LAHAINA: FROM CONFLAGRATION TO RESILIENCE

Insurance Institute for Business & Home Safety
April 2024

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On August 8, 2023, a devastating and tragic fire swept through the Lahaina community as three wildfires burned on the island of Maui. A ***grassfire turned into a conflagration***, causing more than one hundred deaths and destroying three quarters of the structures in Lahaina.

The ***specifics of connective fuels, community layout, unique geography, and weather in Lahaina*** affected how the conflagration unfolded within the community. As Lahaina rebuilds, a crucial set of mitigation actions—based in years of wildfire science, IBHS's Wildfire Prepared Home standard, and Lahaina's unique characteristics—can reduce the risk of future conflagrations.

Key Observations in Lahaina

Disrupting Conflagration: Where manmade and natural conditions reduced heat intensity, fire resistant building materials withstood the fire, creating pockets of unignited structures that disrupted the conflagration.

Exterior Building Materials: Fire resistant building materials are more durable than traditional materials, but their effectiveness was diminished in Lahaina due to intense heat from burning buildings with limited structure spacing.

Structure Spacing: *Flames from burning homes often extended over twenty feet*, rapidly igniting homes at closer distances downwind.

Connective Fuels: Connective fuels acted as pathways that brought wildfires to and enabled them to spread *within* the built environment.

Conflagration: A wildfire that spreads into the built environment leading to uncontrollable structure-to-structure fire spread. Factors associated with conflagration include: drought, wind, a fire start (often human-caused), dense construction with little to no exterior fire resistance, and dense combustible connective fuels surrounding and between structures.

Connective Fuels: Pathways of manmade materials (e.g., fences, outbuildings, sheds, or even automobiles) or vegetation by which fire can spread into or within a community.

Structure Spacing: The distance between buildings.

Defensible Space: The buffer area created and maintained between a structure and the grass, trees, shrubs, or any wildland surrounding it.

Zone 0: A horizontal 5-foot noncombustible buffer area surrounding a structure and outbuildings, including around and under attached decks and stairs. During a wildfire, embers can travel miles ahead of a fire front and accumulate at the base of a home's exterior walls and within the first 5 feet. Anything combustible in this critical zone acts as a fuel source for ignition, increasing the risk of flames spreading to the home.

CRUCIAL ACTIONS TO REBUILD WITH RESILIENCE AT PARCEL-LEVEL AND COMMUNITY-SCALE

Parcel-Level Actions

» **Rebuild homes to at least the Wildfire Prepared Home standard,** preferably to the Wildfire Prepared Home Plus standard in dense neighborhoods.

» **Apply modern building codes** to ensure structures can withstand hurricanes and wildfires.

» **Eliminate connective fuels between homes** by using native hardscapes such as lava rock or concrete fences to disrupt continuous pathways of fuel. Defensible space beyond Zone 0 is paramount for properties abutting grasslands.

Community-Scale Actions

» **Expand or otherwise maximize structural separation** between buildings.

» **Establish and maintain fuel breaks along the periphery of the community,** especially in communities surrounded by grassland. Use noncombustible fencing on properties abutting the grasslands.

IBHS RESEARCH CENTER
WILDFIRE

Background

Nestled between the natural grassland and the Pacific Ocean, the community of Lahaina sits on the northwestern coast of the island of Maui. Prevailing winds flow down the topographic landscape, across the wild grasses, and into the suburban area.

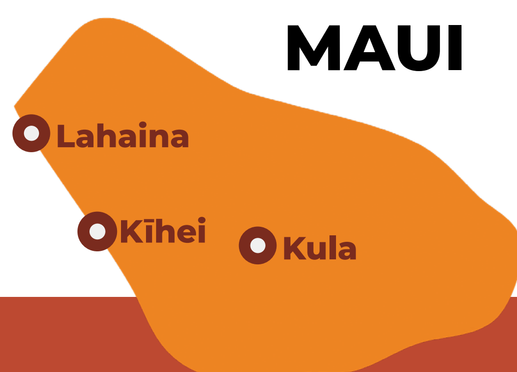
On August 8, 2023, one of three wildland fires burning on the island entered Lahaina. Exacerbated by strong winds, the fire resulted in a catastrophic conflagration within the community. Once fire entered the community from the grasslands, it quickly spread through the built environment, overwhelming firefighting resources. The rapid fire spread from the grasslands to the built environment draws parallels to other grass fires such as the Marshall Fire in Colorado and the Balch Springs neighborhood fire in Texas. In addition to tragic loss of life, the Lahaina Fire destroyed over 2,200 structures—accounting for three quarters of all structures in Lahaina—resulting in the seventh most damaging fire in the United States since 1990, based on structures destroyed.

