Designing Communities for Wildfire Resilience

SOM

DESIGNING COMMUNITIES FOR WILDFIRE RESILIENCE AUGUST 2021

Every year in California, wildfires devastate massive sections of the state's landscape and affect the lives of countless people. Millions of dollars are spent fighting fires, and additional billions are spent repairing fire-related damage. Yet most wildfires are caused by human activity and exacerbated by mitigation guidelines that can vary significantly between jurisdictions. We believe the issue of wildfire must be addressed in a more comprehensive manner and include forest management techniques, urban design strategies and building design criteria.

Therefore, the purpose of this document is to present wildfire guidelines that provide mitigation measures at three scales: the region, the city, and the building. To achieve this purpose, the document provides:

- An overview of wildfires in California and their causes.
- Historical data and trends related to wildfires.
- 18 guidelines for managing wildfire vulnerability at three scales of application: region, city, and building.

We hope this document provides an introduction to, and the inspiration for, more enlightened wildfire mitigation strategies in California.

WILDFIRE DESIGN GUIDELINES 2021

EXECUTIVE SUMMARY

The number of wildfires has been trending upwards over the past decade. California has been breaking its previous records for number of acres burned, number of fires, number of deaths, and number of structures destroyed in the last three years.

The United States policy to extinguish all fires immediately, coupled with more frequent droughts and increased dry seasons due to climate change, have combined to make forests and wildlands extremely vulnerable to fire. In addition to this, the U.S. has approximately 15 million people moving into the Wildland-Urban Interface each decade, equating to approximately 8 million new homes; human intervention in the Wildland-Urban Interface zone is the number one cause of wildfires.

Reducing the impact of wildfires on our communities and our planet will take coordinated effort from numerous stakeholders. Based on data from various sources, there are specific interventions we can take now at multiple scales.

- ↳ Improve communication between stakeholders.
- ↳ Adopt technologies that allow us to coexist with fire.
- ↳ Be intentional about where we build.

A summary of our recommended wildfire design guidelines is indicated to the right and explained further in the following chapters.

WILDLANDS

1.1	Federal, state, and local governments must collaborate to develop a unified response to wildfires.
1.2	Update outdated power lines and equipment in lower risk zones and add more monitoring systems throughout California.
1.3	Decentralize power sources in high risk zones.
1.4	Prioritize and increase prescribed burns in high risk areas.
1.5	Require mandatory fire-resistant building and residential landscape upgrades.
1.6	Bury new power lines where feasible within highest wildfire hazard zones.

URBAN AREAS

2.1	Increase housing in existing urbanized areas to reduce the number of people threatened by wildfires.
2.2	Incentivize no re-build zones in high fre risk areas to reduce property loss and damage from wildfres.
2.3	Implement urban design requirements for fire staging, breaks, and egress.
2.4	Require fire resilient buildings at the edges of urbanized areas.
2.5	Significantly reduce the number of destructive wildfires by reforming the electric grid infrastructure.

BUILDINGS

3.1	Strengthen visual communication tools for Wildland-Urban Interface (WUI) codes.
3.2	Design individual buildings and properties to accommodate fire and evacuation.
3.3	Provide affordable, adaptable, high-quality fire-resistant building designs to facilitate a new regime of fire conscious construction.
3.4	Incentivize fire-resistant upgrades for High Hazard Zones.
3.5	Require specific building configurations for new construction in WUI zones to limit the Venturi effect.
3.6	Implement active fire suppression in WUI zones.
3.7	Modify power delivery to buildings to significantly reduce the number of wildfires.

INTRODUCTION

California Wildfires

Every year wildfires get worse. From Australia to the US Pacific Coast, more severe wildfire seasons have become commonplace.

Smoke blots out the sun in major cities across the world, sometimes hundreds of miles from the fires themselves. Billions of dollars are spent fighting wildfires each year. Lives are lost when wildfires blaze across communities overnight. Homes are destroyed. Entire cities are evacuated. Immense amounts of carbon are released into the atmosphere. As climate change makes dry summers drier, decreases the typical annual snow pack, and increases high wind events, it's hard to see the trend reversing itself anytime soon.

In the past, a fire department's goal was to extinguish fires as soon as possible. An architect's goal was to design a building that would serve its client's needs. Now fire departments must balance the need to protect property and life with the needs of a complex evolving ecosystem: an environment where periodic fire is needed for overall health and longevity. Architects must balance the needs of the client with the impacts of climate change, the safety of the community, and recurring wildfires. Throughout this design manual, we explore data regarding wildfires, and analyze how governments, fire departments, cities, architects, and citizens can better design for coexisting with wildfires. This is by no means comprehensive, but intends to continue the conversations that are already occurring across different fields of expertise and provoke interdisciplinary collaboration and innovation.

In the introduction, we explore data on recent California Wildfires, to set the framework for the trends that have developed over the past decades. Even though our data focuses on California, we believe that there are parallels with other states and countries that have been experiencing increasing numbers of wildfires each year.

In the first chapter, we focus on Wildlands, and how long term and short term strategies can significantly improve the effects wildfires have on the state and communities each year.

In the second chapter, we analyze Urban Areas, identifying specific issues and recommending guidelines for designing cities and other urbanized areas for wildfires.

In the third chapter, we zoom into the Building scale, and develop several guidelines addressing issues that have arisen during our investigations.

The worsening and lengthening wildfire season is not a problem for just fire fighters, city planners, architects, or citizens who live and build in high hazard fire zones; All stakeholders need to communicate with each other, learn from each other's expertise, and apply each others knowledge, to improve the situation in the coming decades.

CALIFORNIA WILDFIRES

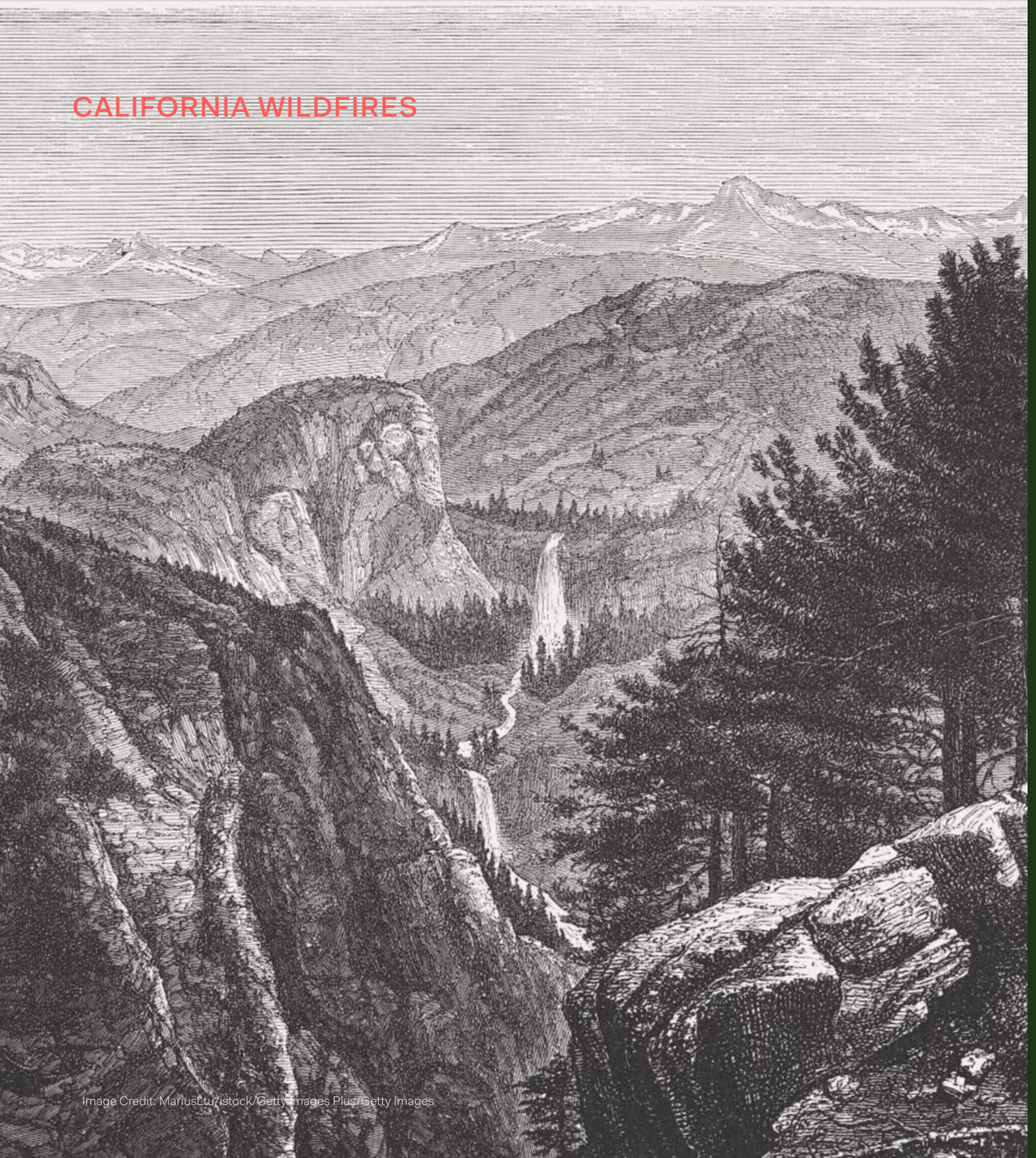


Image Credit: Mariusl.tu/istock/Getty Images Plus/Getty Images

Since pre-colonial times, fire has played an active role in the shaping of California's natural landscapes.

For millennia, tribes across California and the world used small intentional burns to renew food sources, create preferable habitat for animals, and reduce the risk of large, dangerous wildfires.

Early land management, especially in the Sierra Nevada mountains, was shaped through the knowledge of traditional burning practices that harnessed fire as a tool that was necessary for survival.

www.theguardian.com/us-news/2019/nov/21/wildfire-prescribed-burns-california-native-americans

CALIFORNIA WILDFIRES

For more than 100 years, U.S. policy was to immediately extinguish all wildfires and minimally manage the majority of federal and state forests.

This has led to a dangerous buildup of fuel where wildfires spread further, faster, and are significantly harder to contain.

www.theguardian.com/us-news/2019/nov/21/wildfire-prescribed-burns-california-native-americans

Photo Credit: ZU_09/Digital Vision Vectors/Getty Images

WILDFIRES

A prolonged lapse in land management policies is leaving more acres of forests and development vulnerable.

NEARLY 130 YEARS WITHOUT CONTROLLED BURNS

Use of intentional burning by indigenous people to manage forest and prevent large fires

The US government passed the Act for the Government and Protection of Indians which outlawed intentional burning in California.

Supported by ecologists and conservationists, early National Forest Service considered intentional burning to be destructive and contrary to protection of forests.

Realizing that no new giant sequoias had grown in California's unburned forests, the National Park Service changed its prescribed burn policy.

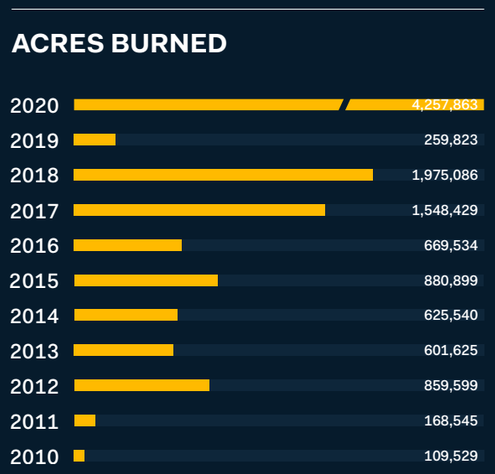
The Forest Service also changed its fire policy to allow prescribed burning.

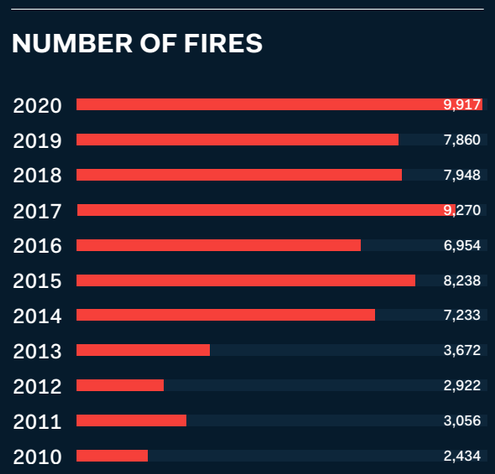
While some state agencies have made prescribed burns a key part of their land management policy, there is over 20 million acres of Federal, state, or private land across California that needs fuel reduction treatment.

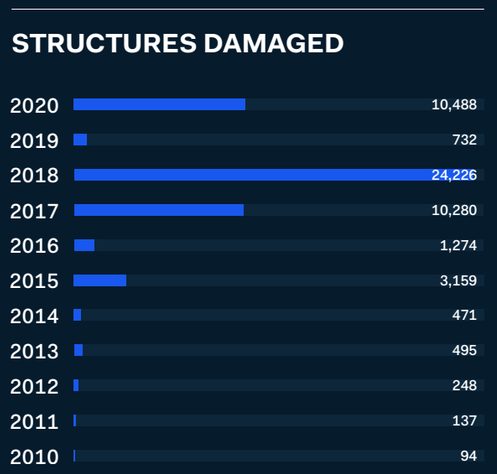
www.theguardian.com/us-news/2019/nov/21/wildfire-prescribed-burns-california-native-americans

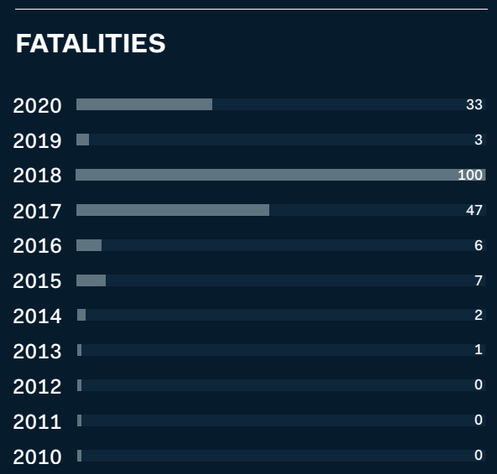
CALIFORNIA WILDFIRES

California's fire records date back to 1932, but the top 10 largest fires have occurred since 2003.







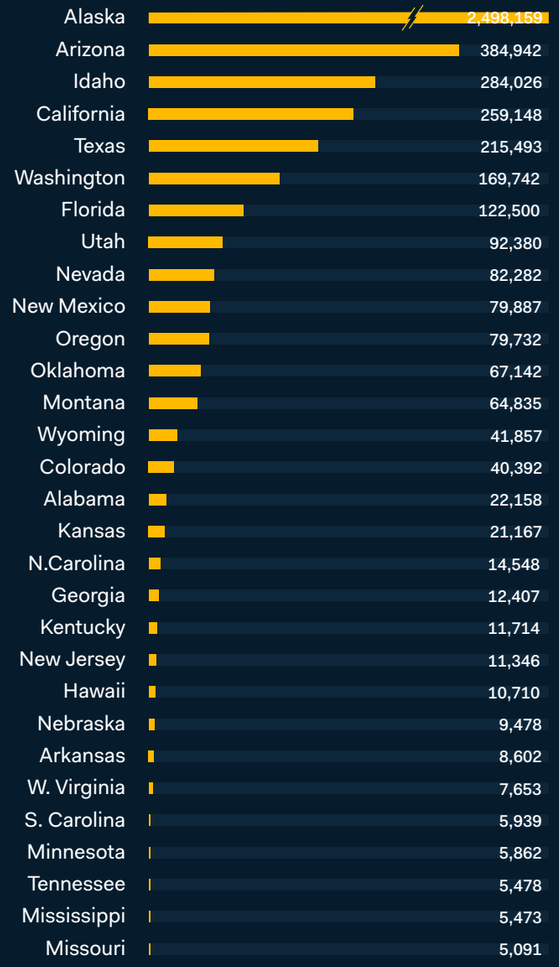


https://www.fire.ca.gov/stats-events/

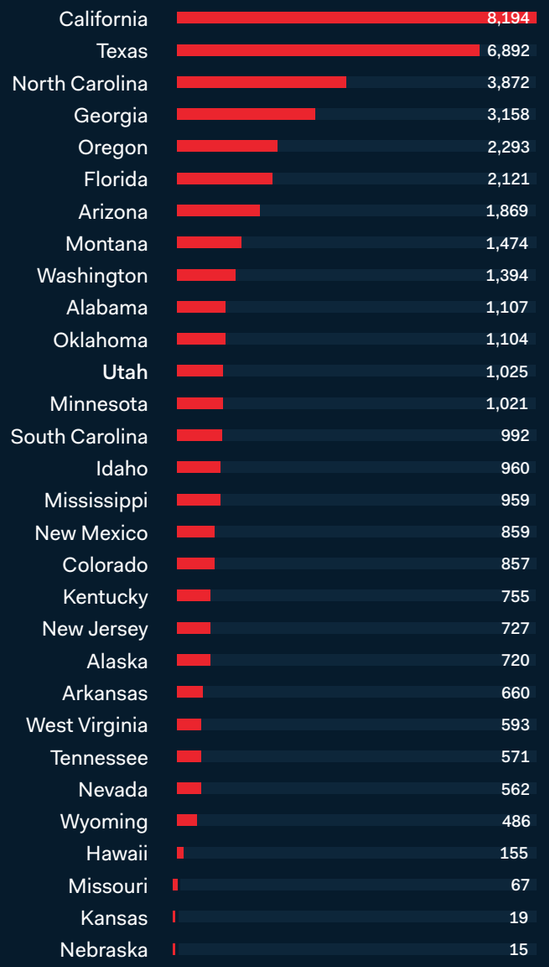
U.S. WILDFIRES

ACRES BURNED BY YEAR

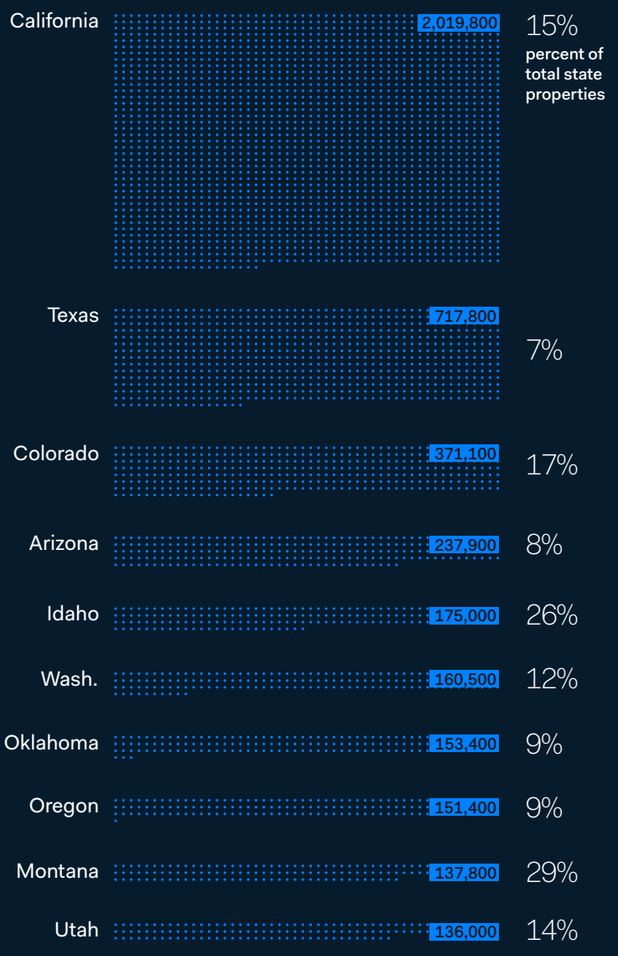
ACRES BURNED BY STATE (2019)



FIRES BY STATE (2019)



OF HIGH-RISK PROPERTIES (2019)



https://www.iii.org/fact-statistics/facts-statistics-wildfires

1991 | Oakland, CA

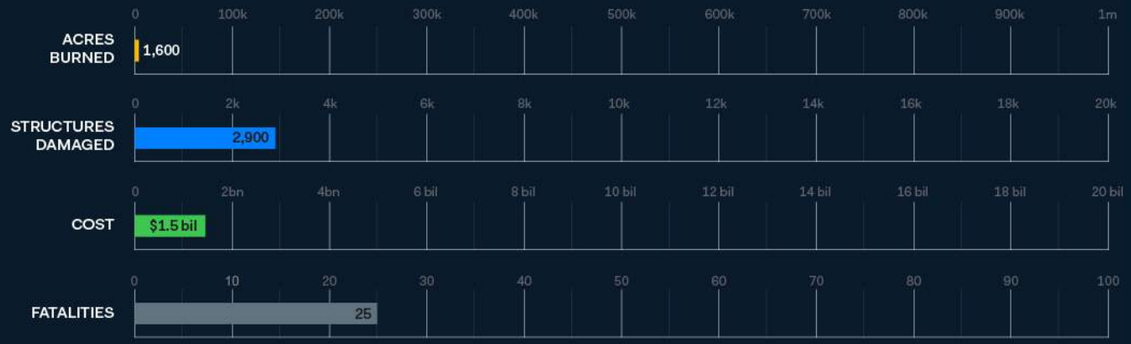
Tunnel Fire

ACRES BURNED
1,600

STRUCTURES DAMAGED
2,900

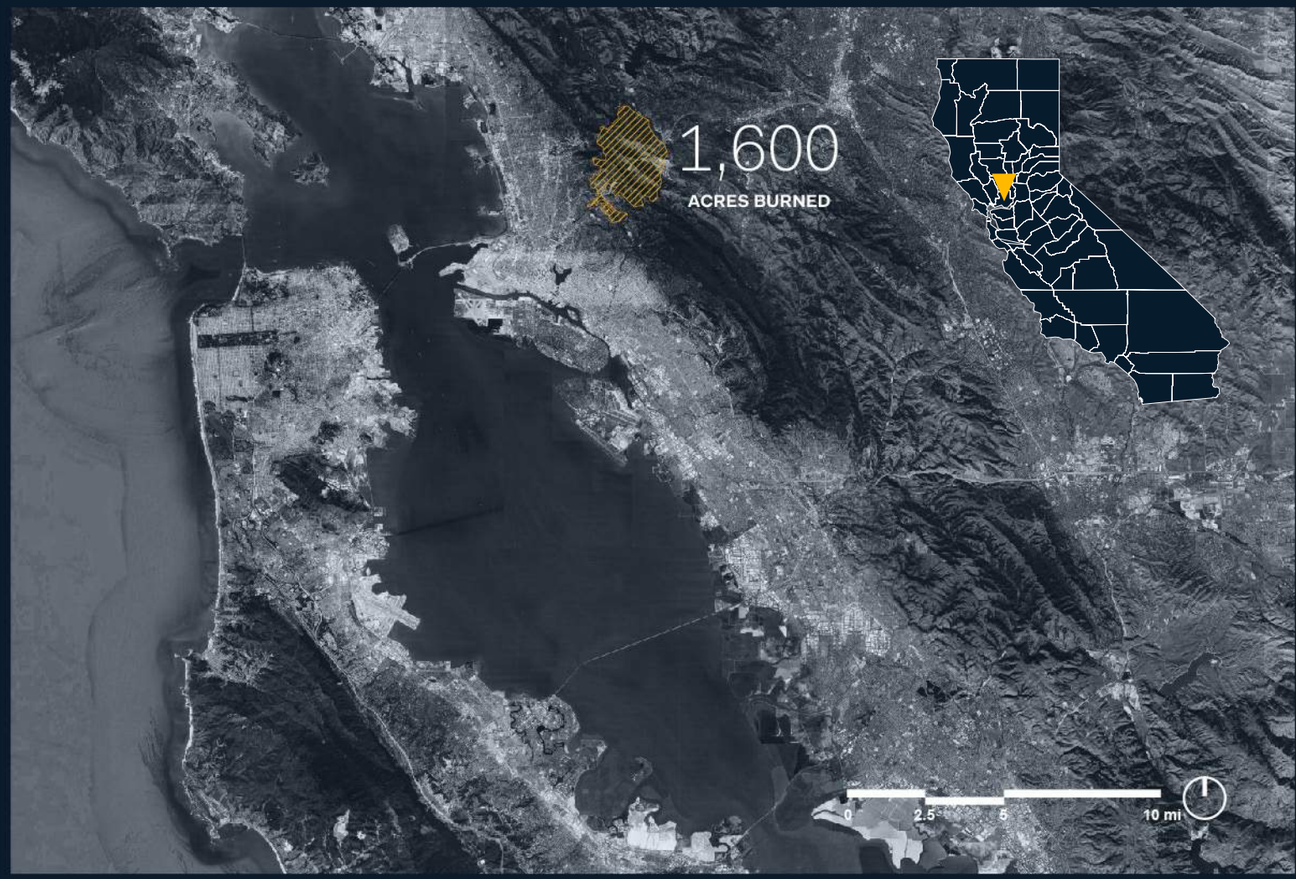
COST
$1.5b

FATALITIES
25



The 1991 Tunnel Fire, otherwise known as the Oakland Firestorm, was started in the Berkeley hills as a small 5 acre grass fire on a steep hillside near the Caldecott Tunnel. Firefighters thought the fire was contained and extinguished, but by the following morning, stark Diablo winds re-ignited the fire and carried the blaze to the top of the adjacent community area to the west, which swept through the Hiller Highlands neighborhood and jumped two multi-lane highways.

