Mitigating Property Destruction Resulting from California Wildfires

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Executive Summary

Introduction

California experienced its largest fire season on record last year and the problem stands to get worse. This report looks at the issue of property destruction and considers the ways, absent global action on climate change and the reduction of homes in fire prone regions, that California can mitigate future losses. It outlines the factors underlying these trends, explains why it is a problem worthy of intervention by state government, and analyzes four options for mitigation.

Problem Severity and Causes

Five times as many acres burn annually in California now than in the 1970s and property damage has grown along with it. There are four main drivers of this trend. Climate change has created a more arid environment. Meanwhile, housing growth has largely occurred in the wildland-urban interface (WUI), which is more fire-prone. This puts more housing in the path of fires and increases the likelihood of damage. Past fire suppression tactics and a lack of sufficient land management have led to a buildup of fuel loads, which have primed California's landscape for more catastrophic fires. Finally, the state's electric grid faces a backlog of maintenance and has been implicated in several destructive fires.

Why the State Government Needs to Intervene

With the problem standing to get worse, much of the burden to act will fall to the state government because the private market is not well-positioned to address them. There are a number of market failures at play, particularly with regard to climate change and the expansion of the WUI, which negatively impact a broad segment of Californians and impose significant costs. Wildfires also cut across boundaries, so the patchwork of landownership in the state requires a stronger coordinated response. Finally, low-income residents are the most vulnerable to fires and stand to lose the most, so there are important equity reasons that require action.

Policy Considerations

To be successful, a policy needs to be cost-effective, administratively feasible, and politically acceptable. Given that options will require additional upfront funding, it is important to keep cost-effectiveness top of mind, especially since the state faces an uncertain fiscal outlook. It is also potentially challenging to scale up these alternatives, so any analysis must consider factors like existing workforce capacity and the regulatory environment. Finally, solutions touch upon contentious issues, necessitating consideration of the political environment.

Policy Alternatives

This report outlines four alternatives: increased funding for firefighting, scaling up forest management, expanding home hardening, and upgrading the electric grid. Much of this work is already occurring, but given recent trends, is not happening at sufficient levels to sufficiently mitigate the problem. Past investments have focused on firefighting, but expenses have grown rapidly, and it is unclear the extent to which further resources will effectively protect structures.

Experts have pointed to increasing controlled burns and thinning, but doing so would require addressing administrative hurdles that have made them challenging to complete. Home hardening and defensible space requirements have proven effective at saving homes, so achieving near-universal adoption could significantly reducing damages. Finally, ensuring more decentralized power generation and better line upkeep could prevent the most catastrophic fires.

Recommendations

Putting more resources toward firefighting and technology is unlikely to be cost-effective compared to upfront mitigation. While costs, uptake, and enforcement have been an obstacle, community-level home hardening and defensible space requirements are likely the cheapest way to reduce property damage and their challenges are likely surmountable. Scaling up forest management and upgrading the electric grid face hurdles around their feasibility due to the required workload and the current political headwinds, but they also could bring cost savings through reduced damages. There is no silver bullet solution and property damage from wildfires will likely persist. But upfront prevention and mitigation efforts stand to be important tools as the state grapples with this complex and growing problem.

