the potential for W-UI residential fire destruction, identifying appropriate and effective mitigating actions, and determining who should take responsibility for home ignitability.

Risk Assessment and Mapping Home Loss Potential. Because home ignitions depend on home ignitability, the behavior of wildland fires beyond the home or community site does not necessarily correspond to the potential for W-UI fire losses. Highly ignitable homes can be destroyed during lower-intensity wildfires, whereas homes with low home ignitability can survive high-intensity wildfires.

This conclusion has implications for reliably identifying and mapping the potential home destruction during wildland fires. The term "wildland-urban interface" suggests that residential fire destruction occurs according to a geographical location. However, this misrepresents the physical nature of the wildland fire threat to homes. The wildland fire threat to homes is not *where* it happens related to wildlands but *how* it happens related to home ignitability. Therefore, to reliably map the potential for W-UI home fire loss, home ignitability must be the principal mapping characteristic. The information related to potential home destruction must correspond to the home ignitability spatial scale. That is, the information must relate to those characteristics of the home and its immediate site within a few tens of meters.

Wildland Fuel Hazard Reduction. Effective landscape fuel reduction does not necessarily prevent W-UI home fire destruction. Given severe fire conditions and high home ignitability, any exposure to flames and particularly firebrands can result in residential destruction. For example, fuel reduction might be effective in limiting the extent of crown fires in pine forests such as ponderosa pine (*Pinus ponderosa*) but not eliminating all torching and crowning that can loft

firebrands into a highly ignitable residential area. And, in cover types such as California chaparral, lodgepole pine (*Pinus contorta*) and spruce/fir (*Picea/Abies*) that normally experience high intensity, stand replacement fires, effectively eliminating a firebrand exposure may not be reasonably attainable. Thus, when considering the use of wildland fuel hazard reduction for protecting homes, an analysis specific to home ignitability should determine the treatment effectiveness.

However, focusing efforts on homes and their immediate surroundings can reduce W-UI home losses. At higher densities where neighboring homes may occupy the immediate surroundings, loss reductions may necessarily involve a community. If homes have a sufficiently low home ignitability, a community exposed to a severe wildfire can survive without major fire destruction. This provides the option of mitigating the wildland fire threat to homes at the residential location without extensive wildland fuel reduction.

This should not imply that wildland vegetation management is without purpose and should not occur. It implies that the W-UI home fire loss issue can largely be addressed separately from other issues that might require landscape fuel management (e.g., ecological, hydrologic, and aesthetic considerations). And this translates to increased management options for the locations and methods used to accomplish landscape benefits with complementary benefits to communities.

WUI Home Loss Responsibility. If no wildfires or prescribed fires occurred, the wildland fire threat to residential development would not exist. However, our understanding of the fire ecology for most of North America indicates that fire exclusion is neither possible nor desirable. Therefore, we can assume that wildland fires will occur at sometime in most of our W-UI areas.

The extent of the home ignition zone corresponds more to specific home and community ownership than to the landscapes of federal, state and local land management agencies. This suggests a corresponding responsibility for W-UI home fire loss potential residing with homeowners and communities. Thus, the home should not be considered a victim of wildland fire, but rather a potential participant in the continuation of the wildland fire. Home ignitability, i.e., the potential for W-UI home fire loss, is a homeowner and community choice and responsibility.

An Alternative

Specific to the W-UI fire loss problem, home ignitability ultimately implies the necessity for a change in the relationship between homeowners and the fire services. Instead of all pre-suppression and fire protection responsibilities residing with fire agencies, homeowners should take the principal

responsibility for assuring adequately low home ignitability. The fire services become a community partner providing homeowners with the technical assistance needed for reducing home ignitability. This will require a change in the current relationship between fire agencies and homeowners from one of protector-victim to one of partners. If a W-UI fire occurs with the partnership implemented, low home ignitability and community awareness will increase firefighter effectiveness for reducing home fire losses. This approach defines a strategy of assisted and managed community self-sufficiency (Cohen and Saveland 1997). For success, this partnership perspective must be shared and implemented equally by homeowners and the fire services.

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