Until 2017 this was the most destructive California wildfire, magnified by high winds in a drought year. In today's dollars, the damages would have amounted to around 4 billion dollars. This devastating fire event initiated years of fire policy and defensible space enforcement.



https://www.fire.ca.gov/incidents/

2017 | Santa Rosa, CA

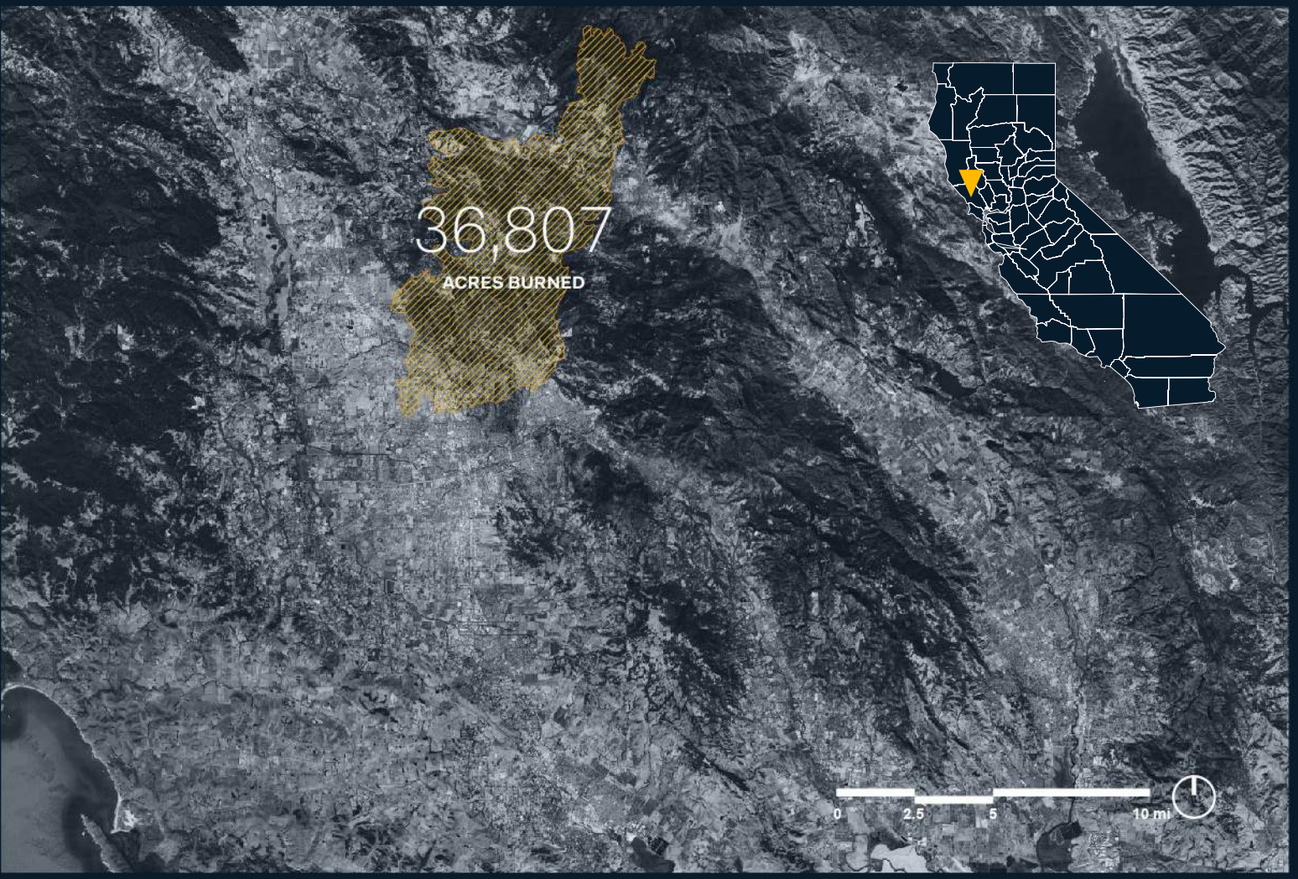
Tubbs Fire

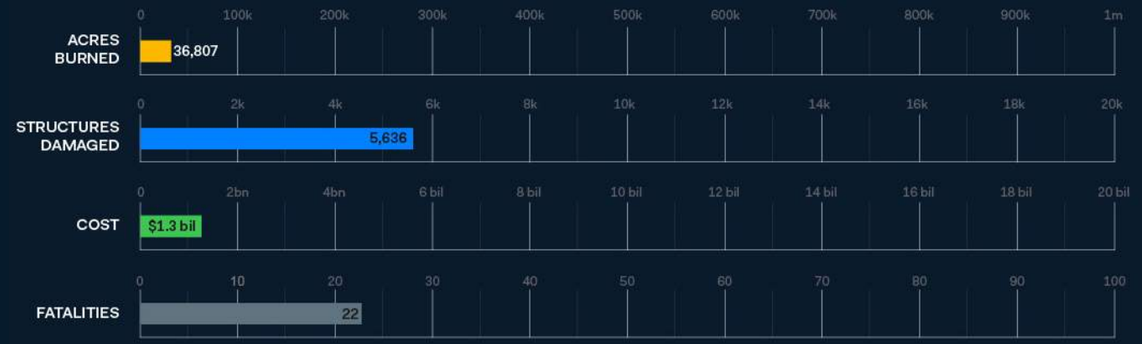
ACRES BURNED
36,807

STRUCTURES DAMAGED
5,636

COST
$1.3b

FATALITIES
22





The 2017 Tubbs Fire was a Northern California wildfire started by a faulty electrical system on a private network that would spread to impact parts of Sonoma, Napa, and Lake Counties, with the worst destruction in the city of Santa Rosa. The fire was one of a dozen burning in tandem in late 2017 over 8 counties, known as the “Northern California firestorm.” The Tubbs fire saw wind speeds exceeding 60 miles per hour which caused great devastation in both urban and suburban areas overnight, damaging over 5,000 structures. At the time, the Tubbs Fire was the most destructive (number of structures destroyed) California wildfire in history.

https://www.fire.ca.gov/incidents/

2017 | Santa Barbara, CA

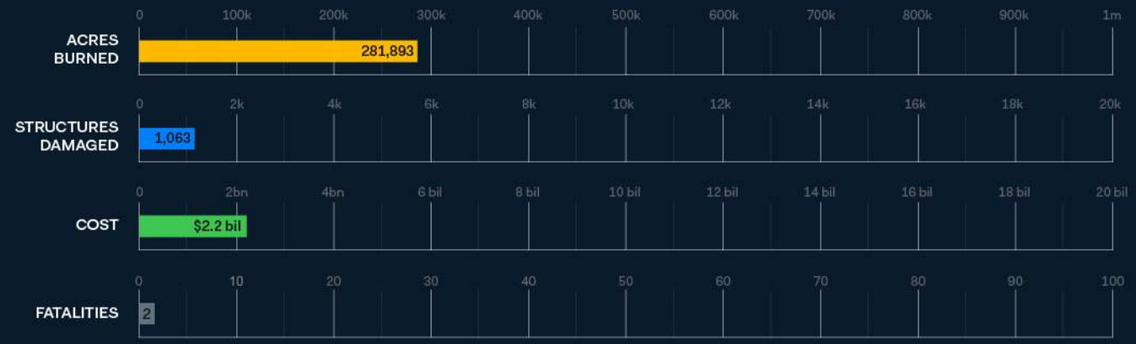
Thomas Fire

ACRES BURNED
281,893

STRUCTURES DAMAGED
1,063

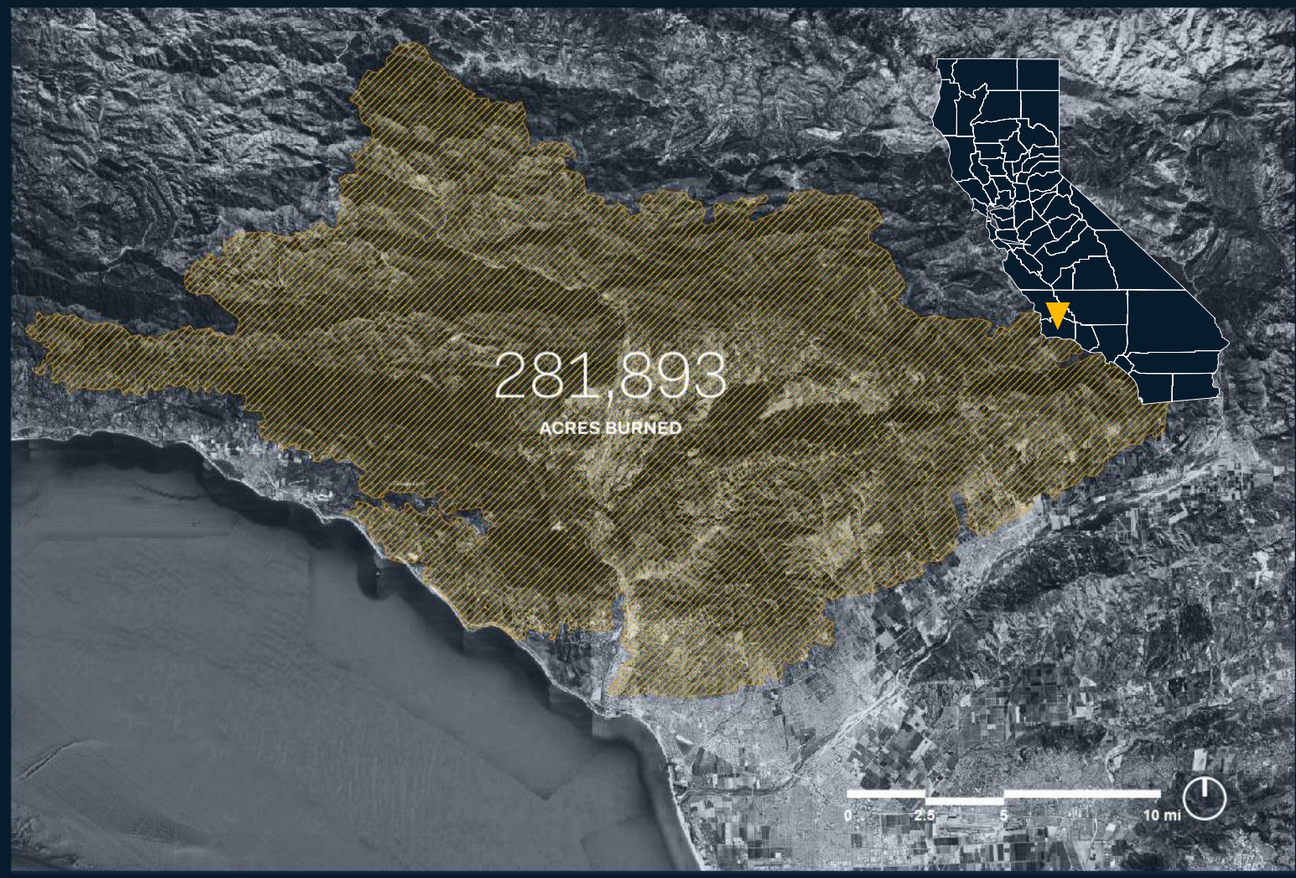
COST
$2.2b

FATALITIES
2



The 2017 Thomas Fire broke out in Southern California and burned in Ventura and Santa Barbara counties. It was one of several Southern California wildfires that occurred during December of the year, and at the time was the largest wildfire (most acres burned) in California history. Today it remains as the 5th largest fire. The fire began near Steckel Park, caused by downed power lines, and quickly spread to neighboring communities stoked by abnormally strong Santa Ana winds. Over 500 homes were destroyed on the first night of the fire in Ventura County, and as many more would be burned in neighboring rural communities.

Less than 1 month later when it began to rain in 2018, the fire-scarred hills transformed into destructive and deadly landslides that caused millions of dollars in damage.



https://www.fire.ca.gov/incidents/

2018 | Paradise, CA

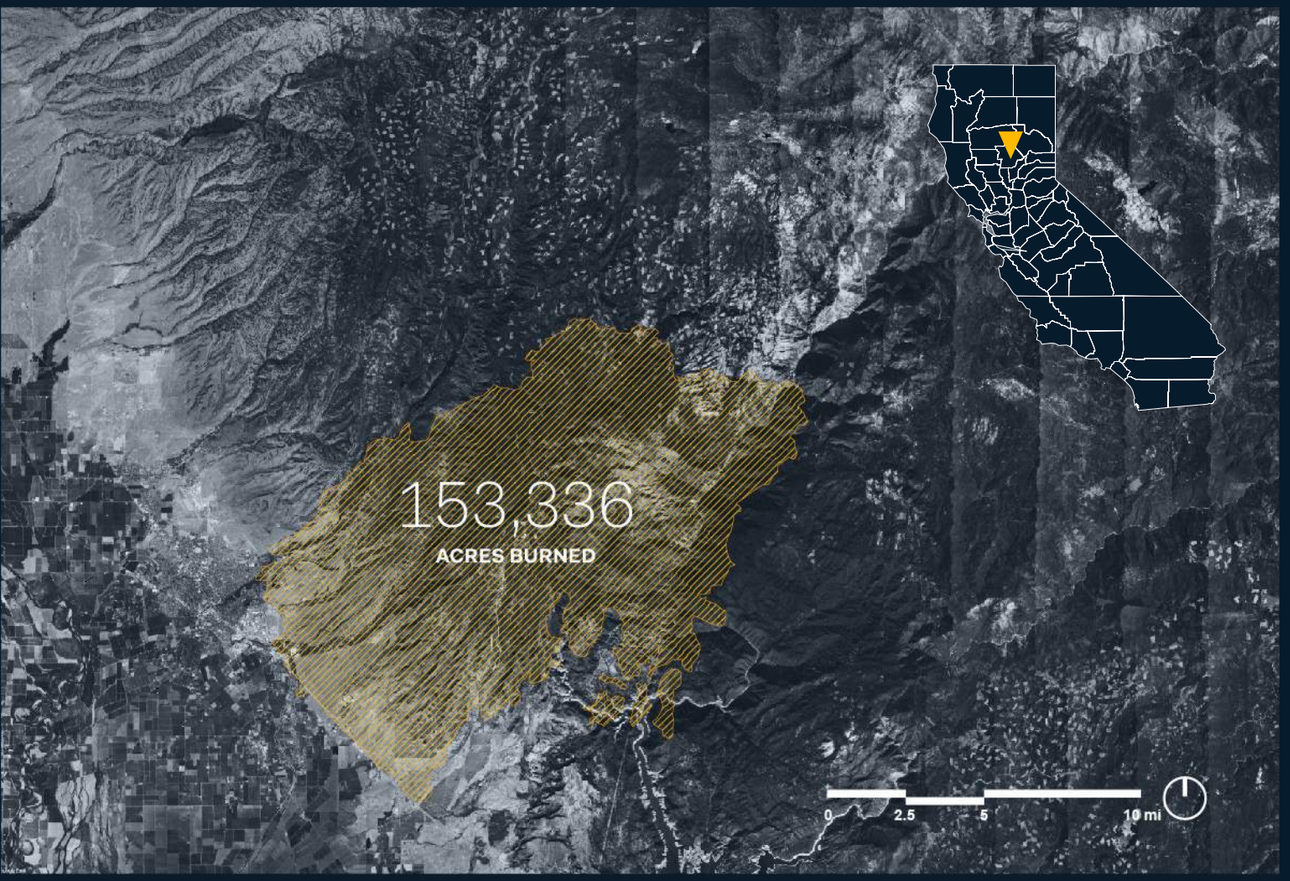
Camp Fire

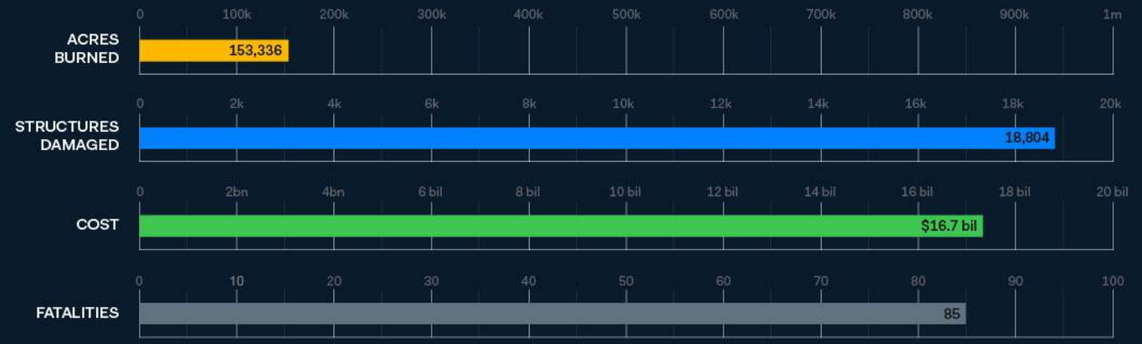
ACRES BURNED
153,336

STRUCTURES DAMAGED
18,804

COST
$16.7b

FATALITIES
85





The 2018 Camp Fire was started in Northern California's Butte County, sparked by faulty electric transmission lines. The fire spread above several rural communities and landed in the urbanized community of Paradise. Drought was a key contributing factor to the spread of the fire.