Introduction

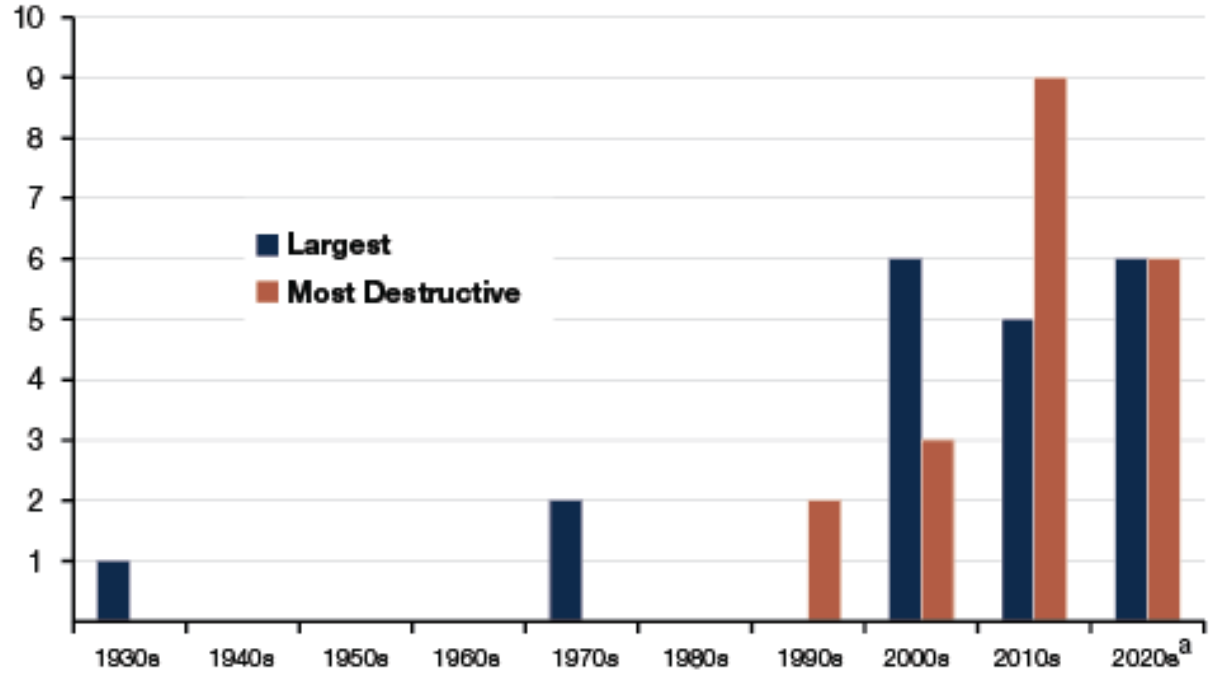
The year 2020 was the largest fire season on record, with an estimated 4.2 million acres burning across California, resulting in more than 10,000 damaged or destroyed structures.[1] At one point, five of the state's six largest fires in history burned simultaneously.[2] However, wildfires are not a new phenomenon. California has regularly experienced fires in its past, especially before the advent of European settlement, when more than 5 percent of acreage would burn annually, an amount greater than the 2020 season.[3] The severity of these recent fires and their impacts on human populations, however, are new. The 2018 Camp Fire alone, for example, was the most destructive California wildfire on record, destroying nearly 14,000 homes and killing 86 people in Butte County.[4] As shown in Figure 1, this follows a trend where 18 of the state's 20 most destructive fires in terms of total damages have occurred since the year 2000.

The ongoing trends driving wildfires mean it likely stands to get worse. Therefore, it should be an extremely pressing concern for policymakers. There are certainly many other negative impacts of these massive fires, like poor air quality and emission levels. However, this report approaches the problem with a focus on residential property losses and assumes that climate change and the location of structures in close proximity to California's wildlands are unlikely to change. Thus, it considers the preventative, mitigation, and response efforts the state could take or build upon to minimize damage, which is already devastating certain exurban and rural communities and altering the lives of those residing there.

This report begins by describing current wildfire trends, including their changing intensity and destructiveness. Then, it outlines some of the major drivers that are behind this: namely climate change, increased housing in the wildland-urban interface (WUI), California's past and current land management practices, and the growing vulnerability of the electrical grid. I cover some of the reasons why the private market will not sufficiently address wildfire destruction and it is important for the state to act. I then layout three criteria for evaluating

policy responses, before considering the alternatives of increased firefighting efforts, forest management, home hardening and defensible space, and electrical grid upgrades. I conclude by recommending that the state prioritize the latter three as opposed to firefighting for increased investments due to their superior cost-effectiveness.

Figure 1. Largest California wildfires by acres burned and properties damaged [5]



Problem Severity and Causes

California's wildfire problem has accelerated rapidly in the past few decades, for a wide variety of reasons. Williams et al. estimate that the annual area burned in the state has increased fivefold since the 1970s.[6] Climate change is playing an irrefutable role in driving this increase, vastly expanding the length of the average fire season.[7] [8] It is also making fires less predictable, allowing them to expand quickly and posing a massive challenge for firefighters' containment efforts.[9] Meanwhile, in part spurred by the state's housing crisis, more people are living in fire-prone areas than ever before.[10] This population sprawl means more residences are in the path of wildfires, increasing the amount of damage they cause. At the same time, California has struggled to do the necessary preventative and mitigation work, with a lack of forest management allowing the buildup of excessive fuel loads and an electrical grid in need of upgrades which has been implicated in some of the state's most catastrophic fires. As noted in Figure 1, in terms of both acres burned and amount of property damage, the vast majority of the largest fires in California have occurred in this century.[11]

Driver #1: Climate Change

California and much of the Western United States is experiencing an ongoing drought, largely driven by the effects of climate change. The drought has impacted wildfires in a few important ways. After multiple years of below average rainfall during the winter months, much

of the state remains abnormally dry, leading many experts to fear that 2021 may have the prime conditions for severe wildfires.[12] Beyond the lack of precipitation, California is also experiencing a sharp increase in the number of dry, warm days during the peak of fire season each fall, with high winds spreading fires more quickly.[13] Warmer nighttime temperatures are changing wildfire behavior, removing moisture and allowing for more overnight spread, when wildfires are normally slowed.[14] Abatzoglou and Williams estimate that, in total, the increased temperatures and reduced precipitation resulting from climate change created more fuel aridity and nearly doubled the amount of acres burned in the western United States from 2000-2015, compared to the rate in the 1970s and 80s.[15] This trend stands to continue.