Figure 1. *Post-fire satellite image showing the boundary (in orange) of the Lahaina Fire and larger areas within the community that escaped the conflagration. Imagery courtesy of Maxar.*

In addition to the Lahaina Fire, the island of Maui experienced two other wildfires on August 8, 2023. One wildfire impacted the community of Kula, Upcountry Maui where the topography and vegetation coverage is similar to Northern California. The other wildfire sparked near Pūlehu Road, north of Kīhei where the vegetation coverage is combination of trees and grassland.

In November 2023, IBHS conducted a post-disaster investigation in Maui to deepen scientific understanding of suburban conflagration by studying how the fire progressed through the community and focusing on structures that were not destroyed by the fire. The IBHS team looked at structures across Lahaina; however, it was not able to collect data from the Kula community or on the Pūlehu Road fire.

The research conducted in Maui sought to better understand why some structures escaped destruction during the conflagration with a particular focus on the building vulnerabilities and features that distinguished these buildings. The IBHS team collected data in three key categories: fuel-related factors, building components, and separation distance between structures.



Existing Wildfire Research

For more than a decade, IBHS has been conducting extensive research at its research facility into the ignition of structures due to wind-driven wildfires by examining building components and parcel features along with building-to-building fire spread. The findings from this research have been presented in numerous studies, most recently IBHS's "The Return of Conflagration in the Built Environment"[1] and "Wildland Fire Embers and Flames: Home Mitigations that Matter"[2]. IBHS also released early insights from the Lahaina Fire[3] in August 2023.

As described in "The Return of Conflagration in the Built Environment," IBHS has identified the set of most important factors contributing to suburban conflagration across the natural environment, the built environment, and human behavior (Table 1). Within the factors related to the natural environment, wildland fuel is the only factor that humans can meaningfully change. In comparison, the factors relating to the built environment and human behavior can be altered by humans over time at differing levels of effort and investment. For example, modifying infrastructures and adjusting structural density is possible but may present significant challenges, whereas reducing connective fuels and retrofitting structures with ignition-resistant building materials are both effective and achievable.

Table 1. *Factors contributing to suburban conflagration as described in "The Return of Conflagration in the Built Environment".*

Natural Environment	The Built Environment	Humans
Topography	Structure density	Preparedness and mitigation
Climatology	Building materials	Ignition sources
Local Weather	Connective fuels	Fire service intervention
Wildland Fuels	Infrastructure	

IBHS research also has investigated the ignition of structures due to wind-driven wildfires by examining building components and parcel features. The findings from this research are set forth in "Wildland Fire Embers and Flames: Home Mitigations that Matter" and inform IBHS's Wildfire Prepared Home[4] mitigation program. This body of work highlights the importance of undertaking a collective set of mitigation actions to drive down the risk of structural ignition from embers and the heightened criticality of removing combustible material from the five-foot zone surrounding structures, sometimes called Zone 0[5]. Although reducing the risk of ignition requires a systemic application of mitigation actions, some mitigation actions are more important than others depending on the type of wildfire threat (i.e., some components are more vulnerable against embers while others are to flames and radiant heat exposure).