The fire was the most destructive, deadliest, and costliest fire in California history. It was also the most expensive natural disaster in the world for 2018. 52,000 people were evacuated during the event, which proved to be a challenging feat given the limited egress routes from the area. Difficulty in evacuation caused people to abandon cars and run on foot. The fire displaced over 1,000 families.

https://www.fire.ca.gov/incidents/

2020 | Coast Range, CA

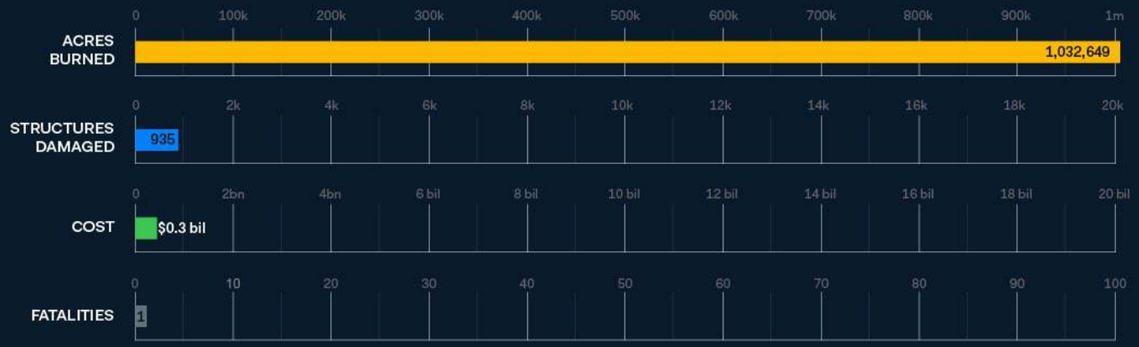
August Fire

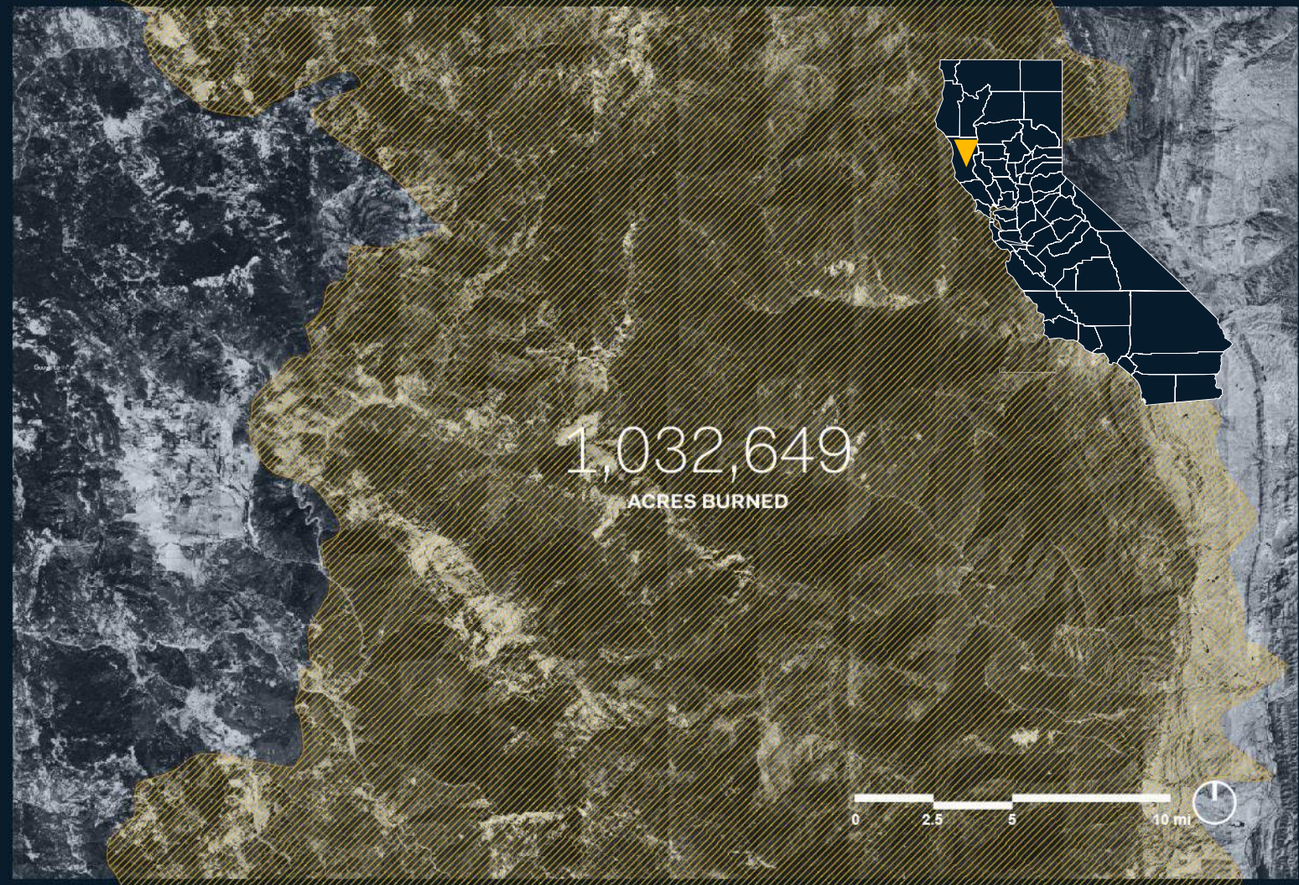
ACRES BURNED 1,032,649

STRUCTURES DAMAGED 935

COST $0.3b

FATALITIES 1



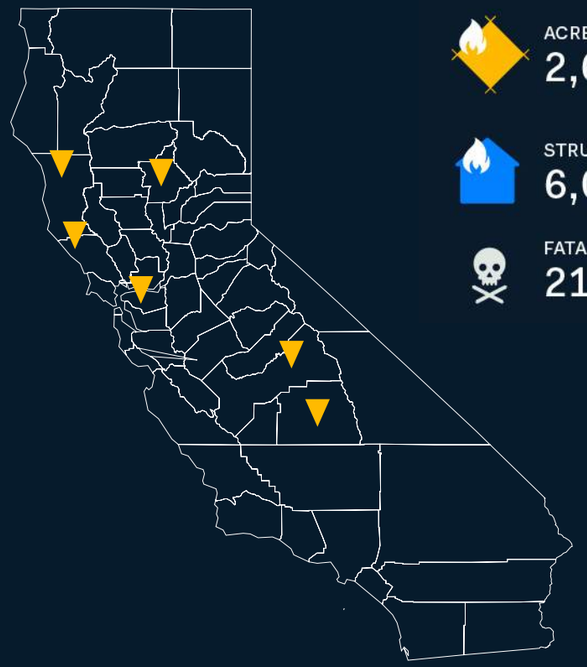


The 2020 August Complex Fire was a devastating event caused by bad electrical storms in Northern California. More than 650 lightning caused fires were started on the same night, with 38 of them fusing together in the Mendocino National Forest to comprise the August Complex. The fire also spread to the Shasta-Trinity National Forest and the Six Rivers National Forest. This stands as the largest fire in California history and tragically burned in the same location as the 2018 Mendocino Complex fire, which was the largest fire at the time, burning 459,000 plus acres. The August Fire would exceed this grim milestone by burning in excess of 1 million acres. Smoke from this fire season led to an estimated 1,200 additional deaths and 4,800 additional ER visits among the elderly.

https://www.fire.ca.gov/incidents/

CALIFORNIA WILDFIRES

2020 saw the most widespread wildfires in California history, comprising 30% of the state's largest fires on record with just six fires.



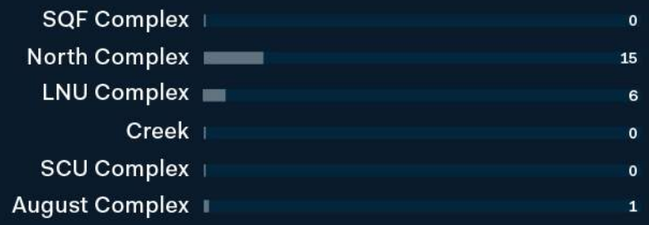
ACRES BURNED
2,659,500

STRUCTURES DAMAGED
6,081

FATALITIES
21

ACRES BURNED

FATALITIES



STRUCTURES DAMAGED

https://www.fire.ca.gov/incidents/

CALIFORNIA WILDFIRES

Strong seasonal wind events in California's mountain regions exacerbate the spread of fire.

Santa Ana and Diablo winds originate from the Northeast and flow to the Southwest and can easily reach gusts of 50 mph. These winds most commonly occur in the fall and winter and are typically worse in the late-night hours. They are characterized as being drier and hotter than standard wind events.

Photo Credit: https://www.nationalgeographic.com/science/article/santa-ana-diablo-winds-propel-fire-season-california-risk

CALIFORNIA WILDFIRES

Photo Credit: Dan Zweig
https://www.fire.ca.gov/incidents/

California wildfires are increasing in frequency and intensity. Climate change is considered to be a key driver of this trend.

Warmer spring and summer temperatures, reduced snow pack, and earlier spring snow melt create longer and more intense dry seasons that increase moisture stress on vegetation and make forests more susceptible to severe wildfire. The length of fire season is estimated to have increased by 75 days across the Sierras and corresponds with an increase in the extent of forest fires across the state.

CALIFORNIA WILDFIRES

Many wildfires are the result of human activity and urbanization in the Wildland-Urban Interface (WUI)

The Wildland-Urban Interface (WUI) is defined by the US Fire Administration as “the zone of transition between unoccupied land and human development. It is the line, area or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels.”

Damaged power lines and other human activities are among the leading causes of wildfires in the Wildland-Urban Interface. Fires in this zone also tend to be difficult to control, more damaging to property, and the most threatening to human life.

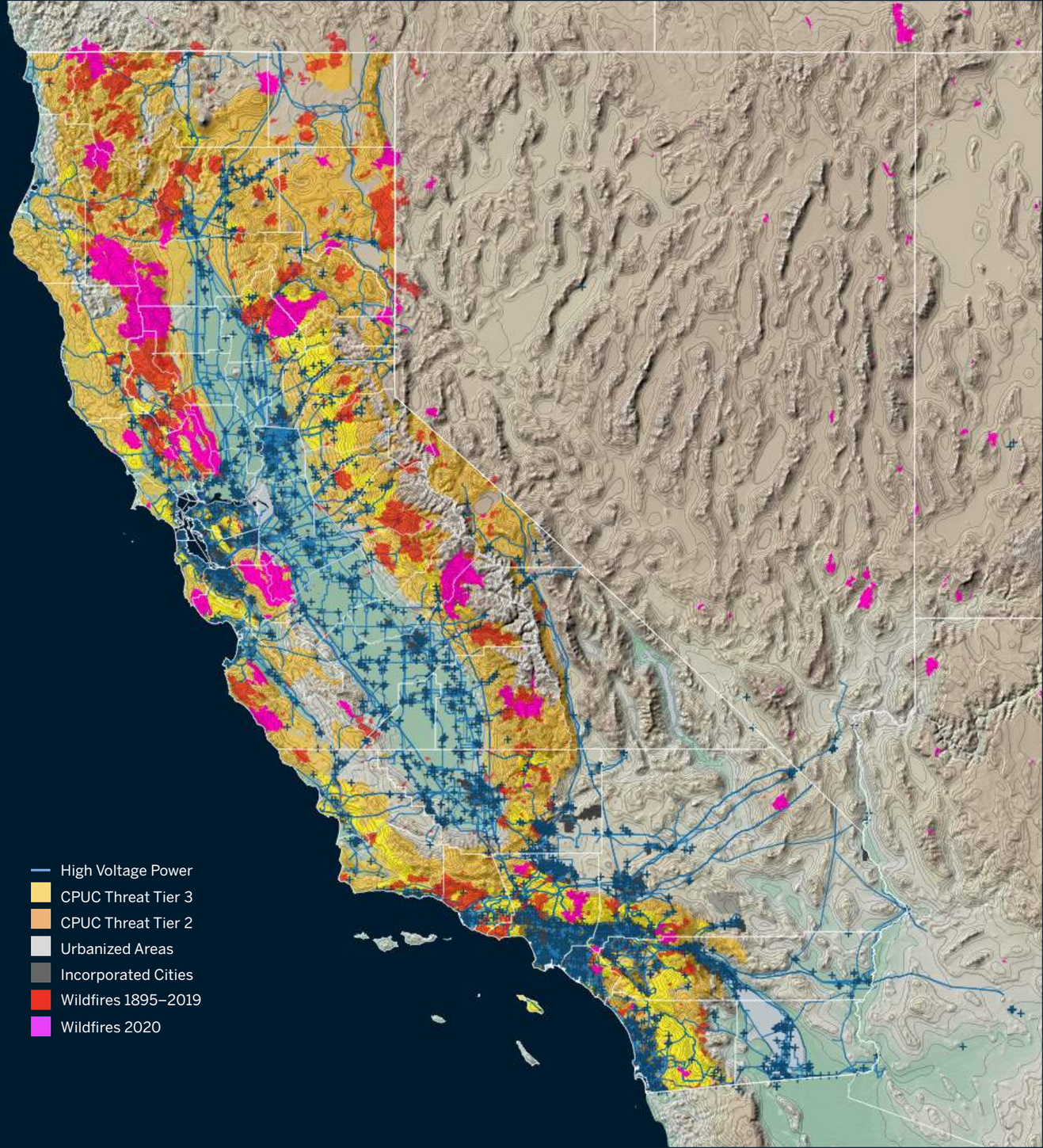
Photo Credit: PasterScott/E+/Getty Images

CALIFORNIA WILDFIRES

Millions of Californians are at risk. 2.7 million residents live in Very High Fire Hazard Severity Zones, which accounts for 7% of the state population.

Cal Fire's hazard metrics overlaid with 2010 census data have determined that more than 75 towns and cities with a population exceeding 1,000 residents are almost fully contained within a high risk area.

Note: Cal Fire's Fire Hazard Severity Zones (FHSZ), Wildland-Urban Interface (WUI), and the California Public Utilities Commission Tier 3 (extreme) and Tier 2 (elevated) fire threat, all describe areas of high fire risk.



https://www.directrelief.org/2019/07/which-california-communities-are-most-vulnerable-to-wildfires/

CHAPTER 1

Wildlands

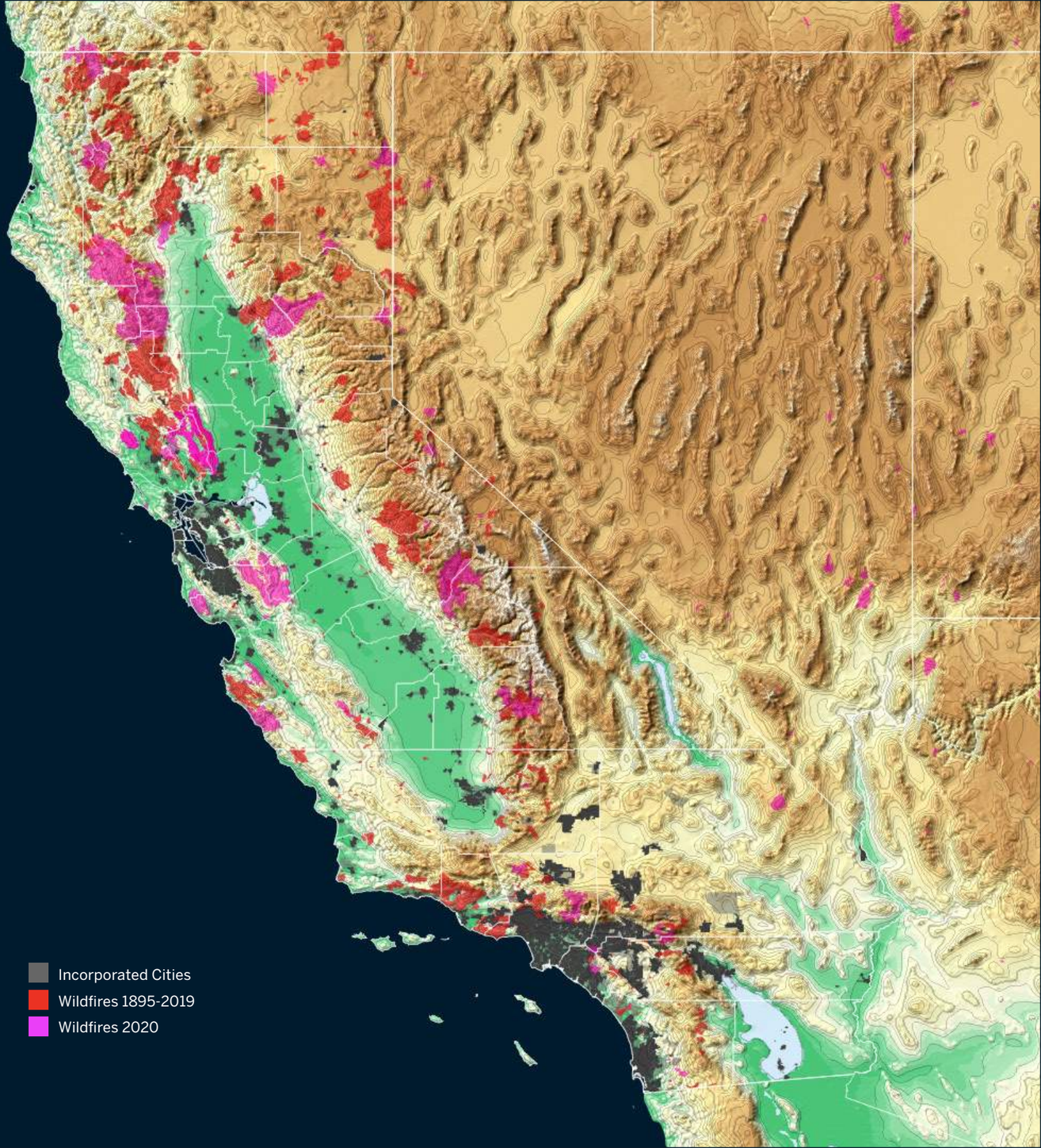
WILDLANDS

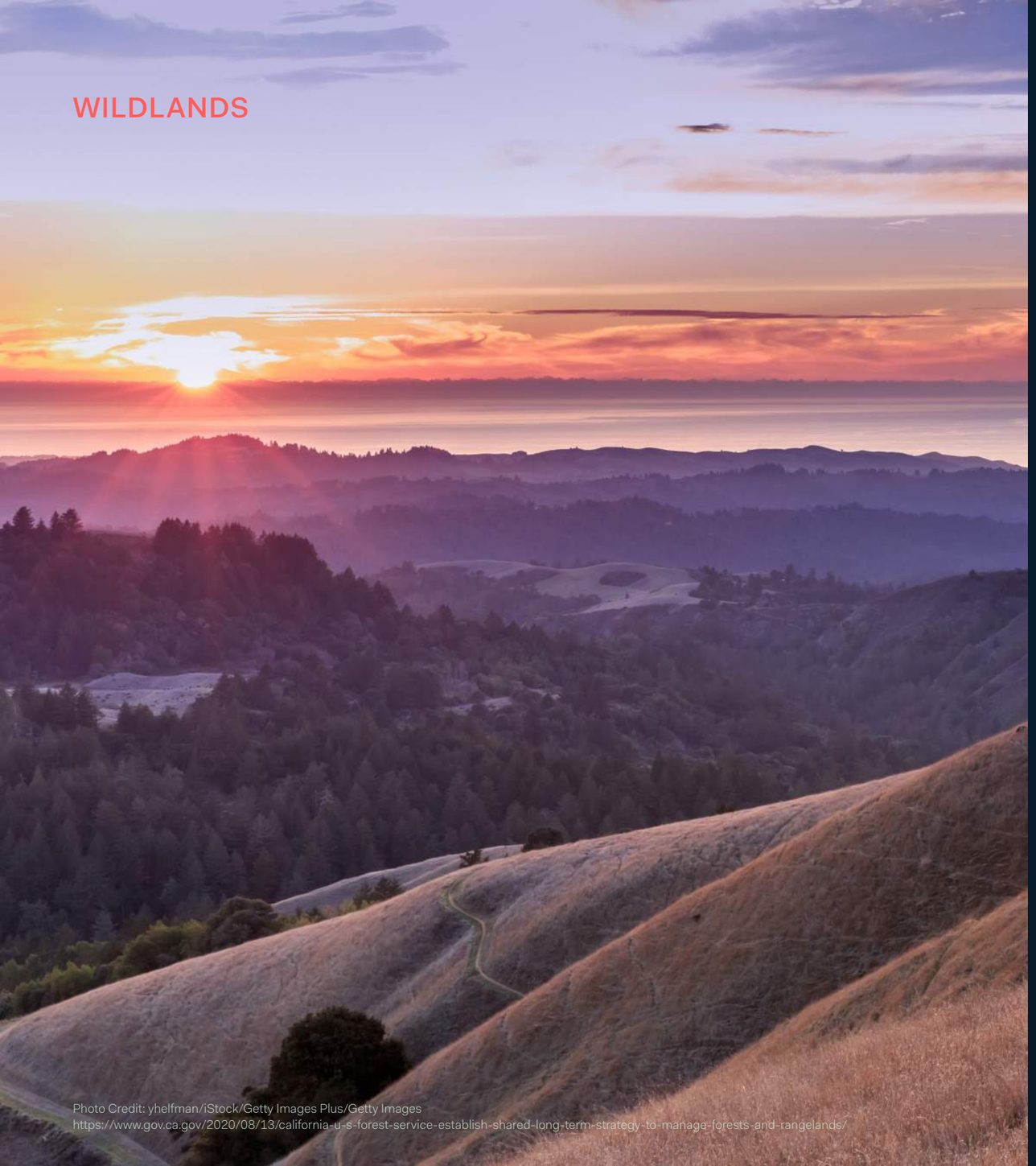
California wildfires occur primarily in its wildlands, outside of urbanized and agriculture areas.

California covers an area of 163,696 square miles (423,970 km2). It's among the largest and most geographically diverse U.S. states.

Much of California's land area is used for agriculture, with concentrations of urbanized areas in several coastal locations—San Francisco Bay Area, Los Angeles, and San Diego. There are also urban areas in the Central Valley.

Fires have always been present in California. An overlay of over 100 years of wildfires show that virtually all of them occurred in higher elevations.





WILDLANDS

Photo Credit: yhelfman/iStock/Getty Images Plus/Getty Images
https://www.gov.ca.gov/2020/08/13/california-u-s-forest-service-establish-shared-long-term-strategy-to-manage-forests-and-rangelands/

Most forests in California are not owned or managed by the state. Ownership and responsibility varies across different agencies and stakeholders.

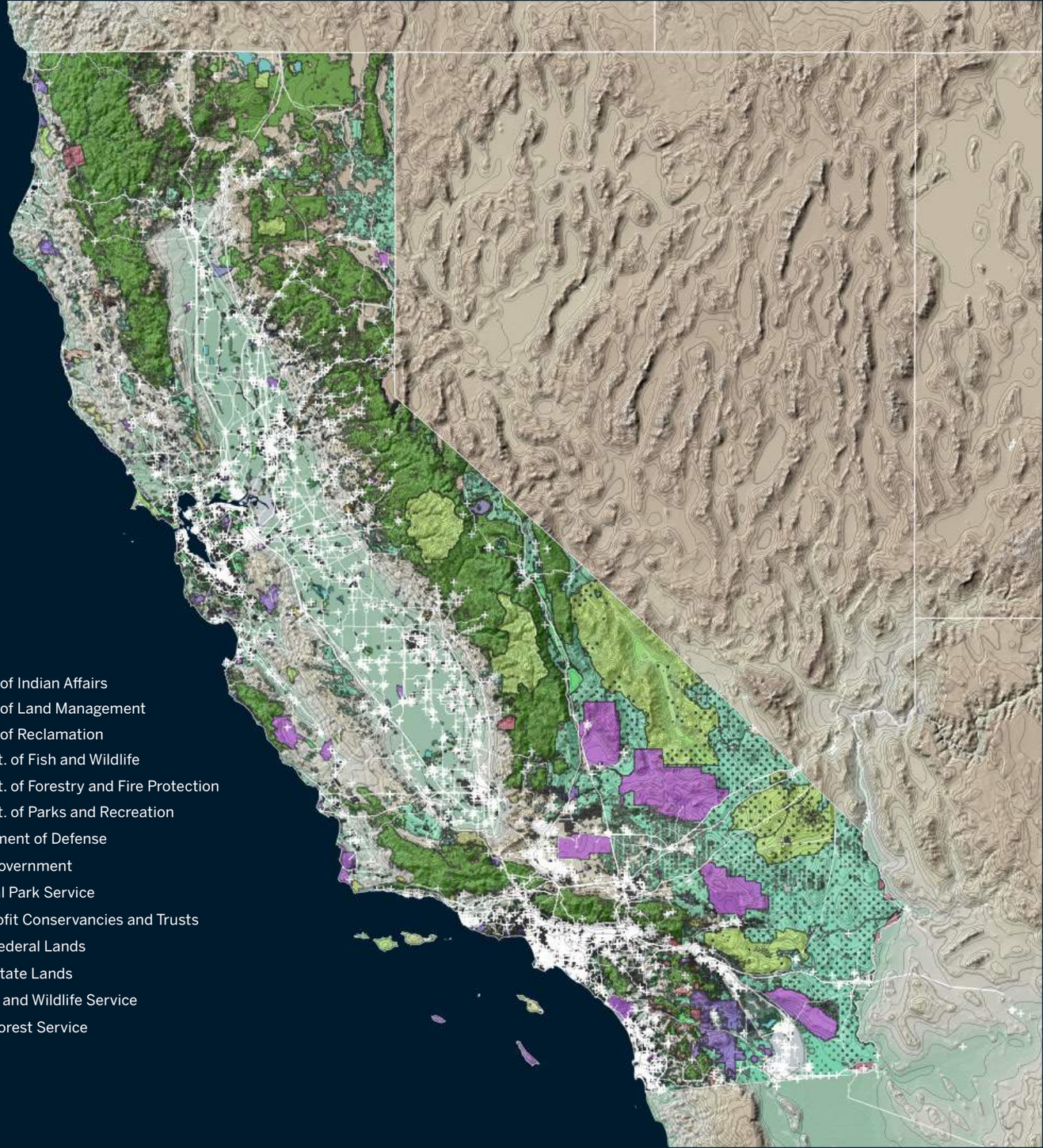
According to the state governor's office, the federal government oversees approximately 58% of the 33 million acres of California forest, which is managed by several different federal agencies. The state is responsible for managing 3%.