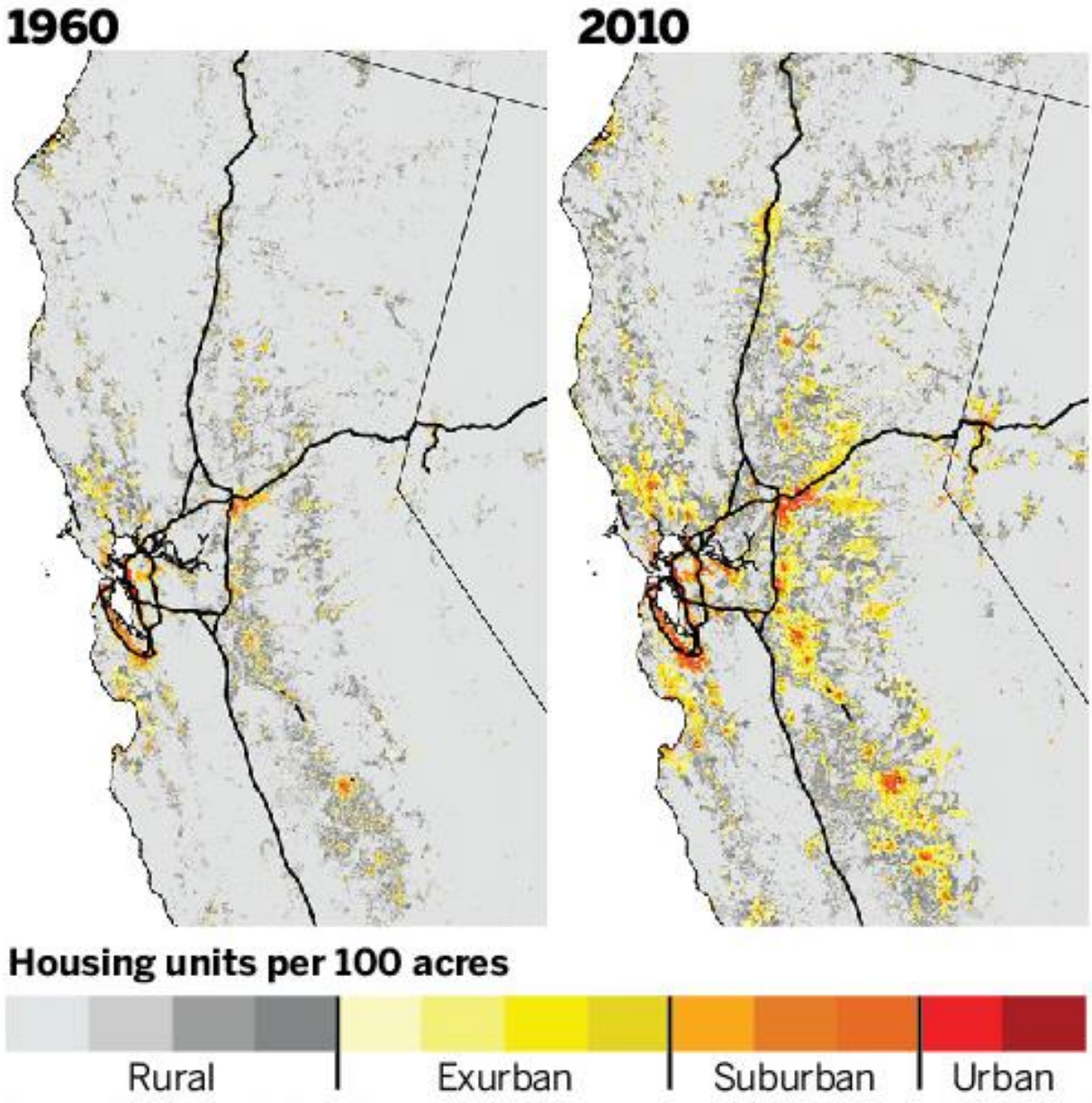
Driver # 2: Housing in the WUI

As alluded to before, another main driver of this increased destructiveness is the location of human habitation. Over the last few decades, the number of people living in the WUI, which is a more fire-prone environment, has grown dramatically across the country. Researchers estimate that, nationally, between 1990 and 2010, the number of houses in the WUI grew 41 percent, to 43.4 million.[16] This trend also holds true in California. Of the nearly 10 million housing units constructed between 1940 and 2000, the majority of acres developed fell in exurban and rural regions that are often situated within the WUI.[17] In large part due to these development trends, nearly one-third of California households are situated in the WUI and one in four people now live in a high fire-risk location.[18] [19] Figure 2 demonstrates the growth in development in less urbanized areas, which has tangible impacts on the destructiveness of wildfires. For example, the 2017 Tubbs Fire left an almost identical burn scar to a fire in 1964. However, it destroyed more than 5,000 homes, while the earlier fire destroyed fewer than 100.[20]

Driver #3: Fuel Loads

Many experts also point to issues with fire suppression efforts over the past century and a buildup of fuels in California's forests.[21] Historically, both CalFire and the U.S. Forest Service have taken the approach of trying to immediately put out fires, as opposed to letting them burn, in order to protect human populations. While this accomplished that goal in the short-term, it also disrupted natural fire cycles, where frequent but low-intensity fires removed brush and other flammable materials, creating more biologically diverse habitat that was less subject to massive fires.[22] At the same time, timber harvest operations have declined dramatically since the middle of the 20th century, which has meant that fewer potential fuels are being removed from forests.[23] However, most trees removed during logging do little to reduce fire risk because it is the small diameter trees and brush which are problematic but have historically not been commercially viable.[24] Therefore, even logging has not generally addressed the core problem, helping create the ripe conditions for high-intensity fires.