1 Ian M. Giammanco et al., "The Return of Conflagration in the Built Environment," Insurance Institute for Business & Home Safety (2023). https://ibhs.org/wildfire/returnconflagration/.
2 Faraz Hedayati et al., "Wildland Fire Embers and Flames: Home Mitigations that Matter," Insurance Institute for Business & Home Safety (2023). https://ibhs.org/MitigationsthatMatter.
3 "IBHS Early Insights: Lahaina Fire—2023," Insurance Institute for Business & Home Safety (2023). https://ibhs.org/EarlyInsights-Lahaina/.
4 https://wildfireprepared.org
5 "Noncombustible Zone 0: Minimizing Pathways to Home Ignition," Insurance Institute for Business & Home Safety (2023). https://ibhs1.wpenginepowered.com/wp-content/uploads/IBHS_Noncombustible_Zone_0.pdf.

What is Wildfire Prepared?

Wildfire Prepared is a mitigation program that guides homeowners through taking preventative measures for the home and yard to protect against wildfire. Available for **new construction and as retrofits** to existing homes, Wildfire Prepared Home features a set of mitigation actions that, together, meaningfully reduce the risk of home ignition. The **Wildfire Prepared Home level** protects against ignition from embers, and the **Wildfire Prepared Home Plus level** includes additional actions to protect against ignition from flame and heat exposure.

Required Mitigation Actions	Wildfire Prepared Home	Wildfire Prepared Home Plus
Create a **5-foot noncombustible buffer**, often known as Zone 0	X	X
Replace combustible fencing within 5 feet of the home	X	X
Ensure the **roof is Class A fire-rated**	X	X
Choose **noncombustible gutters** and downspouts	X	X
Routinely **clear tree debris from the roof and gutters**	X	X
Install **ember-resistant vents** or cover vents with 1/8-inch metal mesh	X	X
Ensure **6-inches of vertical noncombustible material** at the base of exterior walls and decks	X	X
Routinely **clear debris from decks, replace combustible furniture, maintain the underdeck area; enclose low-elevation decks**	X	X
Maintain **defensible space to 30 feet**	X	X
Keep **accessory structures compliant within 30 feet**	X	No accessory structures within 30 feet
Cover gutters		X
Enclose the underside of eaves with noncombustible material		X
Install a **metal dryer vent with a louvers or a flap**		X
Install **noncombustible exterior siding**		X
Ensure **shutters, if present, are noncombustible**		X
Upgrade to **dual-pane tempered windows**		X
Upgrade to **noncombustible exterior doors**		X
Enclose the space **underneath bay windows**		X
Upgrade to a **noncombustible deck**		X
Remove back-to-back fencing within 30 feet		X

More resilient construction practices are not prohibitively expensive. In a 2022 study[6], IBHS and Headwaters Economics compared the additional costs of building a new home with greater wildfire resilience in Southern California than the requirements set forth in California's Building Code Chapter 7A (California's wildfire building code). As the requirements of California's Chapter 7A building code are substantially similar to the National Fire Protection Association (NFPA) 1144 Standard for Reducing Structure Ignition Hazards from Wildland Fire in use in Hawaii, the study provides a notional sense of the cost implications for enhancing Hawaii's existing requirements for new construction.

- Building to the Wildfire Prepared Home level is largely **cost neutral**. The study found additional costs arising from choices in landscaping Zone 0 and in enclosing decks, of approximately $3,000. This cost could be reduced through different material or landscaping choices.
- Building with additional wildfire resilience measures included in the Wildfire Prepared Home Plus level (e.g., dual-pane tempered glass windows, ignition-resistant siding, etc.) and a more resilient tile roof increased costs by approximately **4-13 percent**. These costs can be reduced through homeowner choices without jeopardizing wildfire resilience. For example, the absence of a deck eliminates the costs associated with mitigating wildfire risk associated with the deck.

For communities interested in incorporating the requirements of the Wildfire Prepared Home program into building codes and ordinances, IBHS has created a Model Ordinance for Construction in WUI Area[7].

6 *Kimiko Barrett et al. "Construction Costs for a Wildfire-Resistant Home: California Edition," Headwaters Economics and IBHS (2023). https://headwaterseconomics.org/natural-hazards/wildfire-resistant-costs-california/*
7 *https://ibhs1.wpenginepowered.com/wp-content/uploads/Wildfire_model_ordinances-in-WUI.pdf*

In addition, IBHS continues to conduct research to better understand building-to-building fire spread through flames, heat, and embers. This research indicates that structure spacing of less than twenty feet significantly increases the likelihood of conflagration once a wildfire has entered a community. As demonstrated in Figure 2, the severity of damage declines at distances greater than twenty feet. Under this condition in a Wildland-Urban Interface (WUI) fire, the intensity of the fire exposure surpasses the tolerance of nearly all fire-resistant materials and designs.