The remainder is owned by private individuals, companies or Native American groups.

GUIDELINE 1.1

Federal, state, and local governments must collaborate to develop a unified response to wildfires.

While there is a unifying regulatory framework for fire mitigation policy, many wildfires cross multiple jurisdictions that are owned or managed by different agencies. It is important that all agencies have a shared vision and policy to prepare for and mitigate wildfires. These may include firebreaks between neighborhoods, controlled burns, and shared decision frameworks.



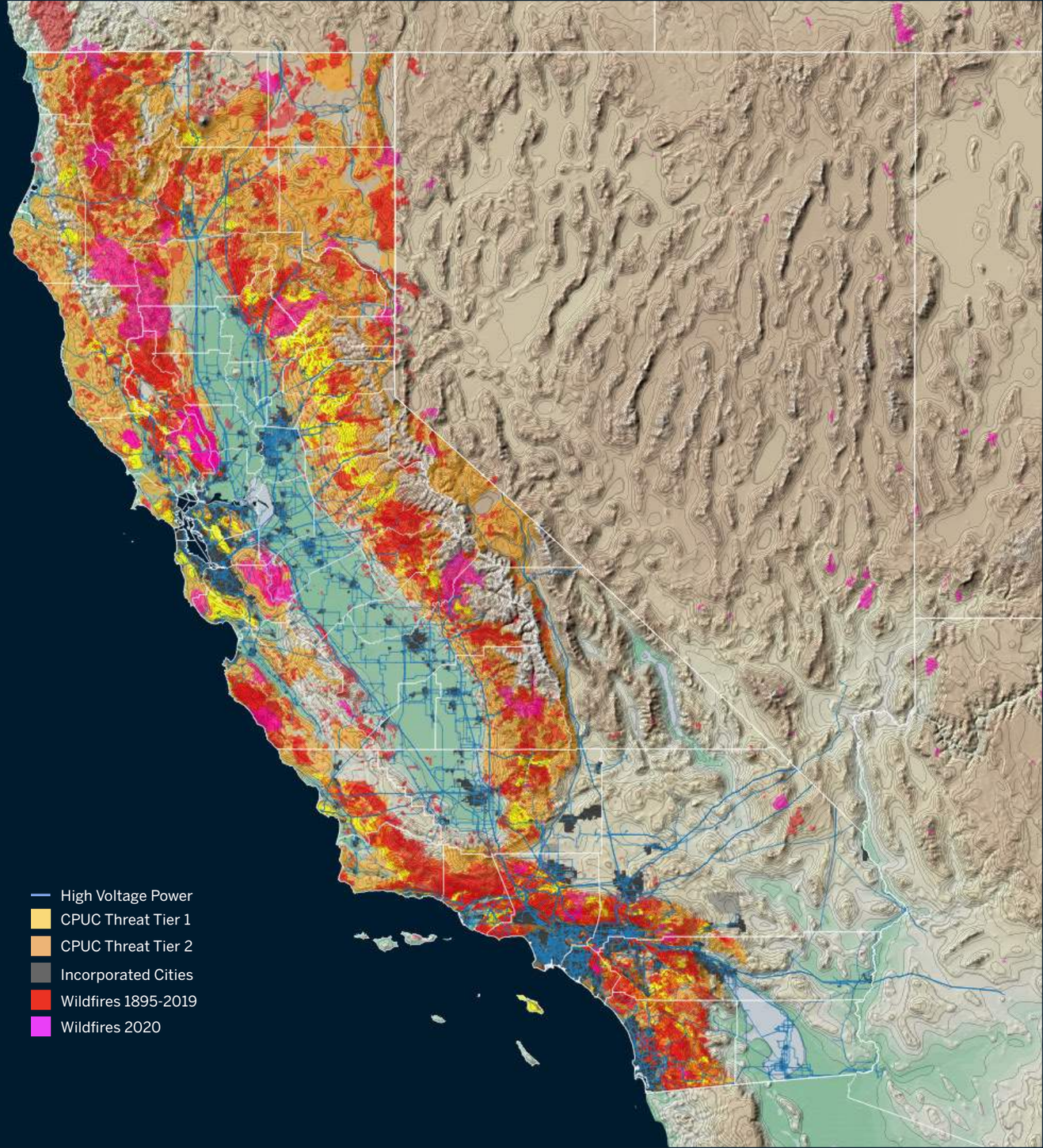
WILDLANDS

Many wildfires are caused by sparks from power lines and electrical equipment.

85% of U.S. wildfires are caused by human-related activities and equipment. In general, electrical lines and equipment break in high wind events, which generates sparks. California does not have rain or snow for the majority of the year, making most of its vegetation extremely dry. Sparks tend to easily ignite adjacent vegetation which spreads rapidly in high winds.

This overlay shows topography in relation to high voltage power lines. In general, high voltage power lines are located in the Central Valley and major cities, with a number of these power lines reaching into higher elevations.

The California Public Utilities Commission (CPUC) has identified areas under wildfire threat. There are two tiers—mostly located at the higher elevations. This map shows an overlay of the two CPUC Threat Tiers and existing power plants and electric power lines.



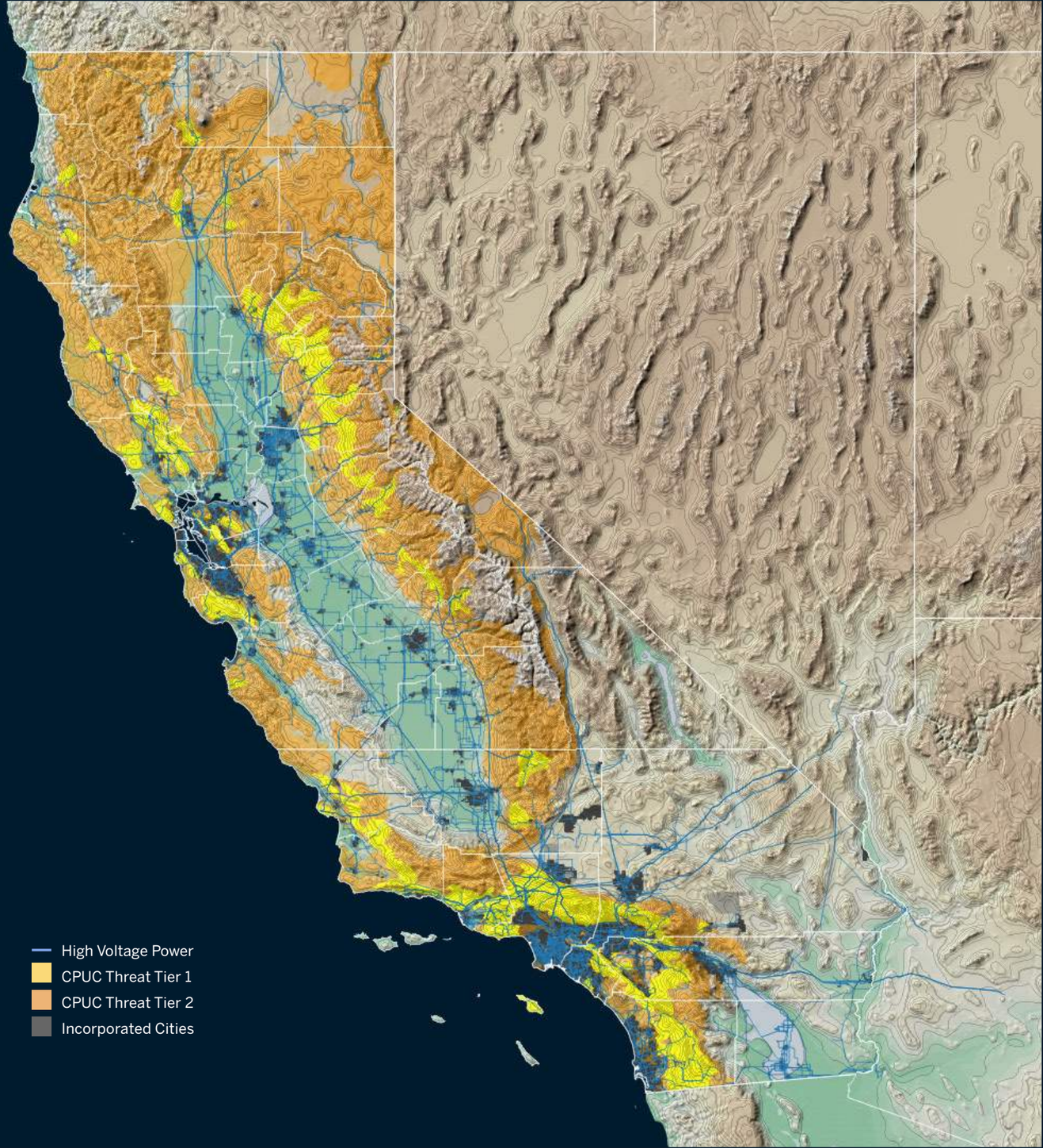
https://www.nps.gov/articles/wildfire-causes-and-evaluation.htm

GUIDELINE 1.2

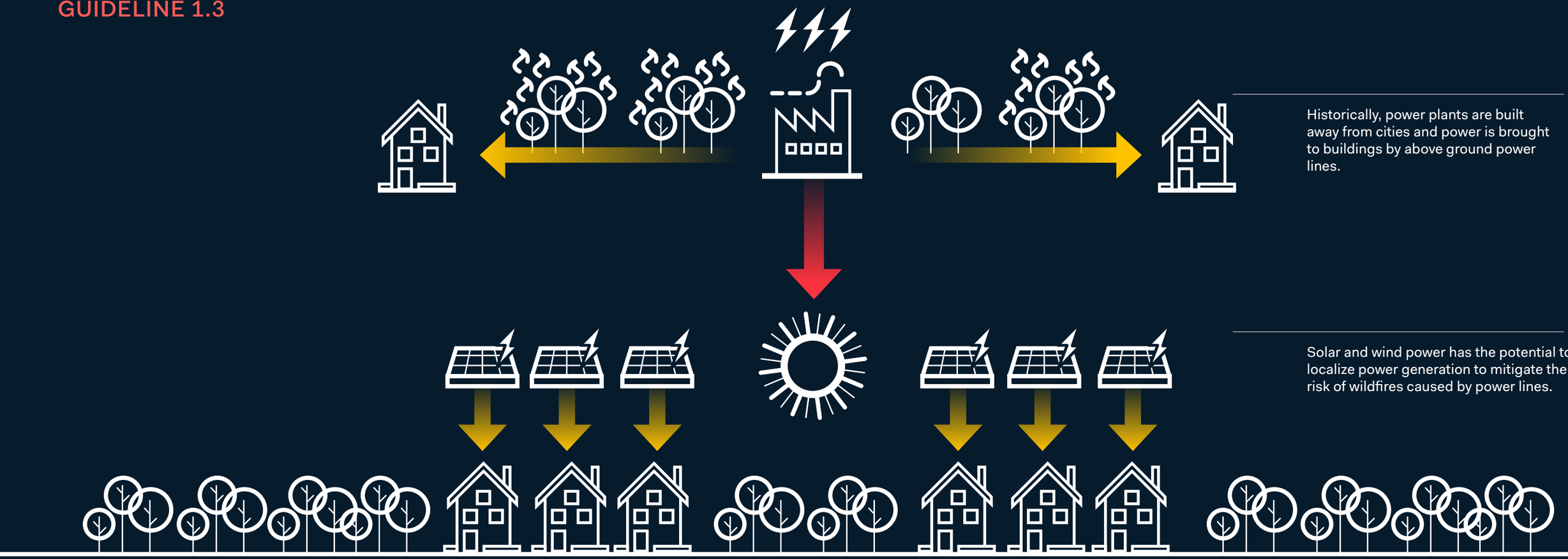
Update outdated power lines and equipment in lower risk zones and add more monitoring systems throughout California.

The first step to reducing wildfires in California is to upgrade the electric infrastructure throughout. In the Central Valley and lower risk zones, this entails hardening of the existing systems to reduce the possibility that they will spark in high wind events.

Additionally, this includes installation of cameras and other equipment to facilitate monitoring of electric infrastructure.



GUIDELINE 1.3



Historically, power plants are built away from cities and power is brought to buildings by above ground power lines.

Solar and wind power has the potential to localize power generation to mitigate the risk of wildfires caused by power lines.

Decentralize power sources in high risk zones to reduce power line infrastructure.

Photo Credit: f00sion/E+/Getty Images
https://www.technologyreview.com/2020/09/17/1008473/wildfires-california-prescribed-burns-climate-change-forests/

A 2018 report by a state oversight agency recommended fuel reduction of 1.1 million acres per year throughout the state. The current rate of controlled burns is less than half of this amount.

Approximate costs* of managing forests:

- Prescribed burns: $200 per acre
- Forest thinning: $1,000 per acre
- Fighting Wildfire: $800 per acre (not including damage costs)

The total cost to manage 1.1 million acres per year can range from hundreds of millions of dollars to more than a billion dollars per year.

In comparison, the Northern California Wine Country Fires in October 2017 caused more than $9 billion worth of damage in a single month.

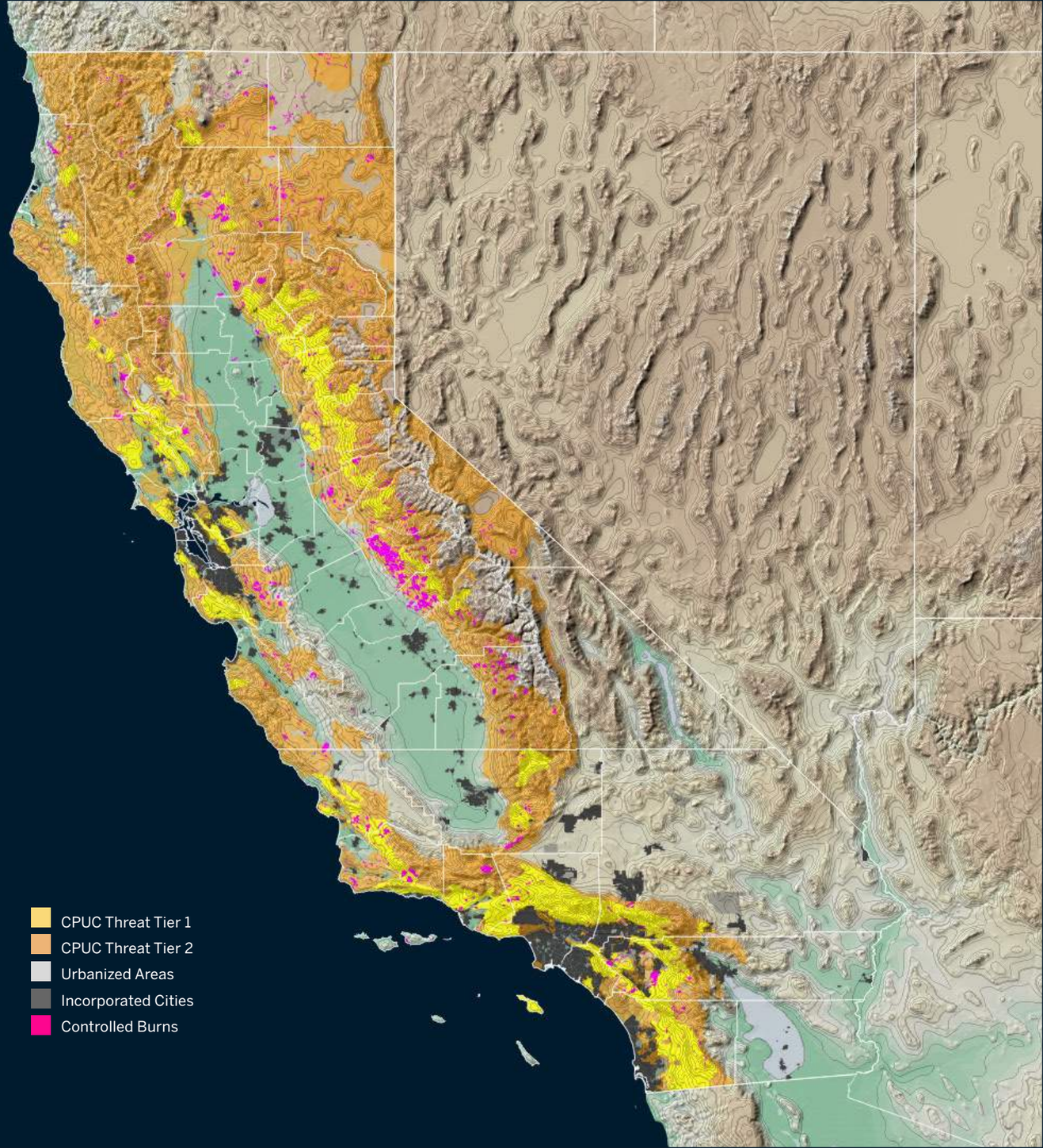
*cost per acre is a generalized value and is different in Southern and Northern California

GUIDELINE 1.4

Prioritize and increase prescribed burns in high risk areas.

Prescribed fires, also known as prescribed burns or controlled burns, refer to the controlled application of fire by a team of fire experts to restore health to ecosystems that depend on fire and decrease the intensity or uncontrollability of future wildfires.

Reducing the fuel load in high risk areas via controlled burns in appropriate locations and intervals has the potential to save over 600 million dollars per year in firefighting costs alone.



Many buildings and landscape areas in California's Wildland-Urban Interface areas are vulnerable to wildfires.

Photo Credit: Thomas De Wever/Getty Images

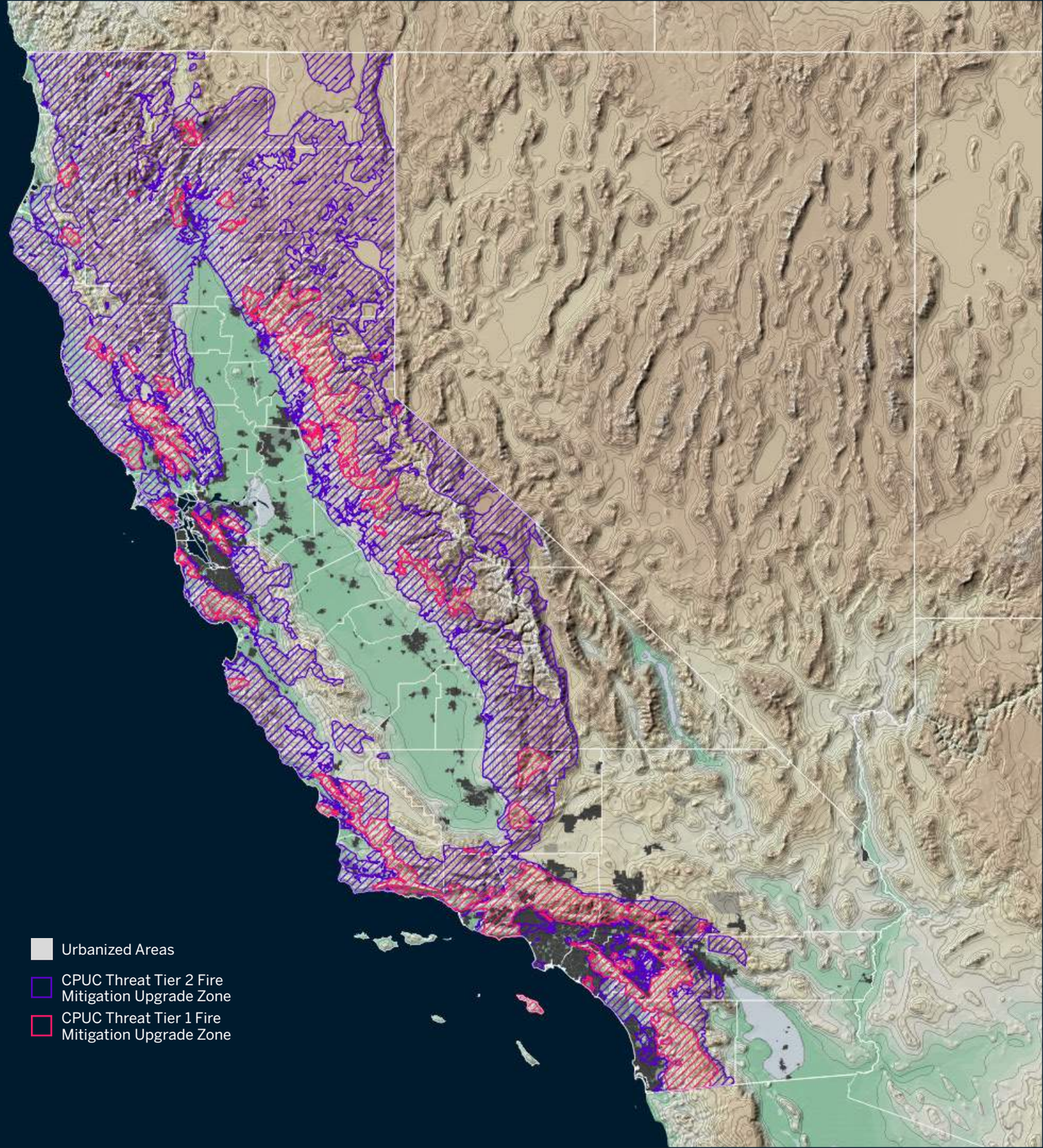
GUIDELINE 1.5

Require mandatory fire-resistant building and residential landscape upgrades.

Similar to the state-wide seismic upgrades in California, the structures located within high risk areas should be required to meet a modern standard of fire resistance.

While new structures in Cal Fire's High Fire Hazard Severity Zones are required to be built to fire-resistant Wildland-Urban Interface (WUI) standards, all existing buildings within the CPUC Threat Tier 1 and 2 zones should be subject to mandatory upgrades to meet the same standards.

This guideline is explored further in the following chapters.