Figure 2. Expansion of housing development between 1960 and 1970, differentiated by type of built environment [25]



Driver #4: Electrical Grid

The electrical grid has ignited a number of California's most destructive fires, including the Camp Fire, and PG&E, California's largest utility has been implicated in a number of fires for not doing sufficient line maintenance.[26] Even though they account for only about ten percent of wildland fires statewide, these fires are often particularly destructive because the high wind events that damage power lines also help them spread rapidly.[27] This is why utilities have taken the step of implementing Power Safety Power Shutoffs (PSPS), de-electrifying the grid during red flag warnings to prevent fires.[28] While these shutoffs have likely prevented fires, they carry

costs to the public and are not necessarily a long-term strategy to manage fire risk. Therefore, fire-prone nature of California's grid continues to be an Achilles heel that necessitates addressing.

Future Projections

Along with the current toll of California wildfires, what makes the trends of particular concern for policymakers is that they are unlikely to abate anytime soon. Mann et al. project that, without a shift in course, there will be 645,000 additional housing units built in "very high" fire risk areas statewide by 2050.[29] And, even if California continues to take strong action on the climate front, that alone will do little to change worldwide emissions. Without concerted international efforts, Spracklen et al. estimate that temperature increases will result in an average of 54 percent more land burned across the Western U.S. by midcentury.[30]

To a certain extent, the State cannot address many of the drivers of destructive wildfires. The vulnerability of California's housing stock would be a logical strategy, but this is largely a result of local land use policies, and the state government has been loath to intercede.[31] Rebuilding efforts after major fires demonstrate the difficulty of disrupting this process, both for local financial and political reasons.[32] For example, following the 2017 Tubbs Fire, 95 percent of destroyed homes in the Coffey Creek neighborhood were rebuilt, even with the knowledge of the ongoing fire risk.[33] Meanwhile, the vast majority of GHGs –about 99 percent—are from outside of California,[34] so its ability to unilaterally act and make meaningful progress is extremely constrained. Therefore, this report operates on the assumption that these two causal factors are unlikely to abate in a meaningful way and considers alternative policies that address their impacts.

Why the State Government Needs to Intervene

Given that the projections indicate this problem will only continue to get worse, it is clear that action is needed. Ultimately, much of this responsibility will fall to the state government, working with the federal government, private sector, and individual homeowners and landowners. Leaving this for the market to solve will not work for a number of reasons. First, the problem is the result of multiple market failures and has the characteristics of a tragedy of the commons, where no single actor has the incentive to solve the problem. Second, the nature of landownership throughout California necessitates coordination that the state is best positioned to provide. And, finally, there are important equity concerns because vulnerable populations stand to lose the most from wildfires.

The problem California is experiencing around wildfires represents a market failure, with a number of underlying causes, including that there are negative externalities, uncertain outcomes, and devolved ownership of potential solutions. Climate change in and of itself is often described as a market failure, wherein activities causing greenhouse gas emissions are not priced to reflect their role in producing negative climate impacts.[35] Meanwhile, the spread of California's housing stock into the WUI does not reflect the vulnerability of this housing if—and increasingly when—a fire impacts that community. Two analyses of the housing market in Colorado Springs, Colorado find that the likelihood of wildfires does not negatively impact residential housing prices, indicating that the costs of these low-probability events do not

outweigh the natural amenities such as viewsheds that these properties provide or that wildfire risk is not top-of-mind for potential homebuyers.[36] [37] Changes in the wildfire insurance market could internalize costs for homeowners and disincentivize living in fire-prone areas, but those changes will meet strong political headwinds. Even though the market failures occurring with climate change and the housing market are unlikely to change, the need to address their impacts remain present.

Wildfires are a community-level problem but depend on the choices of a multitude of actors. The tragedy of the commons offers a similar scenario, describing a situation where a resource is not owned by any single entity and thus it stands to be overconsumed and depleted because each actor behaves in their own self-interest.[38] While wildfires are not a perfect comparison, looking at the good of fire protection as a resource offers strong parallels. Whether it is contributing to climate change, choosing to live in the WUI, not properly managing land, or underinvesting in electrical grid upgrades, a range of actors from individuals to private corporations make decisions that jeopardize the entire community's welfare. Ultimately, this creates a public "bad" whose cost is borne by residents who may lose homes and possessions in a wildfire, but also the general public who may have to contend with smoke or whose taxes must increasingly go toward activities like firefighting costs. No one alone can or will fully address the problem, so it falls to the public sector to act and ensure a more optimal outcome.