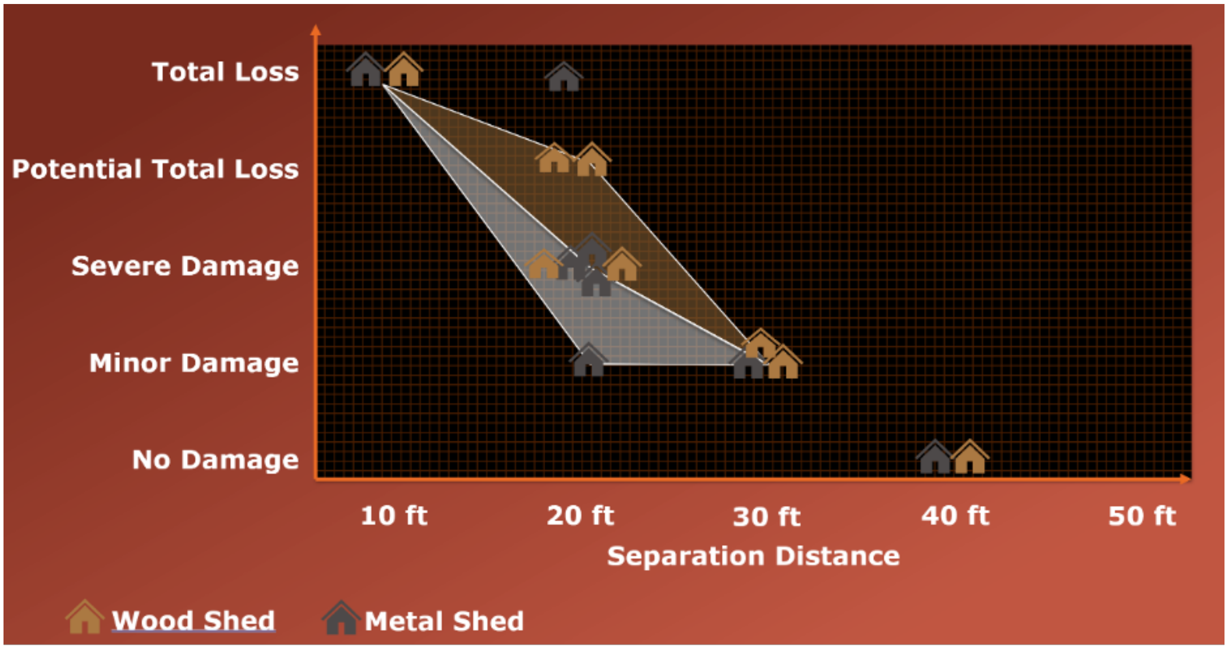


Figure 2. *Different damage severities as a function of distance resulting from a set of IBHS's wind-driven building-to-building fire spread experiments.*

Put together, IBHS's existing body of research demonstrates that a single resilience action is insufficient to reduce the risk of home ignitions and community-level conflagration. Rather, wildfire risk can only be meaningfully reduced through a **multi-layer approach**:

1. At the **parcel level**,
   a. A foundational layer of mitigation actions to protect against ignition through embers;
   b. A secondary layer of mitigation actions to guard against flame and heat exposure; and
2. At the **community scale**,
   a. Community-wide mitigation actions to reduce the likelihood of conflagration once a single structure is ignited.

The mitigation actions that collectively make up the foundational and secondary layers of protection at the parcel level are known. The community-level mitigation actions necessary to reduce conflagration risk are currently under investigation, but this set of actions will certainly include the reduction of connective fuels (vegetation and structural) and a certain threshold of parcel-level mitigated homes in the community.