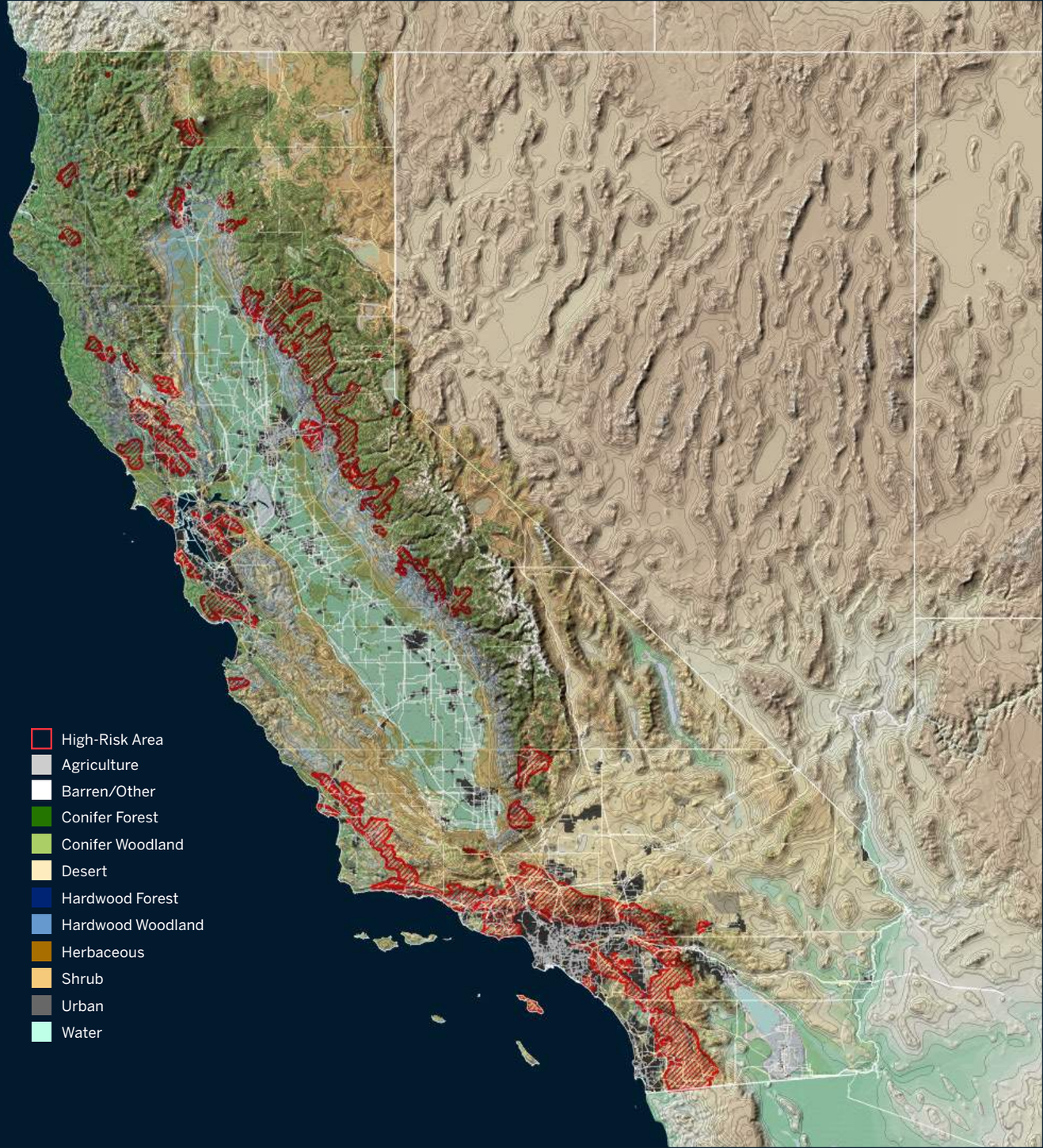
GUIDELINE 1.6

Bury new power lines where feasible within high wildfire hazard zones.

When high risk areas are compared with vegetated zones, it becomes evident that the areas most susceptible to fires are between the lower-elevation urbanized and agricultural lands and the higher-elevation hills and mountains.

Sparks from power lines are one of the leading causes of major wildfires in California. One solution to reduce the total number of wildfires caseued by power lines would be to remove or bury power lines in areas known to be at the highest risk for fires.

Burying selective and specific power lines that lie within the high risk zones would be an effective intervention to minimize exposure to wildfires.



WILDLANDS

Summary

ISSUES	GUIDELINES
Many different governments and other agencies have different policies and responsibilities for forest and fire management.	1.1: Federal, state, and local governments must collaborate to develop a unified response to wildfires.
Power lines have caused many catastrophic fires.	1.2: Update outdated power lines and equipment in lower risk zones and add more monitoring systems throughout California.
High voltage power lines traverse high risk areas to reach remote rural communities.	1.3: Decentralize power sources in high risk zones.
Currently the state does not manage enough of the forest each year via prescribed burns.	1.4: Prioritize and increase prescribed burns in high risk areas.
Existing buildings and landscapes in wildlands and high risk areas are not up to modern fire resistance standards.	1.5: Require mandatory fire-resistant building and residential landscape upgrades.
High voltage power lines are the leading cause of wildfires and currently traverse numerous high risk areas.	1.6: Bury new power lines where feasible within highest wildfire hazard zones.

CHAPTER 2

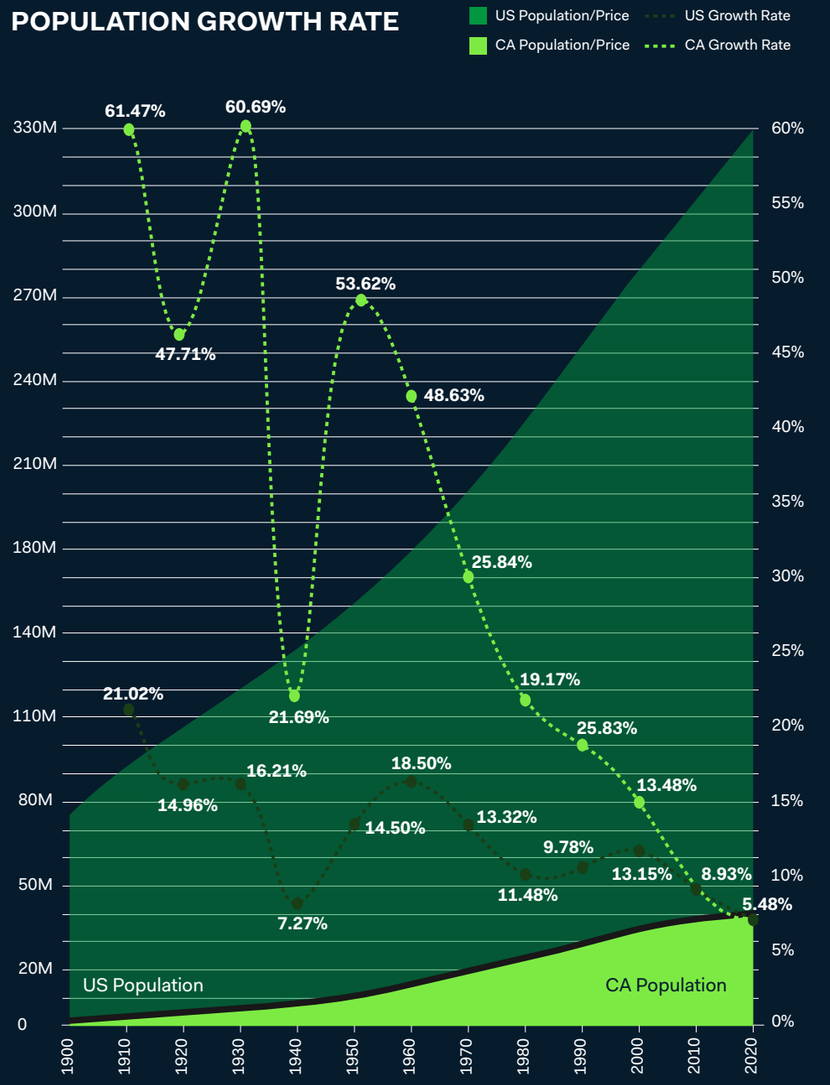
Urban Areas

URBAN AREAS

One in eight U.S. residents lives in California, making it the most populous U.S. state.

The rate of annual population growth in the state has far exceeded the national average throughout the 20th century. California housing is two and a half times more expensive than the average national home price, a trend that has been accelerating since the 1970s. A shortage in affordable housing in urban areas has pushed development into the Wildland-Urban Interface (WUI) areas where wildfires are more likely to occur and harder to contain.

POPULATION GROWTH RATE



AVERAGE HOUSING PRICES

	National Average	California Average
2020	$276,708	$606,410
2019	$262,157	$603,030
2018	$248,653	$584,460
2017	$233,400	$537,950
2016	$219,146	$509,240
2015	$207,209	$484,370
2014	$197,300	$448,720
2013	$187,246	$402,830
2012	$175,155	$312,500
2011	$171,551	$294,140
2010	$182,056	$307,000
2009	$184,959	$253,110
2008	$201,087	$404,590
2007	$217,080	$594,110
2006	$213,341	$562,820
2005	$197,924	$510,400
2004	$178,836	$452,680
2003	$164,362	$364,040
2002	$152,675	$317,121
2001	$143,256	$255,310
2000	$133,788	$237,057
1999	$125,379	$216,490
1998	$118,343	$198,252
1997	$113,432	$181,218
1996	$110,520	$178,536
1995	$106,992	$176,768
1994	$104,551	$186,968
1993	$101,014	$192,600
1992	$98,573	$198,700
1991	$96,439	$207,718

*Based on monthly median values of April each year

US Census Bureau; https://www.macrotrends.net; https://CAR.org

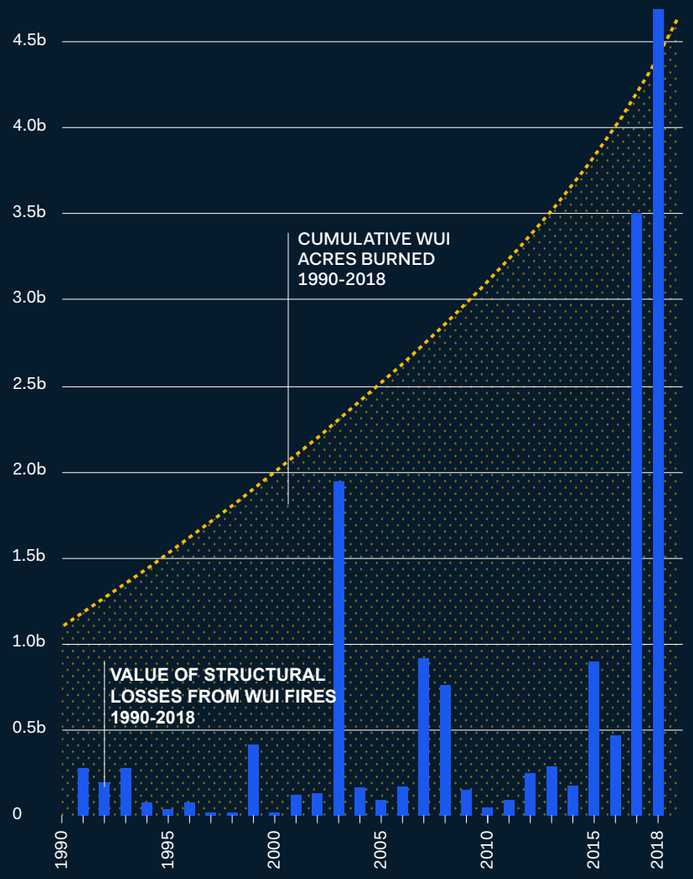
URBAN AREAS

More and more Americans are moving to the Wildland-Urban Interface despite the high risk of fire.

Over the last 100 years, 6 of the top 10 most damaging single fire events in the U.S. that involved structures were Wildland-Urban Interface (WUI) fires. More than 46 million U.S. homes in 70,000 communities are at risk of WUI fires. This corresponds to 32% of U.S. housing units and one tenth of all land with housing.

Over the last decade, the fire season has increased by two and a half months and fires greater than 10,000 acres have increased. The average area burned by wildland fires in the U.S. has doubled in the last three decades, to an estimated seven million acres per year.

WILDFIRES IN CALIFORNIA WUI ZONES



DEVELOPMENT IN WILDLAND URBAN INTERFACES

CA		WUI Zones	Non-WUI Zones	
Developed Area	5.3%	22,618	401,349	1990
	5.7%	24,375	399,592	2000
	6.4%	27,026	396,941	2010
Housing Units	29.6%	3,309,716	7,873,166	1990
	31.0%	3,788,536	8,426,013	2000
	32.4%	4,426,803	9,253,278	2010
Population Count	27.6%	8,211,337	21,548,684	1990
	28.6%	9,673,645	24,198,003	2000
	30.0%	11,157,953	26,096,003	2010

US		WUI Zones	Non-WUI Zones	
Developed Area	7.2%	580,831	7,501,054	1990
	8.5%	688,529	7,393,357	2000
	9.5%	770,301	7,311,585	2010
Housing Units	30.3%	30,782,682	70,858,571	1990
	32.1%	36,946,860	78,236,260	2000
	33.2%	43,434,112	87,444,148	2010
Population Count	29.4%	72,636,475	174,415,125	1990
	30.9%	86,252,862	193,330,573	2000
	31.9%	97,774,215	208,900,791	2010

Denotes number in WUI zones
Denotes percentage in WUI zones
Denotes number in Non-WUI zones

The Nature Conservancy; https://www.SILVIS.Forest.Wisc.edu/data/WUI_change; National Interagency Fire Center

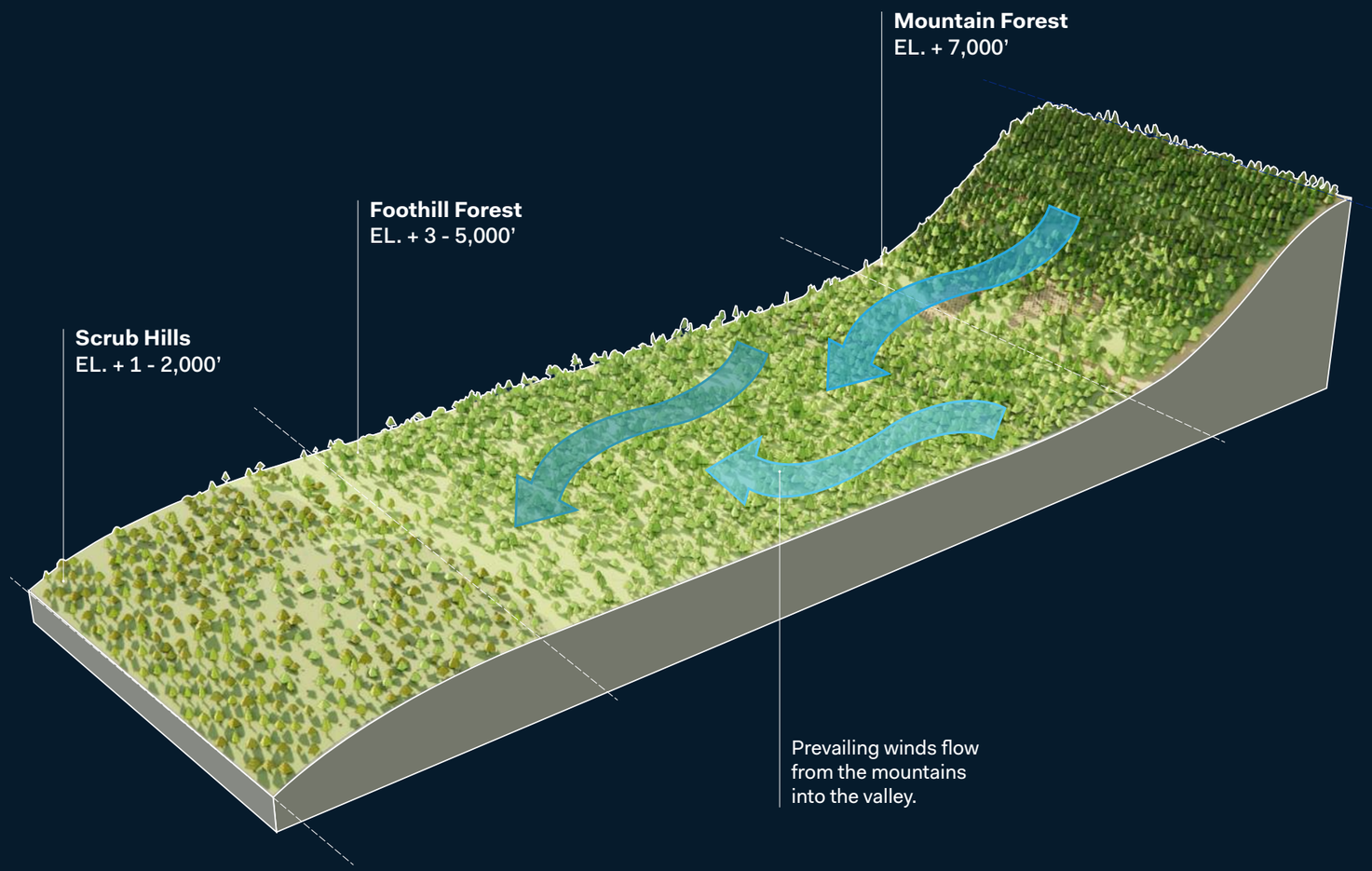
URBAN AREAS

Demand for affordable housing is accelerating development in the Wildland-Urban Interface, where wildfires are more frequent and intense.

Dispersed ingle-family homes are harder to protect from wildfires than larger multi-family homes or uninhabited wildlands.

If aggregated settlements of higher density buildings were prioritized over dispersed single family homes, settlements could be more easily defended against wildfire.

Fewer single-family homes would allow for more open space in wildlands, where controlled burns and periodic wildfires could be easily facilitated.

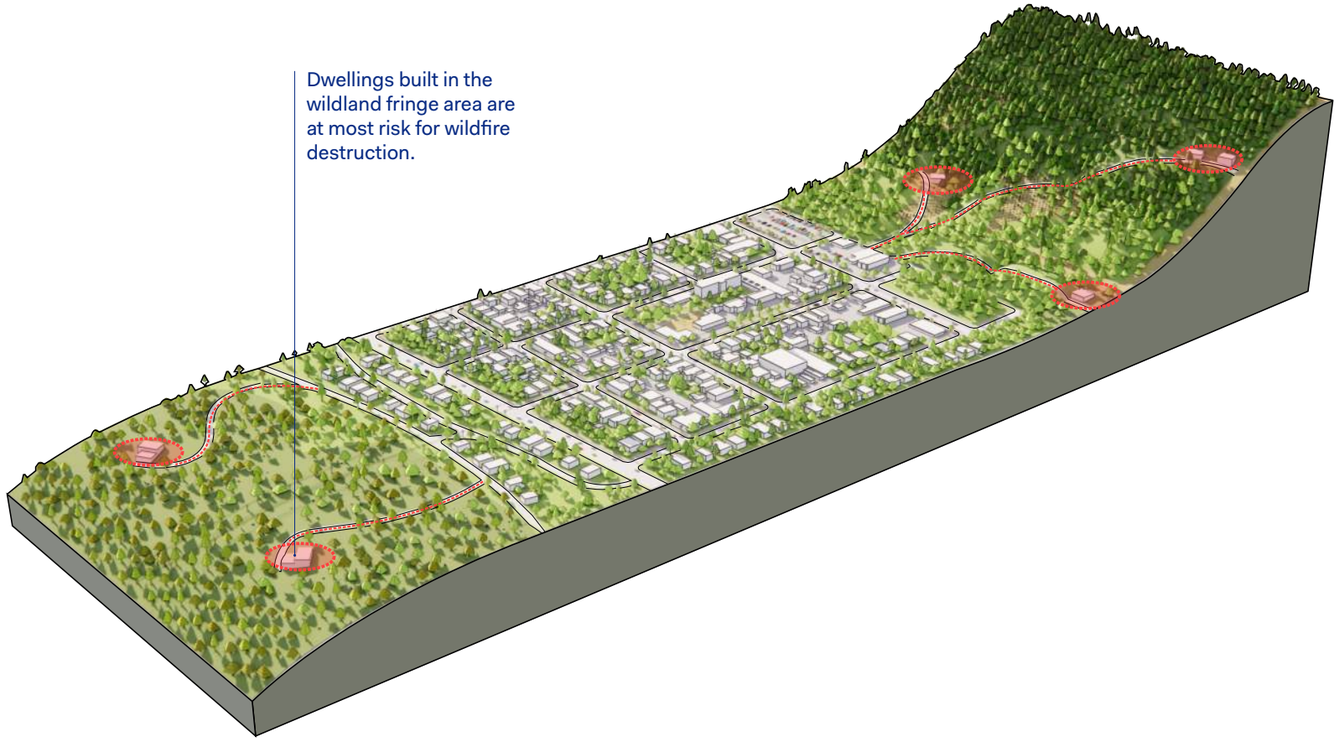


GUIDELINE 2.1

Increase housing in existing urbanized areas to reduce the number of people threatened by wildfires.

Simply put, we can decrease the number of homes in WUI areas by increasing the number of homes available within cities. Increasing density in cities addresses the state's needs to increase the total number of homes and addresses the fact that aggregated settlements may be easier to protect in some instances from wildfires.

Cities across the state should increase the density of homes within their city limits: incentivizing Accessory Dwelling Units (ADUs), multi-family residential infill developments, and below-market-rate housing.