Underscoring the need for government is the fact that wildfires cut across boundaries. In California, there is a patchwork of landowners, ranging from residential properties and private timberland holdings to public lands owned by the federal government.[39] The majority of fire-prone areas in California are owned by thousands of non-industrial private landowners, many of whom have struggled to properly manage their land to reduce fire risk, both due to the high cost and technical expertise required.[40] Creating broad fire protection requires a large share of lands to be properly managed, so this hurdle has many characteristics of a collective action problem where the individual does not realize the benefits unless others follow through as well. Solving it thus necessitates a high level of coordination, which the private market is not well-positioned to do on its own.

Finally, there are important equity considerations at play regarding those who are directly impacted by wildfires. Compared to other natural disasters, wildfires impact a population that is generally more white and economically secure. However, this obscures the fact that thousands of low-income people reside in these regions and have the greatest exposure, lacking the means to invest in fire safety measures, purchase insurance, or rebuild after a fire.[41] Natural disasters also negatively impact communities for years to come, leading to an out-migration and raising the poverty rate, possibly due to wealthier residents leaving or a loss of economic capacity.[42] Therefore, a major question in California is how vulnerable populations will fare and whether some rural communities will be stuck in a cyclical economic depression.

In the aftermath of the largest fire season in modern California history, policymakers are facing the prospect of the problem only continuing to magnify. Even beyond the effects of climate change, a lot is out of their control—or at least they only have a limited capacity for action. However, no other actor is better positioned to address the problem. And events on the ground mean time is of the essence. As a result of multiple years of large wildfires, there have

been a spike in wildfire insurance claims, enough to more than offset twenty years of industry profits.[43] While state regulators have stopped insurers from dropping policy holders in the interim, there are strains on the insurance market that could leave homeowners more vulnerable to future fire events.[44] The potential political costs have undoubtedly been a large factor in past inaction, but the growing problem and flashpoints like the insurance market may alter this calculus and create the conditions for a rapid policy shift and sharp increase in investments.

Policy Considerations

This analysis draws upon the rational model of Meltzer and Schwartz,[45] as well as Bardach and Patashnik's eightfold path.[46] A central element of both is defining the criteria by which potential alternatives can be systematically judged and considered in relation to the problem definition. The chosen criteria here are cost-effectiveness, administrative feasibility, and political acceptability. The state has taken actions on wildfires over the last few years, so many remedies involve expanding upon the work that is already being done. Therefore, some of the central questions are which options are the most feasible to implement at a sufficient scale in light of the regulatory and governmental constraints, as well as protect fire-prone communities with the smallest further impact to the state budget. Wildfires have also grown in their political salience, so any option must be evaluated based on why it has not yet been attempted, particularly by way of political pressures preventing its approval.

Criterion #1: Cost-effectiveness

In my opinion, the most important criterion is efficiency. Put another way, it is protecting the greatest number of homes at the lowest possible cost. This is crucial for California to consider due to the state's ongoing fiscal uncertainty, driven in large part due to the COVID-19 pandemic's impact on revenues, expenditures, and the overall economy.[47] The budgetary impact of wildfires has grown over the past few decades, particularly with emergency suppression costs mounting along with recovery efforts in some communities.[48] At the same time, it is important to acknowledge that the true cost of wildfires is extremely hard to estimate, and many experts argue we have not fully encapsulated its impacts in a systematic way.[49] Therefore, the state will find significant cost savings by getting wildfires under control. However, in the immediate term, nearly every remedy will require additional funding in order to implement at the scale needed to sufficiently address the problem, which could be challenging if the state's fiscal outlook remains less than robust.

Criterion #2: Administrative Feasibility

In order to be achievable, a potential solution must also meet a threshold of administrative feasibility. This includes it being within the purview of the state government, whether there are the technical and workforce capabilities to properly implement it, and the legal and regulatory hurdles that exist. This is the major reason why, from the perspective of state government, directly addressing climate change is not a plausible solution to reduce the destructiveness of wildfires. California has a very limited ability to unilaterally impact worldwide emissions and, even if its efforts would make a tangible difference, it would struggle to meet the technological, infrastructure, and societal changes to meet these rapid benchmarks.

Criterion #3: Political Acceptability

Finally, a solution must be politically acceptable to warrant serious consideration. The wildfire issue is highly intersectional and cuts across topics related to land use, housing, forest management, energy, and emergency management. Many of these include political third rails that make serious changes unlikely, at least in the short-term. Shifting population growth away from the WUI, for one, would do a lot to reduce the destructiveness of future fires, but the political appetite for such decisions does not exist at present. The Legislature has been reticent to assume meaningful control of land use from local governments, while, in light of an acute housing shortage, it could be counterproductive to restrict construction.[50] Therefore, a narrower set of options have the potential to pass in the near future.