Maui Deployment: Observations and Findings

While the unique geography and topography surrounding Lahaina contribute its vulnerability, the data IBHS collected in Maui demonstrates the acute reality of wildfire in a suburban community. This also aligns with IBHS's scientific research and field observations over the past decade. Observations in Lahaina advance scientific knowledge by demonstrating the factors that are most important for understanding how wildfires ***enter*** communities from grasslands and how wildfires ***spread within*** communities once the initial structural ignitions occur.

When a wildfire threatens a community in or near the Wildland-Urban Interface, reducing structural ignitions is of paramount importance. Once fire enters a community, a variety of factors—including structural spacing, connective fuels, and lofted structural embers—vastly increase fire spread.

For wildland areas featuring grassland, as is the case in Lahaina, the structures abutting the wildland are the first line of defense against community conflagration. Because these wildland fires typically ignite structures through direct flame contact rather than embers, the risk of conflagration is reduced if the exposed structures do not ignite.

For wildland areas featuring forests, as is the case in Kula, vegetative embers lofted by the wind play an important role in bringing the wildfire into the community by igniting sporadic spot fires and causing structural ignitions. In these cases, all structures in the community are equally vulnerable to ignition from embers—and mitigating all structures is equally important to preventing the initial structural ignitions that lead to conflagration.

Wildland fire entering Lahaina

Wildland fire entered Lahaina through connective fuels that bridged the grasslands with the community. These connective fuels are present in many forms, ranging from natural elements like vegetation (e.g., wildland grasslands, shrubs, and trees) to manmade objects such as vehicles and building components like fences. These connective fuels created a pathway for fire to reach and ignite structures–setting off a conflagration.

In areas like Lahaina, characterized by predominantly grassland and shrub vegetation, the primary mechanism of fire spread to the built environment was direct flame contact. The community lacked fuel breaks that would have disrupted the continuous connection between buildings at the edge of the community and the wildland, minimizing the risk. Evidence suggests that structures that did not burn created a discontinuity–i.e., a fuel break–in the fire's pathway which resulted in lower thermal exposure for nearby structures, lowering the risk of ignition.

Figure 3. *Homes in northern Lahaina that did not burn because of disconnected fuel as the fire propagated from the wildland on the right side of the image.*

This phenomenon can be seen twice in Figure 3. In Case 1, the connective fuel path is interrupted by a noncombustible fence. In Case 2, the disruption occurs in two stages, involving irrigated grass and a concrete driveway.

Fire spread within Lahaina

Once the wildfire entered Lahaina, it spread throughout the community. From observations on the ground, IBHS identified ten community and building features with the greatest impact on how the fire spread within Lahaina–which drives which structures escaped destruction and which ones did not.

By a wide margin, structure spacing—the distance between one structure and another—was the most critical factor to fire spread within Lahaina. The potential intensity of a structure fire is so high that, for other structures within twenty feet, it surpasses the tolerance of even fire-resistant building materials and designs. At separation distances larger than twenty feet, building components can make a difference in the ability of a structure to withstand a neighboring structural fire—if building components allow a sufficient number of structures to be able to do so, the conflagration can be stopped.