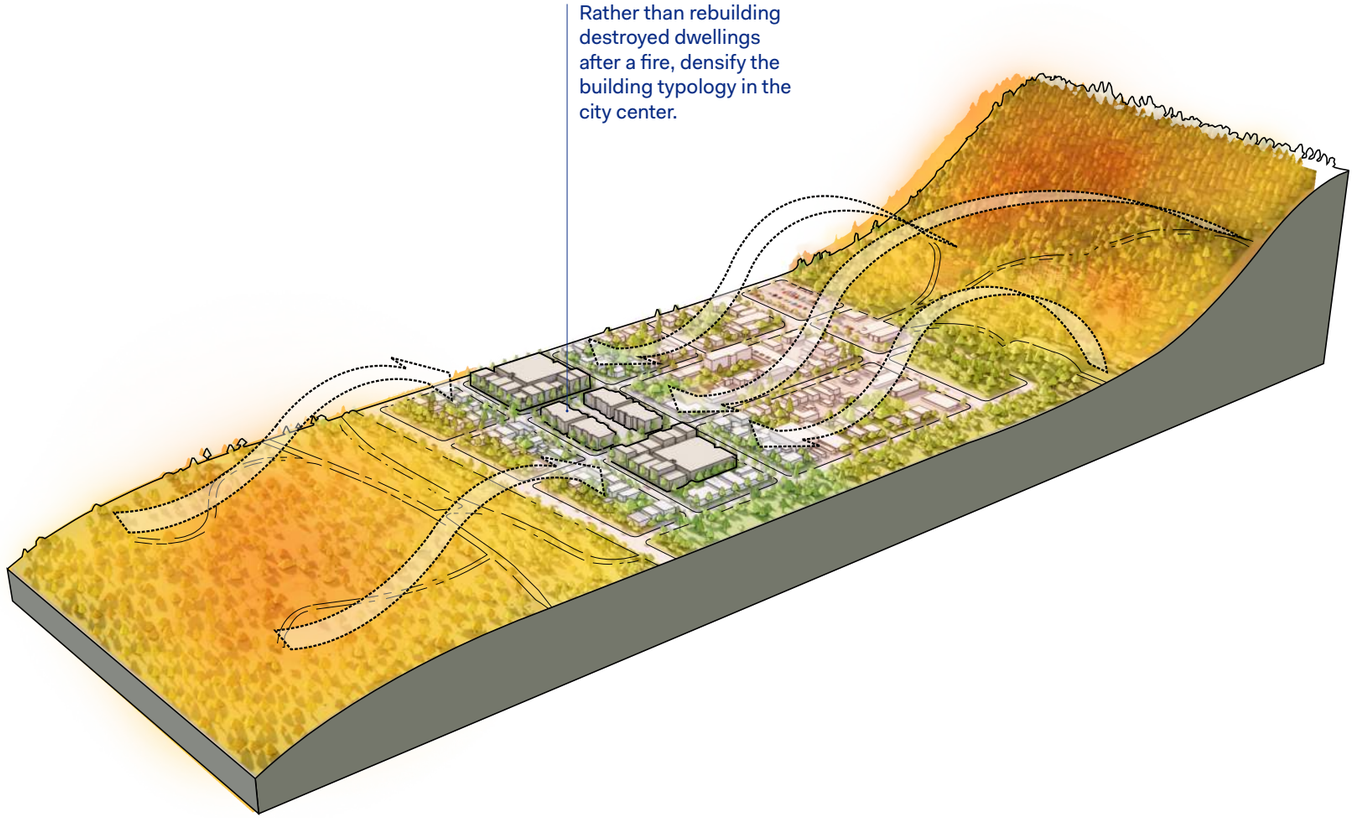


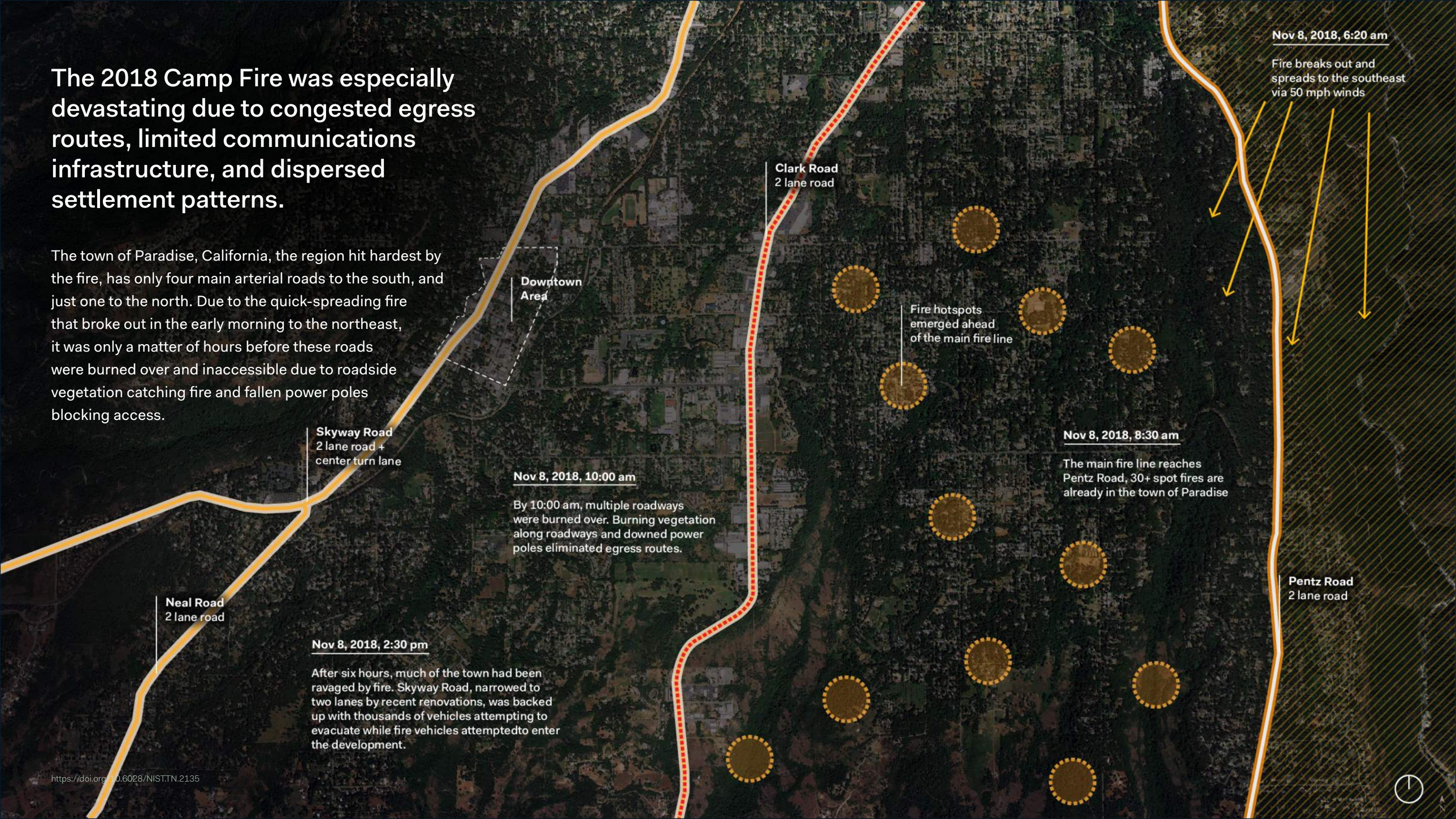
GUIDELINE 2.2

Incentivize no re-build zones in high fire risk areas to reduce property loss and damage from wildfires.

New buildings in high risk zones already need to abide by strict WUI codes as discussed in the Buildings section, but limiting the number of single-family homes in high risk zones will make wildfires easier to manage as well as people and property easier to protect.

Insurance companies are already making fire insurance more difficult to receive and maintain in high risk zones, despite executive action. Funds for rebuilding homes destroyed by wildfires in high risk zones should be redirected towards densifying housing within city limits. With fewer homes in WUI zones, prescribed burns and other forest management policies will be easier to implement and maintain.





https://doi.org/10.6028/NIST.TN.2135

GUIDELINE 2.3

Implement urban design requirements for fire staging, breaks, and egress.

2020 California legislation requires cities to evaluate wildfire risks when defining the layout of roads, services, and zoning.

Existing cities should consider how they can adapt their communities to better respond to fires, modernizing infrastructure to align with current trends of wildfire impacts.

Cities that have been impacted by wildfires should reconsider their design requirements to accommodate more frequent and intense wildfires.

Vulnerable structures at the city edge allow fires to spread from the wildlands into the city center.

The 2017 Tubbs fire destroyed much of the Coffey Park neighborhood in Santa Rosa. The wildfire started in the Wildland-Urban Interface region and quickly spread through forested areas to reach more populous development well within the city limits.

High winds sent embers across more than 6 lanes of Highway 101, spreading the wildfire from the Fountaingrove neighborhood into the neighborhood of Coffey Park. Due to the density of the urbanized areas, the bulk of ember-generating fuel was buildings, contrary to wildland fires that are generally fueled by trees and other vegetation.

https://www.arcgis.com/apps/MapJournal/index.html?appid=cd71b2d738e0481a9b6a764f802d27d2

GUIDELINE 2.4

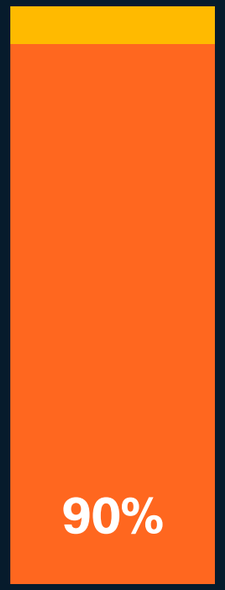
Require fire resilient buildings at the edges of urbanized areas.

Ideally, if one building in a community is required to comply with WUI fire resistant requirements, then the entire community should be compliant, so that wind-driven embers don't cause fires to penetrate deeper into urbanized areas.

However, to start, all buildings at urban edges should be built or retrofitted to be fire resilient. When wildland fires reach urban areas, these buildings may significantly contribute to the area's wildfire resilience. Fewer buildings will succumb to the wildfire, which equates to less fuel for the wildfire and fewer embers spreading downwind.

URBAN AREAS

90% of the most destructive California wildfires are caused by human activity.



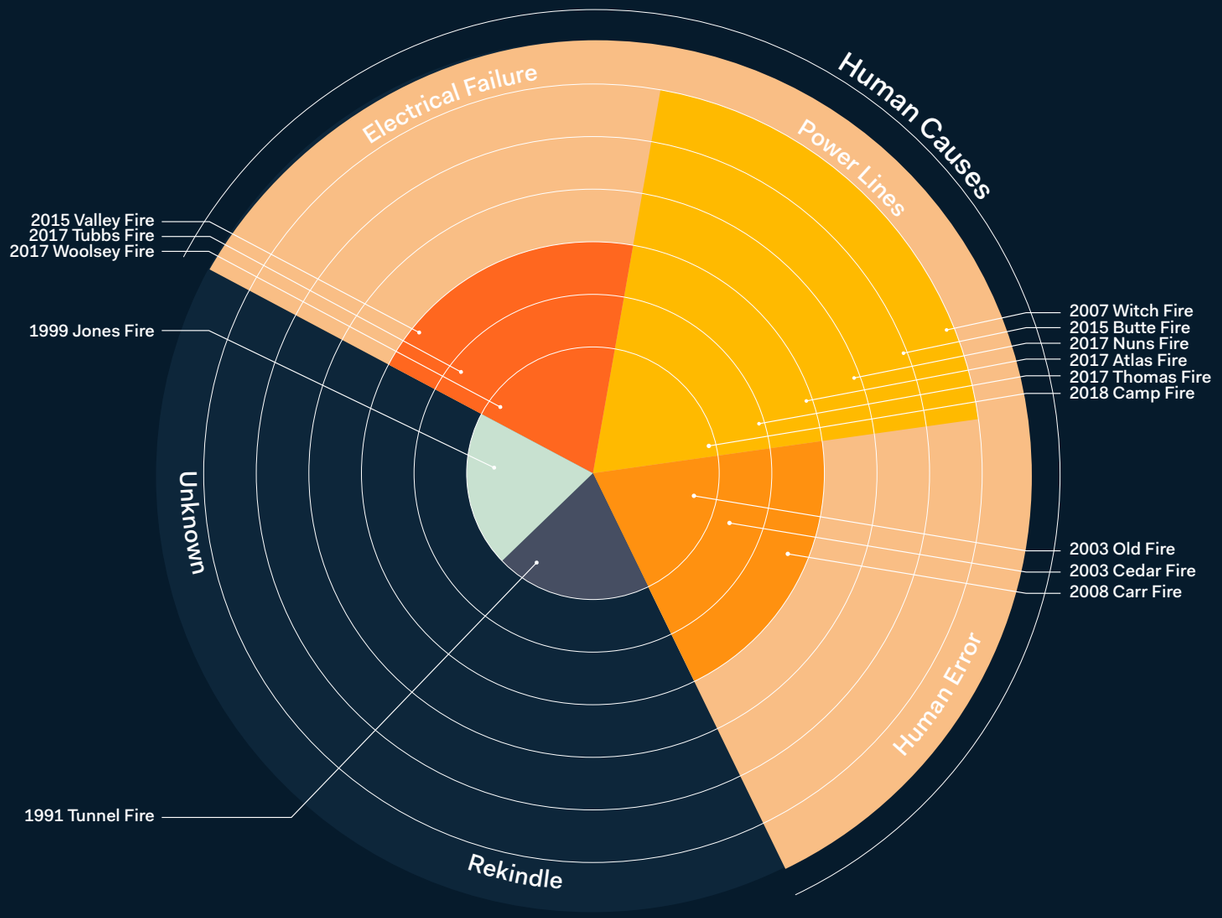
Continued urban sprawl creates more fire risk in forested areas as electrical networks expand and human intervention is multiplied.

Other

Human Caused

CAUSES OF THE MOST DESTRUCTIVE* CALIFORNIA WILDFIRES THROUGH 2019

*fires that destroyed 750+ structures



California Department of Forestry and Fire Protection, https://www.seia.org/solar-industry-research-data

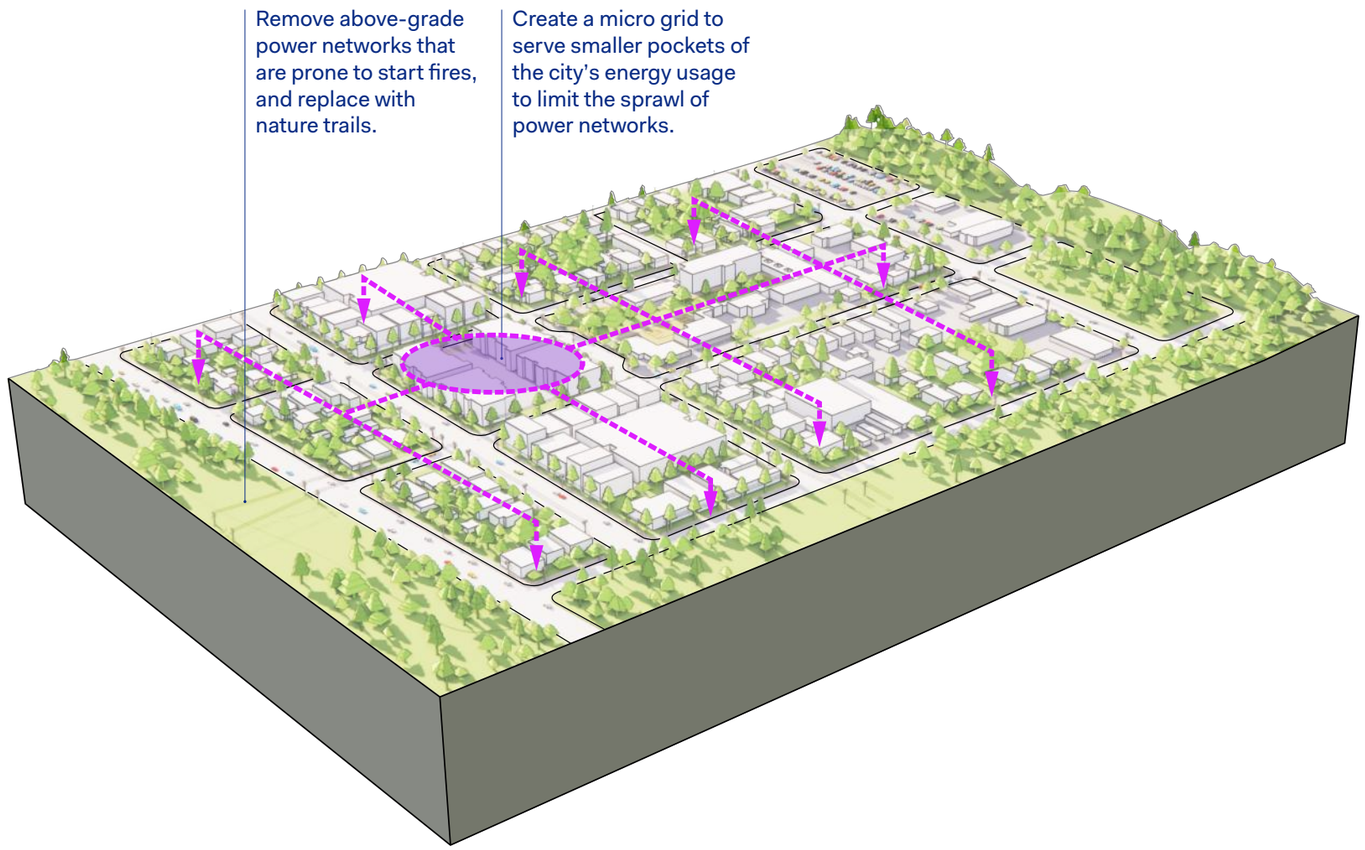
GUIDELINE 2.5

Significantly reduce the number of destructive wildfires by reforming the electric grid infrastructure.

Sparks from electric infrastructure outside of urban areas is the one of the leading causes of wildfires. If cities can embrace micro-grids and lessen the electrical infrastructure leading to their communities through the surrounding wildlands, then significantly fewer wildfires will be started.

As solar and other renewable technologies improve, cities should be less reliant on the major power generation hubs throughout the state, and instead strive to generate as much power as they consume.

This parallels the state's goals to make all buildings net zero by 2050, but widens the lens to realize what impacts that could have on decreasing major wildfires.



URBAN AREAS

Summary

ISSUES	RECOMMENDATIONS
More and more Americans are moving to the Wildland-Urban Interface despite the high risk of fire.	2.1: Increase housing in existing urbanized areas to reduce the number of people threatened by wildfires.
Single-family homes are harder to protect from wildfires than larger multi-family homes or uninhabited wildlands.	2.2: Incentivize no re-build zones in high fire risk areas to reduce property loss and damage from wildfires.
Insufficient access routes to wildland communities makes evacuation difficult.	2.3: Implement urban design requirements for fire staging, breaks, and egress.
Vulnerable structures at the city edge allow fires to spread from the wildlands into the city center.	2.4: Require fire resilient buildings at the edges of urbanized areas.
Most California fires are human-caused, and many large wildfires are the result of a sprawling electrical network.	2.5: Significantly reduce the number of destructive wildfires by reforming the electric grid infrastructure.

CHAPTER 3

Buildings

BUILDINGS

Even though Wildland-Urban Interface (WUI) codes exist, wildfires destroy thousands of homes each year.

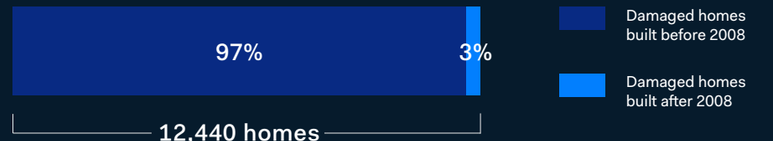
Over 50% of homes built according to WUI codes were undamaged from the Camp Fire. New WUI building codes mandate non-combustible materials, fire truck access, and other preventative measures for new construction in High Hazard Zones of California.

For the Camp Fire, these new codes were effective, but not perfect. In contrast to the 50% of WUI homes that were undamaged, only 18% of non-WUI code compliant buildings were undamaged.

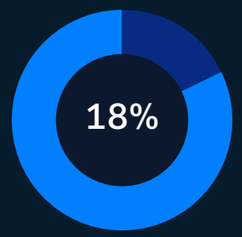
POST-2008 BUILDING IMPROVEMENTS

*Housing data as of 2018, prior to the Camp Fire event

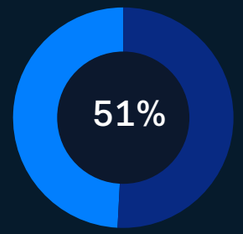
DAMAGE IN THE 2018 CAMP FIRE



SURVIVING HOMES BUILT BEFORE 2008 (2019)



SURVIVING HOMES BUILT AFTER 2008 (2019)



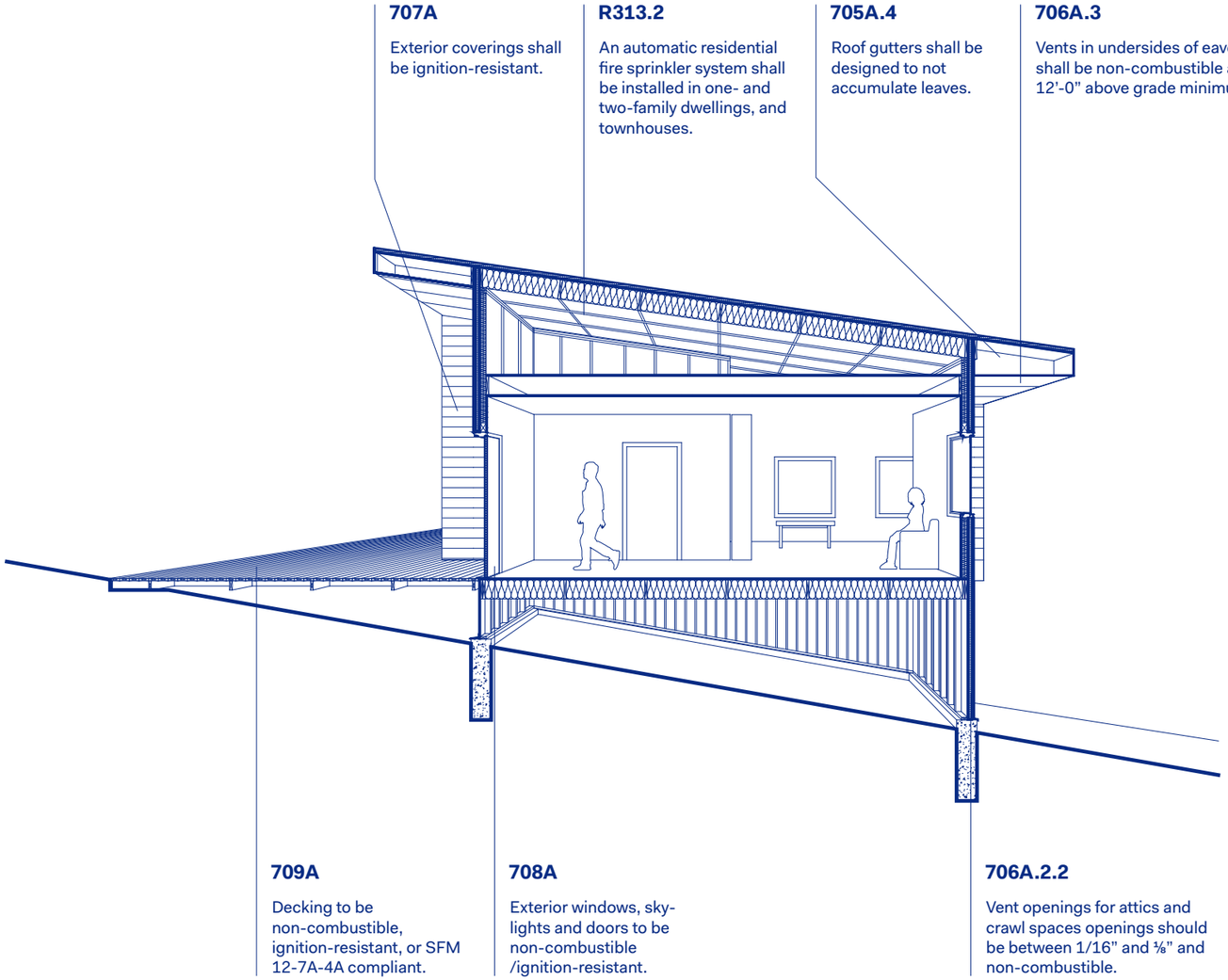
https://www.denverpost.com/2019/04/11/California-building-code-wildfires

GUIDELINE 3.1

Strengthen visual communication tools for WUI codes.