Policy Alternatives

The Legislative Analyst's Office defines four groups of activities related to wildfires: prevention, mitigation, response, and recovery.[51] In determining how to limit destruction, the first three are the most relevant. The Legislature, Brown, and Newsom Administrations have taken many actions on this front, including investing in new technologies to fight wildfires, making funds available to communities for home hardening, and conducting more vegetative management work.[52] In this section, I describe four options to address wildfires, focusing on more funding for firefighting, scaling up forest management, expanding support for community home hardening, and upgrading utility lines.

Alternative #1: Continued Investment in Fire Response

In recent years, the state has invested a lot of resources in expanding Cal Fire's firefighting capabilities. This includes hiring more than one thousand additional seasonal firefighters, upgrading its aviation fleet through the purchase of new air tankers and Black Hawk helicopters, and providing ongoing funding to install and operate state-of-the-art wildfire detection and modelling systems.[53] Even before wildfires emerged as such a central challenge facing California, the state eschewed changes forestry practices in favor of firefighting, as Cal Fire's firefighter ranks grew to over 7,000 during the 2000s.[54] The large appetite for these investments is not surprising given the political and public support for fire suppression efforts.[55]

Even though it enjoys significant support among the public and lawmakers, wildfire response likely represents a far less cost-effective method of defending residential property in California. Research shows that disaster response and recovery is far costlier than prevention.[56] Meanwhile, most of the space for improvement is before a fire starts, with manpower and technology only able to accomplish so much in the face of intense wildfires.[57] Particularly due to the impacts of climate change on fire behavior, traditional firefighting strategies have been overwhelmed during intense fires.[58] There is a general consensus that past fire suppression policies have contributed to more intense fires in the long run, calling into question the effectiveness of these efforts.[59]

The sheer size and intensity of recent fires has contributed to burgeoning costs. Once a fire expands beyond the initial efforts to contain it, the cost of fighting it grows dramatically, requiring more personnel and equipment, oftentimes a more concerted air attack, and all the auxiliary resources that go into supporting these efforts.[60] This is paid for through Cal Fire's E-

Fund, which the 2020-21 budget set at $373 million. However, because of numerous historically large fires, Cal Fire had already spent $893 million through September, far exceeding the budget levels with months still remain in fire season.[61] This follows a general trend for Cal Fire, which has seen its firefighting budget increase from less than $1 billion to more than $3 billion in the last fifteen years.[62] An analysis by Houtman et al. finds that allowing wildfires to burn more freely makes fires in the subsequent decades more manageable and less costly to contain.[63] Therefore, if California prioritizes suppression efforts, this could continue a cyclical process that makes fires less manageable and thus firefighting even more challenging and costly in the coming years.

To a certain extent, the facts on the ground might make increasing Cal Fire's response efforts unsustainable, even ignoring the cost constraints. For one, the state has historically employed thousands of inmates at a given time, representing as much as 40 percent of Cal Fire's total firefighters. There, they have lived in one of the state's fire camps, working on crews that do a lot of the manual labor tasks on the fire line.[64] However, due to a combination of judicially mandated prison releases and the continued effects of the covid-19 pandemic, the number of inmate crews have decreased significantly, forcing the state to compensate for the loss of manpower.[65] At the same time, Cal Fire has struggled to retain and support their existing firefighter ranks. Retention has long been a challenge for Cal Fire due in large part to competition from other fire departments. In 2016, about 15 percent of its positions were vacant because many firefighters moved to local departments due to better pay and less consuming work.[66] Due to the difficult nature of wildland fires, many firefighters are also experiencing mental health issues, including high rates of PTSD, depression, and suicide.[67] Especially in the aftermath of multiple large fire seasons, this has the potential to compound these stressors and exacerbate retention issues. While there are certainly steps that can be taken to make Cal Fire a more attractive employer and improve mental health outcomes, all this points to the administrative hurdles the state faces just to maintain its existing firefighting force, let alone expand it.

Alternative #2: Forest Management

In response to the often-cited unhealthy state of California's forests, increased attention has been given to reforming management practices and scaling up mechanical thinning and controlled burns. They are often used in tandem, with burns applied to piles of vegetation.[68] Both can be effective in reducing the intensity of future fires, but their use has lagged due to a combination of lack of funding and technical staffing, the riskiness of the work, and the large amount of planning that can derail projects.[69]

There is some evidence that forest management is an effective way of reducing the severity of wildfires, but it depends on how and where it is conducted. Most studies have found that a combination of thinning and burning is optimal because it removes surface, ladder, and canopy fuels, while using either practice individually lends mixed results and may even create more severe fires.[70] For burns, the cost-effectiveness also depends in part on its geographic location. Florec et al. conduct a case study in the southwest of Western Australia. They find that burns within the WUI reduce structural losses compared to landscape burns in rural areas because they reduce fuels adjacent to houses and may also reduce wildfire ignitions, which have a greater probability near human populations. However, despite the apparent benefits, due to the

higher costs of doing burns near structures, in most situations, they are not as cost-effective as landscape treatments.[71]