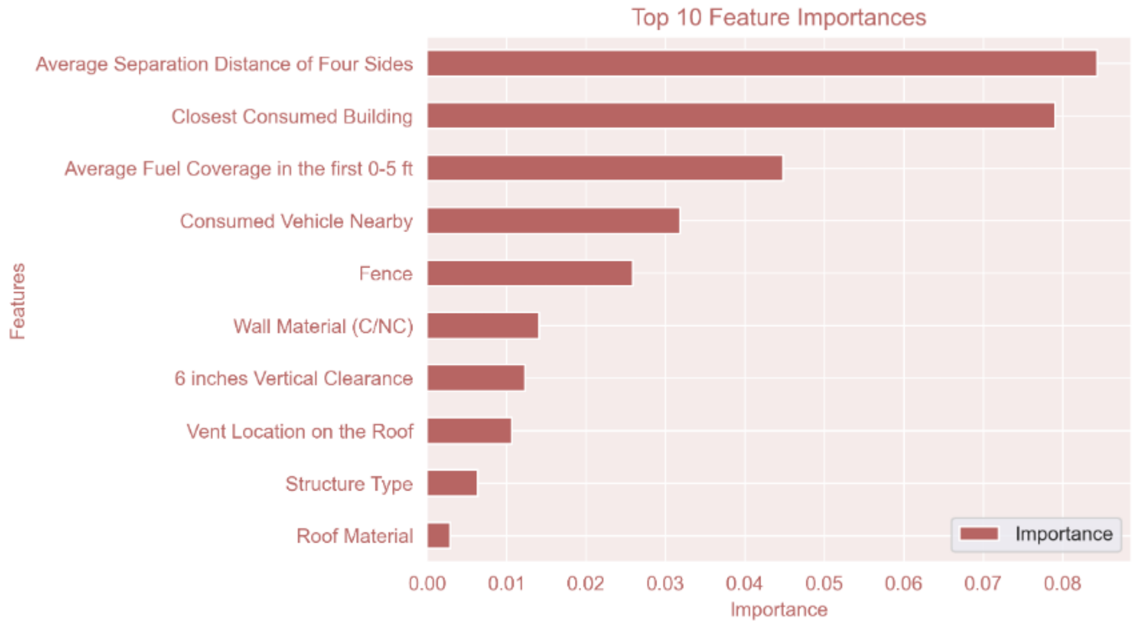


Figure 4. *The community and building features influencing damage state.*

Other influential factors highlight the significance of available connective fuels in communities. Particularly in densely packed communities like Lahaina, connective fuels—which can encompass both stationary items like sheds and fences, as well as more dynamic elements such as vehicles—must be monitored and mitigated to disrupt the potential continuous pathway between buildings. IBHS researchers observed cases where the abundance, scarcity, or discontinuity of connective fuels changed the degree to which nearby buildings were damaged. As demonstrated in the buildings featured in Figure 5—both of which experienced only minor damage from the fire—the absence of connective fuels can reduce exposure and protect structures.

Figure 5. *Examples of reduced exposure with non-connective fuel (A) The building on the left of image experienced minor damage due to radiation only (no connective fuel). (B) Embers ignited the combustible fence and vegetation on the leeward side of this building, leading to minor damage. The attached combustible fence was likely disconnected during the event.*

IBHS researchers observed specific instances in Lahaina where this reduced thermal exposure—either through structure spacings exceeding twenty feet or by disrupting the connective fuel path—allowed fire-resistant materials to withstand the fire, thereby preventing ignition and resulting in areas of unburned structures within Lahaina. These observations are consistent with past field observations and laboratory experiments.

In addition, structures in Lahaina that escaped being a total loss underscored the importance of the same parcel-level mitigation actions highlighted in "Wildland Fire Embers and Flames: Home Mitigations that Matter" and included in IBHS's Wildfire Prepared Home program. Features like a noncombustible Zone 0, protected openings, a Class A fire-rated roof, and a 6-inch noncombustible vertical clearance around the base of structures mitigated the risk of structural embers igniting additional homes as conflagration unfolded. By preventing these ignitions, pockets of Lahaina escaped conflagration.

MULTI-HAZARD CONSIDERATIONS

Community leaders must help residents grapple with risks to multiple hazards faced by the community and not just the most recent disaster. Preparing and mitigating for each hazard may require careful consideration of overlapping vulnerabilities in the built environment. Ensuring buildings are rebuilt to modern building codes is paramount for resilience to the high wind experienced during hurricanes. While wildfire mitigation centers on connective fuels, building spacings, and material choices, wind resilience centers on how all the building materials are connected together.

Recommendations for Resilient Recovery

A resilience-centric recovery approach that ensures the community rebuilds in a stronger and safer way is possible for Maui following the Lahaina Fire and the wildfires in Kula and Kīhei. Coupling years of research with the recent observations from the IBHS deployment, the following considerations can help Maui recover with resilience.

Although grounded in IBHS's observations in Maui, these considerations incorporate years of wildfire research and are broadly applicable to other communities, whether similar to Lahaina (experiencing exposure to grassland) or Kula (experiencing exposure to forests).