The 2018 International WUI Code is an extremely thorough and technical documentation on the topic, but contains zero images or visual representation of data.

We recommend code councils publish graphic depictions of WUI codes. Graphic explanations for WUI codes would help architects, builders, and reviewing authorities understand and implement the strict WUI code requirements. Additionally, they could help inform architects and owners of potential design solutions to the risk of wildfire.



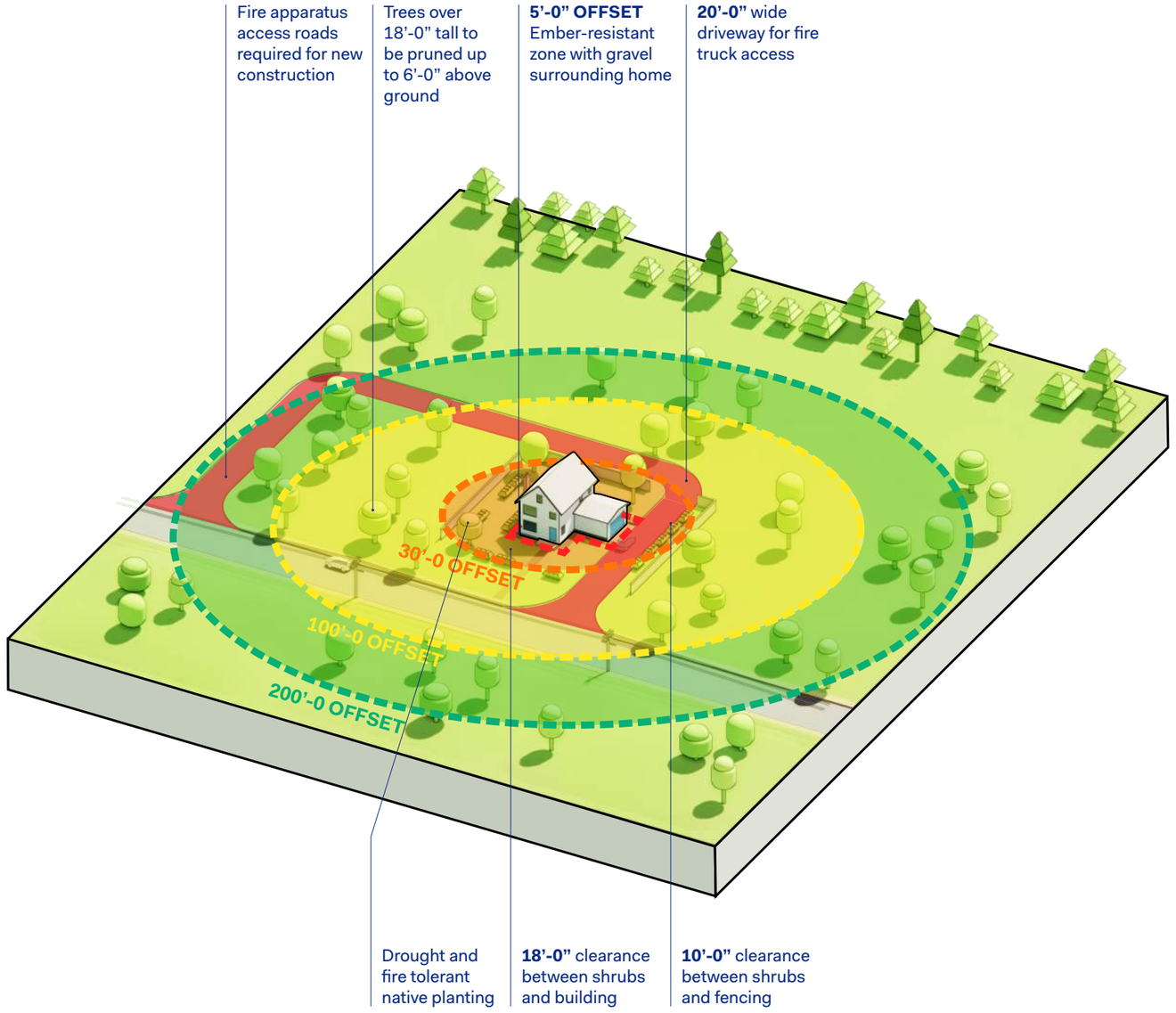
GUIDELINE 3.2

Design individual buildings and properties to accommodate fire and evacuation.

Many site design regulations are already in place for existing and new construction in High Hazard Fire Zones and need to be enforced and maintained.

In addition, the following should be considered during design:

1. **Fire truck staging areas** for fighting fire on the property or at buildings on site
2. **Intentional fire breaks** to slow the spread of fire across the site
3. **Second means of egress** from a property in case the primary escape route is blocked by active fire
4. **Drought and fire tolerant native planting** to lessen the contribution to fire fuel loads. Proper placement, spacing, watering, and maintenance also must be considered for maximum benefit.

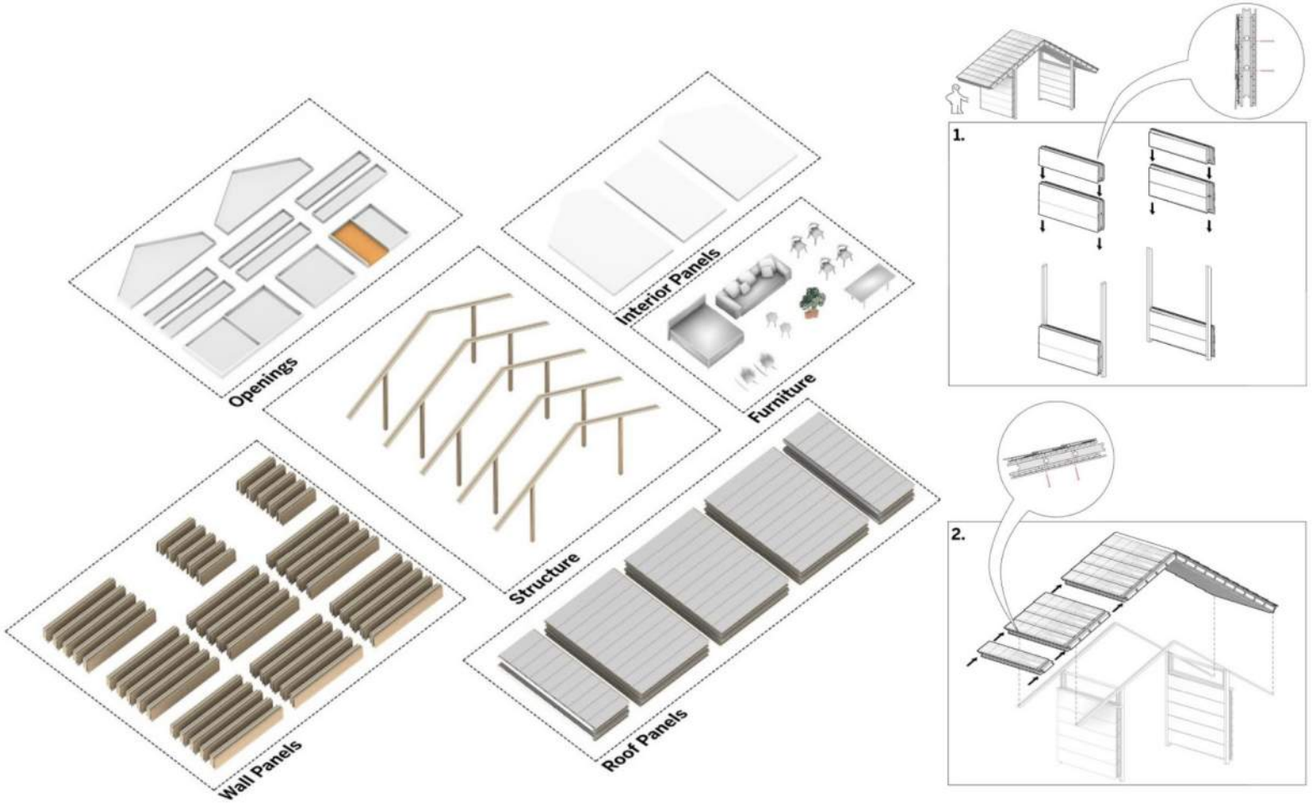


GUIDELINE 3.3

Provide affordable, adaptable, high-quality fire-resistant building designs to facilitate a new regime of fire-conscious construction.

Homes destroyed by fires are generally rebuilt. These rebuilt homes have a chance at being constructed to a new standard of fire resilience if the designs are available, affordable, and adaptable to the project location.

New homes throughout the state should be designed to coexist with fire. Planners, policy makers, architects, and construction professionals are key to accomplishing this goal.



BUILDINGS

California is leading the nation with habitation in WUI areas, creating fire crises that are much more costly to contain.

While new homes in these areas are required to comply with WUI Building Codes in California, existing homes are not.

The average home in California was built in 1950, long before WUI codes. These existing homes are not only at high risk of being destroyed by fire, but they add to the fuel load of wildfires, making them harder to contain.

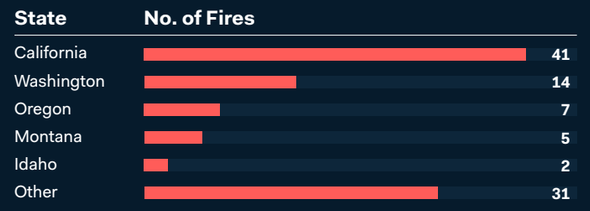
TOP 5 STATES WITH THE MOST EXPENSIVE FIRES

*Data collected from fires between 2014-2017

COST PER ACRE TO EXTINGUISH A FIRE

WUI	Forest	Grassland
$1,695	$840	$55

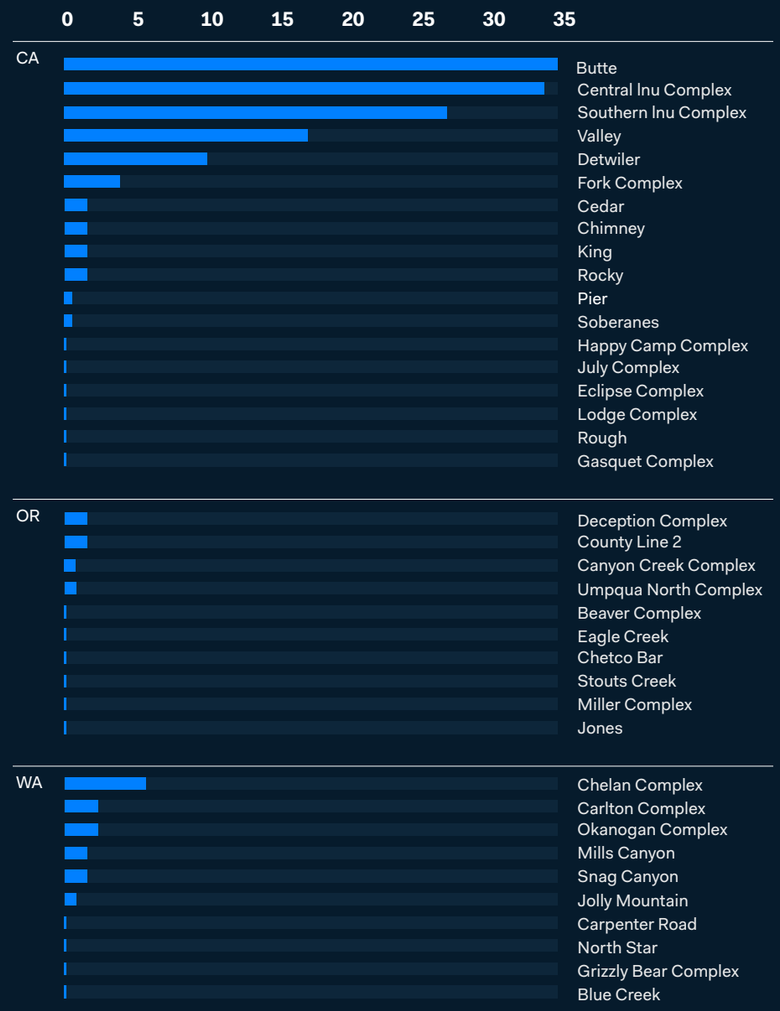
100 MOST DESTRUCTIVE FIRES BY STATE



State	No. of Fires
California	41
Washington	14
Oregon	7
Montana	5
Idaho	2
Other	31

FIRE SPREAD TO WUI REGIONS IN TOP 3 EXPENSIVE FIRES

*Percent of fire in WUI designation



https://www.KQED.org/news/11713393/wildland-development-escalates-california-fire costs

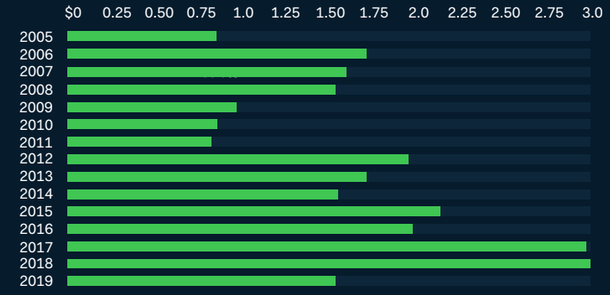
BUILDINGS

Earthquake retrofits are mandatory for certain non-complying buildings. Consider similar guidelines for buildings in areas susceptible to wildfires.

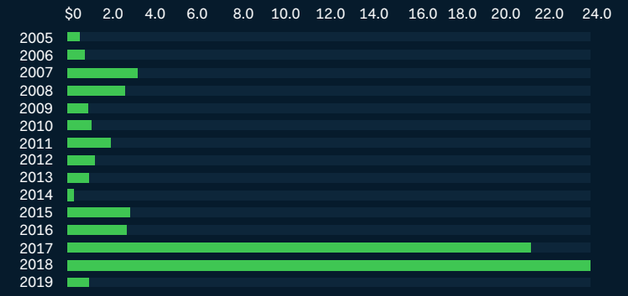
The amount of money spent preventing wildfires from damaging unsafe buildings, paying insurance claims for fire-damaged buildings, and rebuilding homes and businesses that have been destroyed, easily outweighs the cost of bringing non-complying homes up to current WUI building code standards.

ANNUAL WILDFIRE EXPENDITURES NATIONWIDE (BILLIONS)

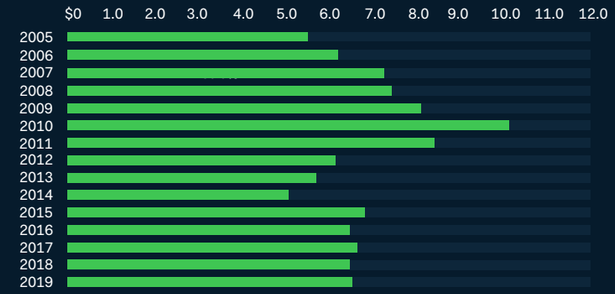
Annual Federal Wildfire Suppression Cost



Annual Federal Wildfire Insurance Payout Cost



Annual Federal Wildfire Rebuild Construction Cost



https://www.nifc.gov/fire-information/statistics/suppression-costs, https://www.iii.org/fact-statistic/facts-statistics/suppresion-costs
https://statista.com/statistics/238506/public-residential-construction-put-in-place-in-the-united-states/

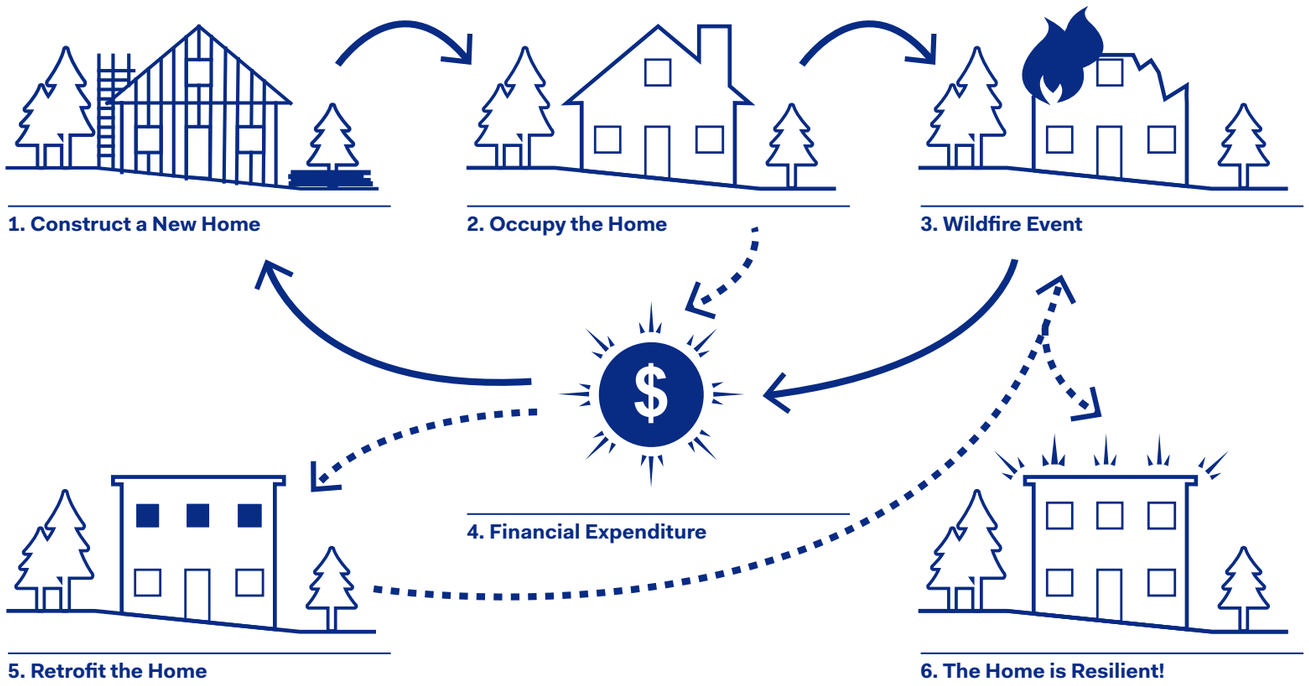
GUIDELINE 3.4

Incentivize fire-resistant upgrades for High Hazard Zones, potentially saving $24 billion annually in insurance claims.

California Assembly Bill 38, which passed in 2019, indicates that the state will develop a comprehensive financial assistance program to help property owners, whole communities and local governments retrofit existing buildings in wildfire hazard areas to protect structures from wildfires.

In addition, the state should grant tax breaks to families and businesses that fire-retrofit their homes.

Lastly, insurance companies should incentivize retrofits by lowering fire insurance costs for homes that meet certain criteria.



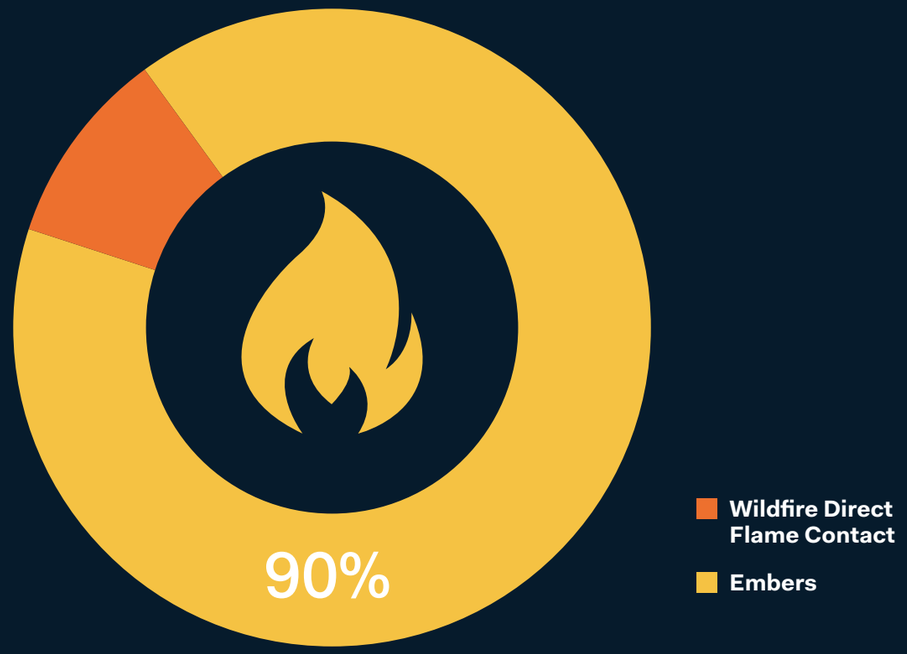
Wildfire embers have been determined to be a leading cause of building ignition, such as when they are drawn into attics and crawl spaces, or land on building surfaces.

Flying sometimes more than a mile in front of wildfires, embers will ignite buildings if they land on a surface that is not fire resistant.

Additionally, in high wind events, the differential pressure between the inside and outside of a building can cause embers to be drawn into a building's attic or crawl space by the Venturi effect*. Even if a building's exterior is hardened per WUI codes, embers on the interior will likely find something vulnerable to ignite.

*A pressure imbalance that draws air into lower pressure zones such as a building's attic or crawlspace.