While there is a high level of buy-in that improved forest management would help reduce the severity of future wildfires, they have continued to be under-utilized. The rate of controlled burns has not increased since the 1990s and California has only averaged about 125,000 acres per year, which pales in comparison to its 33 million acres of forestland and 15 million acres of grassland and chaparral.[72] Meanwhile, mechanical thinning has faced fewer roadblocks and has been more easily implemented, but it has still not been done on the level required.[73] Part of this could be due to the fact that private individuals own a significant portion of fire-prone land and many have struggled to properly maintain it, particularly due to financial constraints.[74] This makes the upfront costs extremely relevant to understanding some of the barriers in their implementations. However, part of this is also a scaling problem. In the case of thinning, a lack of certified foresters and the necessary equipment and infrastructure to do these projects limits their implementation.[75]

Mechanical thinning requires intensive work and can cost as much as $1,400 per acre.[76] Combined with the required manpower, the total costs can balloon when including the planning, administrative, and profit margin costs that are present when this work is contracted out.[77] Some of these costs could be reduced through timber sales. However, that is not likely to be especially helpful because the most flammable materials are small trees, brush, and grasses, while large trees are what carry market value. So, in many ways, traditional commercial logging operations are inconsistent with the goals of effective fire mitigation.[78] The advantage of prescribed burning is it is relatively affordable at only about $150 per acre.[79] That said, it carries significant barriers beyond those upfront costs.

The current challenges with controlled burns are the risk of potential damage and concerns of liability, a lack of the necessary personnel and funding to carry out the projects, and environmental constraints, namely due to smoke emissions.[80] Ultimately, they require nearly perfect conditions. Too much wind and a lack of moisture can allow the fire to get out of control and risk millions of dollars in damage and liabilities, while the absence of wind means smoke will linger in nearby communities. Especially since burns can take years of planning, that leaves a lot up to chance.[81] Getting them approved in the first place has historically also been challenging due to the need to get permits from air regulators and signoff from Cal Fire, which is consumed with firefighting duties and is oftentimes not sufficiently staffed to process this paperwork.[82] Therefore, even though many experts have highlighted controlled burns as a key to combatting wildfires, conducting them at scale has been elusive.

Fuel reduction projects in general continue to contain political fault lines. Research on natural disasters shows that politicians benefit less from preventative efforts than from what they do for response and recovery, meaning they often have far less to gain from making these upfront investments.[83] In part due to the issues around liability and smoke, many policymakers have remained hesitant regarding efforts to streamline controlled burns.[84] Even though thinning is generally more politically palatable, fuel reduction can carry the prospect for negative environmental outcomes, as Cal Fire found with regard to sediment discharges into watersheds from some post-fire logging projects.[85] These impacts and a potential lack of fire safety benefits

can lead to opposition from environmentalists. Some have argued that certain types of fuel removal do little to actually reduce the severity of fires and may make them worse by creating a more flammable understory.[86] Therefore, while there is some evidence of its efficacy, at the very least how these projects are conducted could lead to less optimal outcomes and opposition from environmental groups.

There have been a number of significant steps to expand forest management work, so it remains to be seen how successful these will be. Last year, the state and U.S. Forest Service signed a memorandum of understanding pledging to more than double the amount of thinning and burning treatments to one million acres annually by 2025. Meanwhile, the state has also, among other things, indemnified landowners for controlled burns under certain preconditions and invested millions of dollars to assist private landowners with management projects.[87]

Alternative #3: Home Hardening and Defensible Space

Some experts argue that forest management is not the right strategy to reduce property losses because it imposes a high financial and environmental cost and may not be as effective as other alternatives. Even if fuel loads are effectively minimized, wildfires have the potential to spread rapidly if weather conditions permit, which negates that mitigation work, and could help it spread to untreated areas. Instead, they claim that the state's effort should focus on the residence and that using fire-safe materials and creating defensive space can more effectively ensure that homes survive.[88]

Home hardening can take a number of different forms. Some of the steps that are recommended to reduce risk include installing fire-resistant roofing, noncombustible siding, creating a 5-foot buffer in the immediate perimeter of the home, cleaning debris out of gutters, and upgrading vent screes to prevent embers from entering.[89] This work can also extend to creating defensible space by removing vegetation in a large area around the structure, including clearing debris. These efforts often need to be done regularly to remain effective.[90]

California has already taken a number of steps to bolster its building codes to reduce structural fire risk. In 2008, the state put in place stronger building codes for fire-prone areas, which affected new construction. So far, the evidence indicates that these codes have worked and have reduced the likelihood that a wildfire will destroy structures. During the Camp Fire, there was a large gap between homes built before and after the stricter codes. Overall, 79 percent of older homes were destroyed or suffered major damage, while the same was true for only 40.6 percent of new homes.[91] This follows the case of the 2007 Witch Fire in San Diego County, where a Rancho Santa Fe neighborhood built under similar codes did not lose a single home.[92] However, the major challenge currently is that the vast majority of California's housing stock was constructed prior to the adoption of these codes, meaning a large share of structures remain vulnerable to wildfires.[93]