IBHS: TURNING SCIENCE INTO SOLUTIONS

IBHS's groundbreaking research is closing gaps in building science to **strengthen the nation's resilience** against the growing threat of severe weather and wildfire, bringing science to life, educating audiences, and driving change.

The Institute's unique capabilities to **test full-scale structures** against high-wind, wind-driven rain, hail, and wildfire allow researchers to identify vulnerabilities – the points of failure – during these events. That research then flows into **achievable, affordable, and effective solutions** to guide building practices, retrofits, and mitigation programs for residential and commercial properties.

IBHS has been at the **forefront of building science research** since the opening of its Research Center in 2010. IBHS has **fundamentally shaped the state of scientific knowledge and the resilience solutions** available across our core perils of wind, wind-driven rain, hail, and wildfire. This includes:

- Synthesizing existing wildfire research into the Wildfire Prepared Home program to **provide homeowners with a clear pathway to meaningfully reduce wildfire ignition risk**.
- Unraveling the details of **building-to-building fire spread**.
- Exposing the **true vulnerability of asphalt shingles to wind** and expected lifespan in high wind environments.
- Bringing the **sealed roof deck** into the International Residential Code.
- Reaching **60,000 FORTIFIED designations** and launching the FORTIFIED Multifamily standard.
- **Driving market changing actions** by shingle manufacturers through impact resistant shingle product testing and performance rating, resulting in **improved products**.

Insurance Institute for Business & Home Safety®

LAHAINA: PATHWAY TO RESILIENCE

	Key Observations	Resilient Recommendations
Community-Scale	The type and intensity of **potential exposures** from the wildland vary depending on the location of communities, influenced by factors such as topography, surrounding fuels, and weather.	Recovery efforts should put emphasis on **different mitigation strategies** in areas of the community that abut the natural environment and areas of the community that are surrounded by the built environment.
Community-Scale	The most effective strategy for preventing suburban conflagration is to **reduce the likelihood of initial structural ignitions**. For homes that border the grassland, the main threat of ignition is from direct flame contact through connective fuels, as grassland embers have a short flying range and burn out quickly. Maintaining wildland vegetation in forested areas such as Kula can reduce the rate of fire spread, but these fuels still have the potential to generate long-range embers.	**Establish and maintain fuel breaks** along the periphery of the community, especially in communities surrounded by grassland.
Community-Scale	**Structural spacing** is of paramount importance in reducing conflagration risk for structures within a community.	**Expand or otherwise maximize the separation distance** between buildings to at least 20 feet where possible. In cases where increasing the separation distance is not possible, it is crucial to prioritize safety by avoiding the construction of larger buildings on the parcel that would reduce the space between structures.
Parcel-Level	Homes abutting wildland are vulnerable to embers and flames. **Maintaining a defensible space** can significantly reduce the risk of flame contact to these homes, especially for homes surrounded by grassland. Noncombustible fencing can mitigate this vulnerability while also, in the event of a home ignition, compartmentalizing the fire, reducing thermal exposure on surrounding homes.	**Defensible space** beyond Zone 0 is vital for properties abutting grasslands. These parcels should feature concrete or noncombustible fencing on all sides, without vegetation in close proximity to the fence.
Parcel-Level	The density of buildings directly correlates with the **presence of connective fuels**—such as vehicles and ornamental vegetation—which are also a source of embers once conflagration starts.	**Eliminate connective fuels** between homes. Maintain defensible space and a noncombustible Zone 0. Use native hardscapes such as lava rock and concrete or noncombustible fencing to break the connective fuel path and compartmentalize potential fires. Avoid outbuildings in yards within dense communities. The requirements in the Wildfire Prepared Home program can guide decision-making.
Parcel-Level	**Fire-resistant building materials** can stall fire progression when the thermal exposure is not extreme. The level of thermal exposure varies spatially and temporally throughout an event and, even under reduced exposure, ignition-resistant building materials can ignite.	When possible, rebuild homes to the Wildfire Prepared Home Plus standard. **At minimum, rebuild homes to the requirements of Wildfire Prepared Home.**