LEADING CAUSES OF WILDFIRES IGNITION IN BUILDINGS



https://www.nfpa.org/Public-Education/Fire-causes-and-risks/Wildfire/Preparing-homes-for-wildfire

GUIDELINE 3.5

Require specific building configurations for new construction in WUI zones to limit the Venturi effect.*

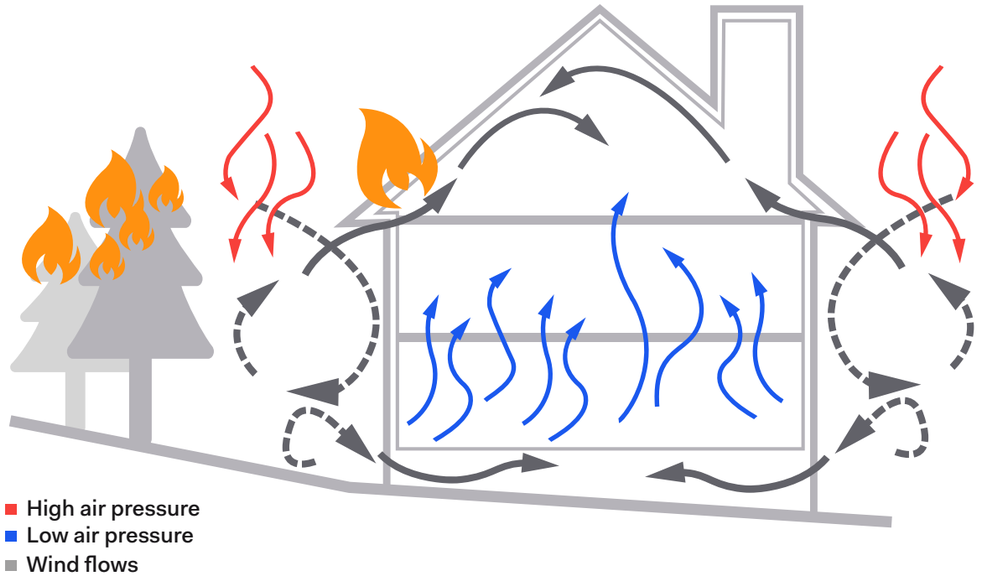
In addition to implementing vent size limitations per WUI codes, we recommend building configuration restrictions and stricter fire resistant requirements in future code cycles.

As of April 2021 the California State Fire Marshall allows solid wood decking, plywood siding with ship-lap edges, and wood doors according to their WUI Building Materials Listings.

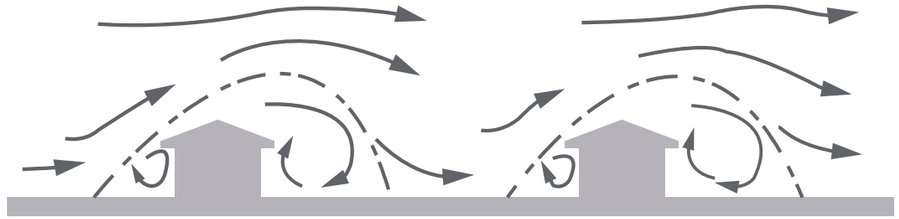
Consider non-combustible exterior materials in all new construction.

*A pressure imbalance that draws air into lower pressure zones such as a building's attic or crawlspace.

ATTIC AND CRAWL SPACE VENTS DRAW IN EMBERS



VENTURI EFFECT ROUGHNESS FLOW



BUILDINGS

Many of the most commonly used building materials are highly susceptible to quick flashover.

While WUI codes dictate fire resistant materials on the exterior of buildings, most materials within buildings and even some allowed on the exterior are known to easily ignite when exposed to embers.

Sprinklers within buildings, required but not enforced on most buildings throughout the state, would only typically engage after fire has already began within a building.

In order to be proactive about building ignition, most fire protection consultants recommend exceeding code minimums.

FLASHOVER TIMES IN ROOM/CORNER TESTS

A study of full scale building materials mocked up in a room corner simulation tested time to flashover.

Materials were exposed to direct flame at 100 kW for the 10 minutes, and then exposed to 300 kW for the following 10 minutes.

FLASHOVER

Flashover occurs at the moment a combustible material experiences near simultaneous ignition over the exposed surface. This process causes thermal decomposition and the release of flammable gasses emitted from the material. This study considered a material to be at the flashover threshold once is registered 1 megawatt of energy.

FLAMES OUT OF THE DOOR

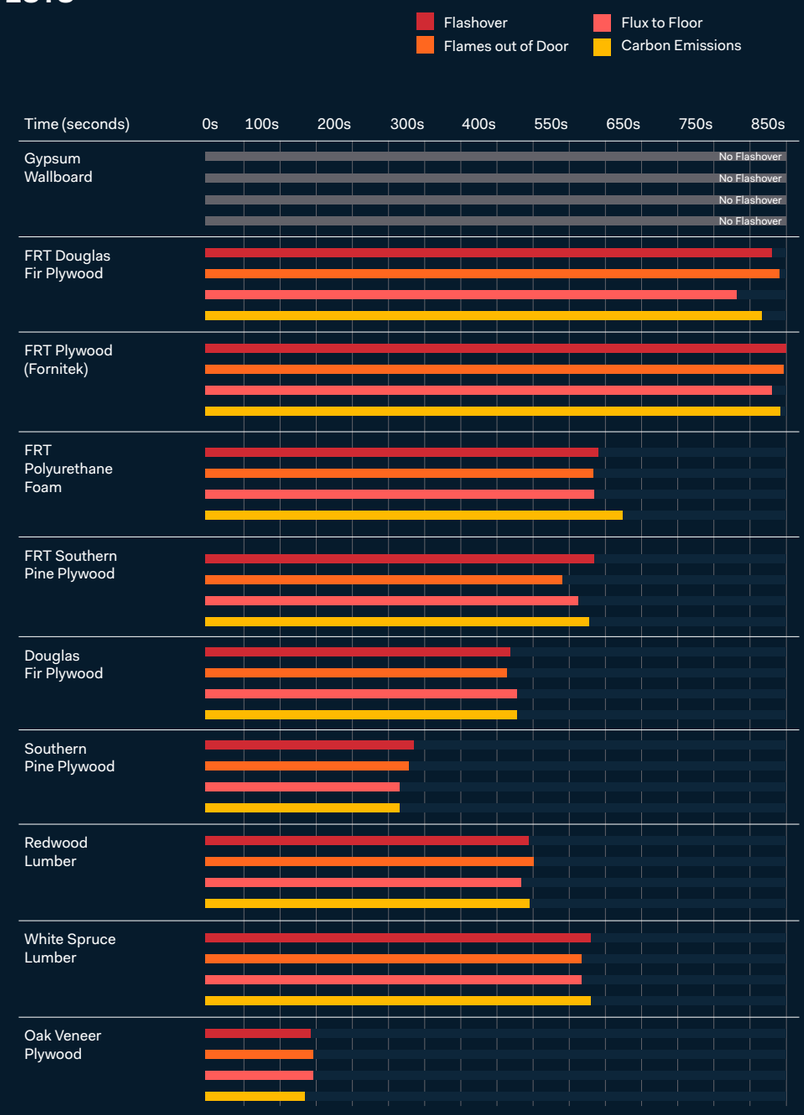
This metric measures the time it takes for fire spread to visibly exit the room and potentially pose a threat to adjacent rooms in a structure.

FLUX TO FLOOR

This metric measures the level of heat energy spread to the adjacent floor surfaces proximate to the fire. In this study, flux to floor time was triggered at the moment flux levels exceeded 20 kW/m^2.

CARBON EMISSIONS

Harmful carbon dioxide emissions are a byproduct of burning materials. In this study, the time to trigger CO2 levels at a sustained rate of 60 g/s was registered.



USDA, Forest Service, Forest Products Laboratory, Research Paper FPL-RP-663

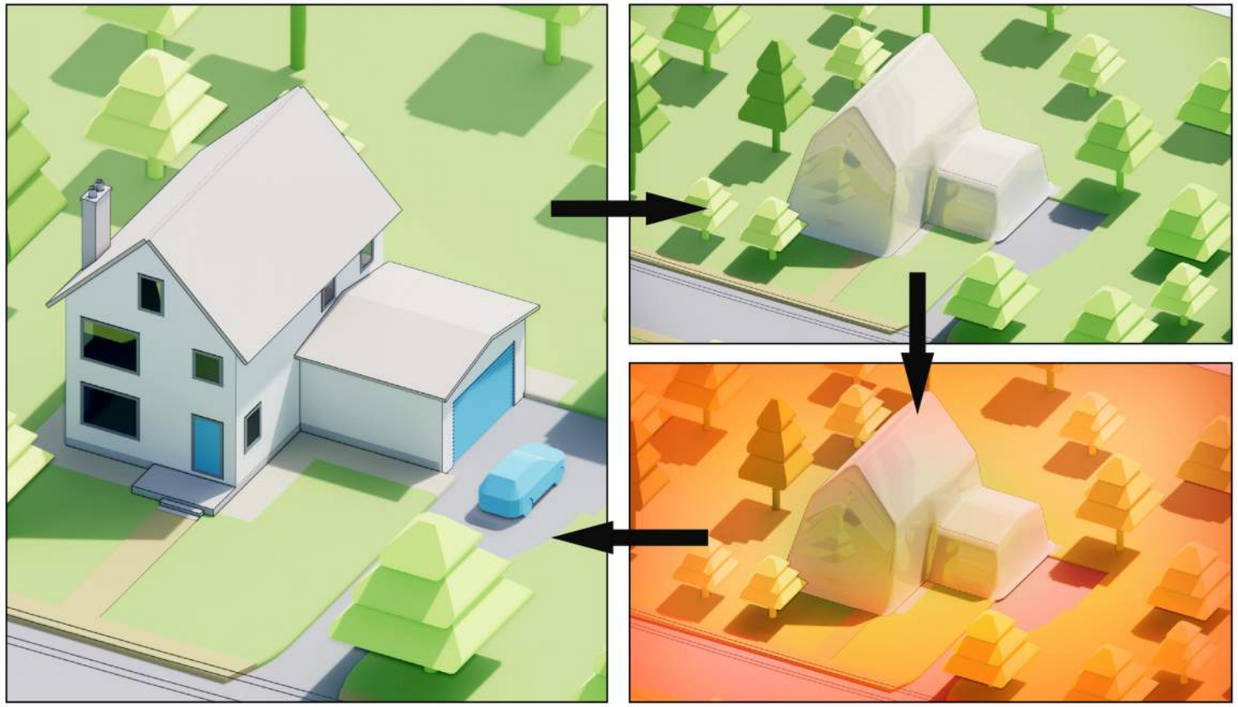
GUIDELINE 3.6

Implement active fire suppression in WUI zones.

While not currently a recommended mitigation strategy, many homes in California have installed exterior sprinklers for wildfire protection.

Additional active strategies should be researched and developed to prevent wildfires from damaging buildings, and could include:

- Deployment of large-scale fire blankets
- Installation of roof ponds
- Remote wildfire detection systems
- Exterior fire retardant sprinklers



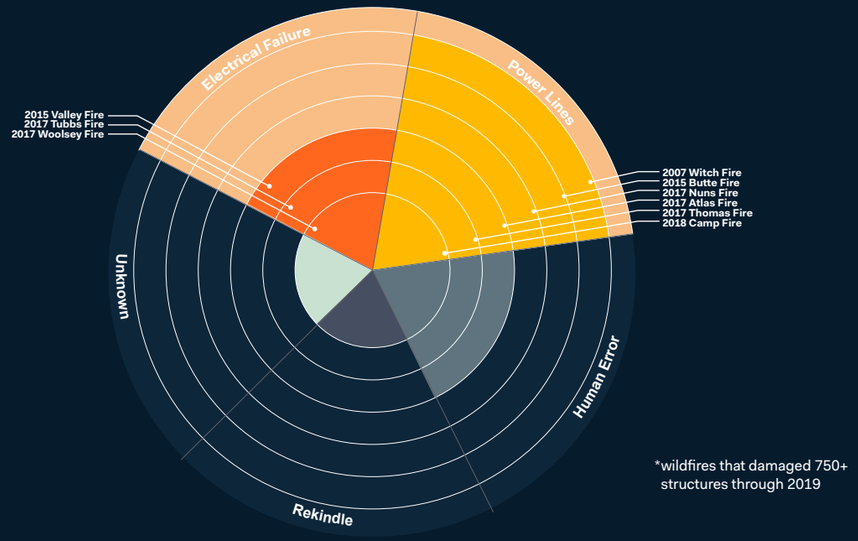
BUILDINGS

The transmission of electricity from central power plants to buildings is a leading cause of forest fires

Continued urban sprawl creates greater fire risk in forested areas as electrical networks expand and human intervention is multiplied. 90% of California wildfires are caused by human activity, which is only exacerbated by the number of people moving into Wildland-Urban Interface zones.

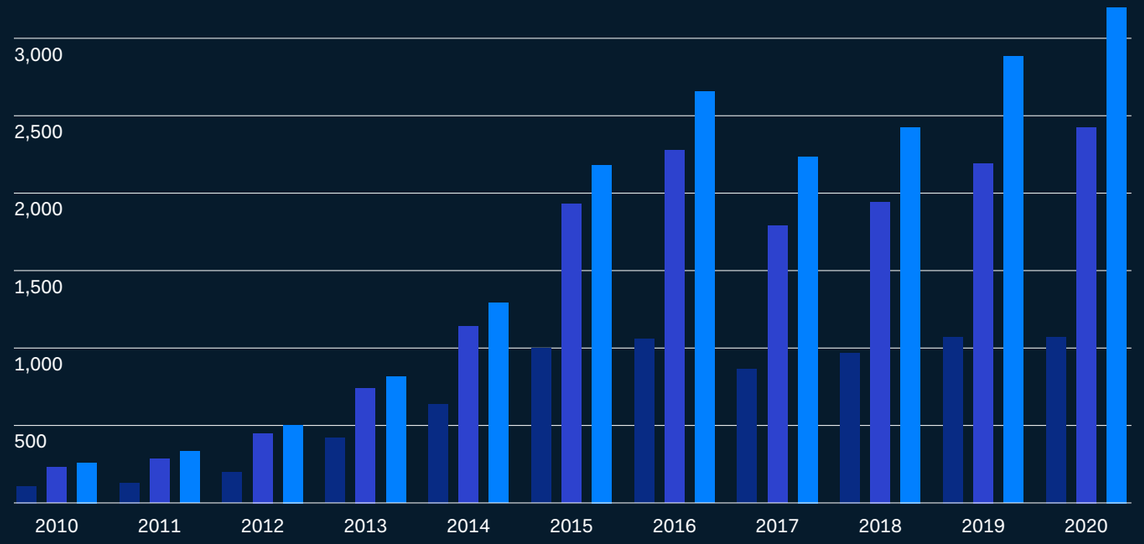
It's worth noting that it is now code minimum for all new residential construction to be net zero in California. In addition, the California Energy Commission and the State of California Building Standards Commission voted to require all new homes in the state to install solar panels.

WILDFIRES CAUSED BY ELECTRICAL ISSUES



*wildfires that damaged 750+ structures through 2019

ANNUAL RESIDENTIAL SOLAR PV INSTALLATIONS NATIONWIDE



https://www.seia.org/solar-industry-research-data

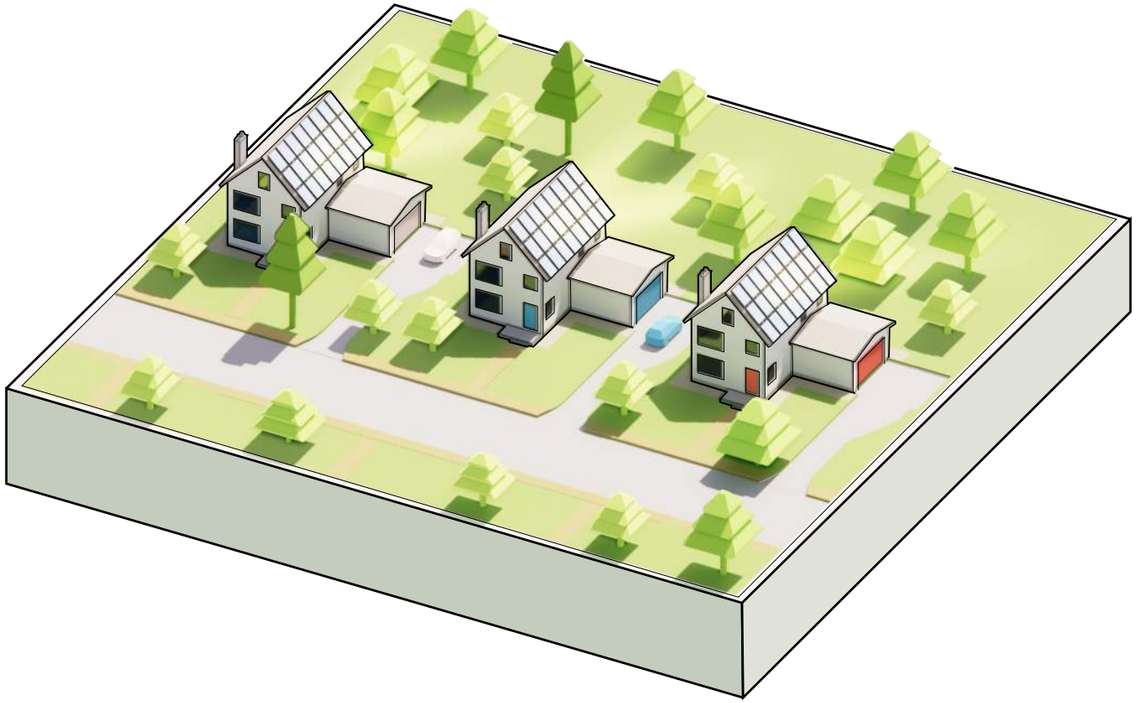
GUIDELINE 3.7

Modify power delivery to buildings to significantly reduce the number of wildfires.

All buildings should receive power from local neighborhood or district sources or from means on their own property. Residences are already decentralizing their power supply. If the remainder of community energy demand can be accommodated by district power, then major electricity infrastructure can be eliminated.

Buildings in Wildland-Urban Interface zones should receive power from renewable sources on their own properties.

Buildings in cities should receive power from district sources as discussed in the previous chapter and as much as possible from means on their own properties.



Summary

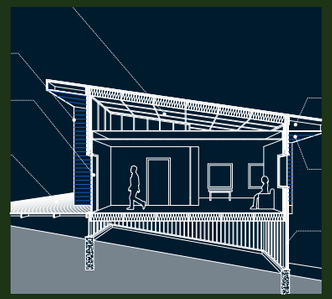
ISSUES	RECOMMENDATIONS
Even though Wildland-Urban Interface (WUI) codes exist, wildfires destroy thousands of homes each year.	3.1: Strengthen visual communication tools for WUI codes.
The majority of California homes were built prior to WUI fire resilient building codes.	3.2: Design individual buildings and properties to accommodate fire and evacuation.
Homes destroyed by fires are generally rebuilt and should be rebuilt to a new standard of fire resilience.	3.3: Provide affordable, adaptable, high-quality fire resistant building designs to facilitate a new regime of fire conscious construction.
California is leading the nation with habitation in WUI areas, creating fire crises that are much more costly to contain.	3.4: Incentivize fire-resistant upgrades for High Hazard Zones.
Wildfire embers drawn into attics and crawl spaces have been determined to be a leading cause of building ignition.	3.5: Require specific building configurations for new construction in WUI zones to limit the Venturi efect.
Many common building materials are highly flammable.	3.6: Implement active fire suppression in WUI zones.
Bringing electricity from central power plants to homes is the number one cause of forest fires.	3.7: Modify the delivery of power to buildings.

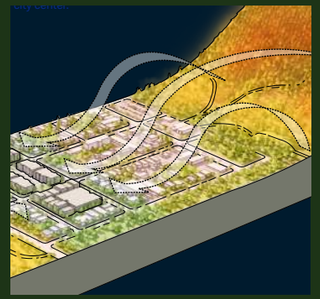
CHAPTER 4

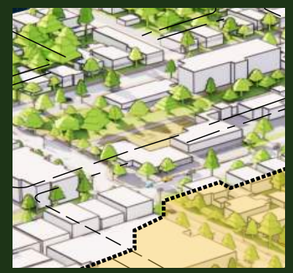
Conclusions

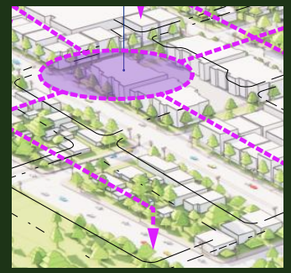
CONCLUSIONS

There is no quick fix to mitigating the effects of wildfires. Reducing the annual impact of wildfires on our communities and our planet will take concerted effort from numerous stakeholders.









We call upon all professionals in the planning, design, and construction industry to contribute towards addressing wildfires with a response appropriate to the magnitude of the problem. Similar to how designers across the country and world have worked together towards attaining universal accessibility and risen to the challenges posed by global climate change, we need to step forward to assist with this epidemic of wildfires.

Utility companies need to accept responsibility for the disasters they have caused and assist in moving our communities towards a new paradigm of decentralized power generation and energy independence.

States, counties, and cities need to prioritize their long term fire resilience by streamlining and incentivizing greater density in city centers and new fire resilient construction, in tandem with private stakeholders such as insurance companies.

Federal, State, and Local Fire Protection Authorities need to continue their commitment to reducing the detrimental effects of wildfires and double down on their commitment to forest management and fire-safe preparedness. Where needed, their funding and manpower should be increased with assistance from government agencies, taxpayers, and private investment.

CONCLUSIONS

Guidelines

WILDLANDS

1.1	Federal, state, and local governments must collaborate to develop a unified response to wildfires.
1.2	Update outdated power lines and equipment in lower risk zones and add more monitoring systems throughout California.
1.3	Decentralize power sources in high risk zones.
1.4	Prioritize and increase prescribed burns in high risk areas.
1.5	Require mandatory fire-resistant building and residential landscape upgrades.
1.6	Bury new power lines where feasible within highest wildfire hazard zones.

URBAN AREAS

2.1	Increase housing in existing urbanized areas to reduce the number of people threatened by wildfires.
2.2	Incentivize no re-build zones in high fire risk areas to reduce property loss and damage from wildfires.
2.3	Implement urban design requirements for fire staging, breaks, and egress.
2.4	Require fire resilient buildings at the edges of urbanized areas.
2.5	Significantly reduce the number of destructive wildfires by reforming the electric grid infrastructure.

BUILDINGS

3.1	Strengthen visual communication tools for WUI codes.
3.2	Design individual buildings and properties to accommodate fire and evacuation.
3.3	Provide affordable, adaptable, high-quality fire-resistant building designs to facilitate a new regime of fire conscious construction.
3.4	Incentivize fire-resistant upgrades for High Hazard Zones.
3.5	Require specific building configurations for new construction in WUI zones to limit the Venturi efect.
3.6	Implement active fire suppression in WUI zones.
3.7	Modify power delivery to buildings to significantly reduce the number of wildfires.

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United States Department of Agriculture and Forest Service Understanding and preparing for Wildfire in the Wildland-Urban Interface	https://www.fs.fed.us/openspace/fote/reports/GTR-299.pdf
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California Public Resources Code

California Fire Code

California Residential Code

International Wildland-Urban Interface Code

National Interagency Fire Center

National Fire Protection Association

National Aeronautics and Space Administration

USDA, Forest Service, Forest Products Laboratory

Federal Emergency Management Agency

US Census Bureau

National Park Service

California Department of Forestry and Fire Protection

The Nature Conservancy

Getty Images

Noun Project

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SOM