Past research has also found creating defensible space to be effective in the WUI. Stockmann models the impact of fuel removal within 100 feet of structures and compares this with thinning and prescribed burns within a 1.5 mile perimeter. While they both reduced the hazard, the defensible space mitigation efforts were more cost-effective by comparison.[94] Syphard, Brennan, and Keeley analyze structures that were destroyed or survived 10 years of

wildfires in San Diego County and find that treating an area 16-58 feet from a structure most effectively improves its likelihood of surviving a wildfire, while extending the perimeter past 100 feet does not offer additional protection.[95]

Many experts argue that structures are only as protected as the weakest links in their community.[96] This is because fires can jump from one structure to another, meaning that if neighbors have not taken steps like upgrading building materials or creating defensible space, this has to potential to significantly reduce the efficacy of individuals' efforts. That creates a potential coordination problem because homeowners will not have the same incentive to invest unless they know their neighbors will as well. Or, alternately, they may want to freeride on others' work, knowing they might gain some protection from it as well. In addressing this, some of the funding made available for home hardening is distributed at the community level. AB 38 (2018) created a joint powers authority to distribute funding for home hardening and one goal was to ensure that whole communities could work together to reduce their risk.[97] However, the hurdle still remains that effective efforts require widespread buy-in.

This has been a challenge because certain requirements have struggled to gain communitywide support. In the town of Mill Valley, for example, the city council weakened an ordinance that would have required a hardened three-foot perimeter around some homes due to opposition from residents, who protested it would restrict the vegetation they could plant in their yards.[98] However, this is not exclusive to Mill Valley. In 2019, Governor Newsom vetoed AB 1516, one part of which would have mandated a hardened perimeter for homes in high fire risk areas.[99] What these cases demonstrate are that some effective fireproofing methods may face implementation challenges if they prove unpopular. Those views might shift as more Californians realize the risk wildfires pose to their homes, but the fact that sufficient protection from home hardening requires communitywide adoption, this has the potential to significantly curtail efforts.

Another issue has been properly enforcing both building codes and defensible space requirements. On top of the aforementioned codes that California strengthened, it requires homes in high fire severity areas to maintain defensible space. However, inspections have occurred at very low rates. In 2018, Cal Fire inspected just 17 percent of properties within its jurisdiction, about half of its goal, while some areas fire-prone regions saw rates even lower than that. It attributed this to a lack of funding and resources.[100] Therefore, if the state wants to increase residents' preparedness, it could invest more in these efforts. It could also incentivize local defensible space programs. Some have achieved success by notifying residents of upcoming inspections and following-up with noncompliant properties, abating those that do not take steps to rectify the situation.[101]

While home hardening might be one of the more cost-effective options for protecting structures, it still requires funding to ensure low-income individuals take action. This has been difficult to come by In Governor Newsom's 2019-2020 budget proposal, he only proposed allocating $5 million to fund defensible space programs, while emergency response, forest management, and warning systems received the bulk of $900 million in new spending. Similarly, when it passed in 2018, the joint powers authority created by AB 38 was unfunded and had to secure money later.[102] Therefore, home hardening has often not been a priority in relation

to other options. Reforms to the insurance market, wherein insurers offer reductions in premiums in return for homeowners completing work might help. However, the problem would remain among lower-income residents, who often do not have the means and are less likely to have fire insurance. Thus, there is a paradox where the most vulnerable houses are also the least likely to get upgrades to reduce their fire risk, jeopardizing their neighbors' safety along with their own.

Alternative #4: Upgrading Utilities

Since electrical utilities have been the root cause of many of the most destructive wildfires, reducing the risk from the grid is a key potential route for addressing California's problems. However, it comes with immense challenges and political pitfalls. Currently, due to deferred maintenance and the expansive nature of the electrical grid, California has a massive backlog of work and infrastructure that is highly susceptible to sparking wildfires.[103] Following a requirement by the state, all utilities submitted wildfire mitigation plans to the Public Utilities Commission (CPUC), but in many cases their new investments would only begin to scratch the surface of the problem.[104]

The scale of work that the state and utilities would need to do to sufficiently mitigate risk is daunting and would impose significant and ongoing costs. PG&E alone operates nearly 100,000 miles of overhead electrical lines and many of them run adjacent to fire-prone terrain.[105] Many utilities have historically done too little maintenance. For example, through September 2019, PG&E had only completed one-third of its planned yearly tree-trimming near power lines.[106] Similarly, PG&E has not replaced lines and equipment on a regular basis, meaning many are decades old and subject to failures. One reason for lags on both fronts is that utility line work is very technical and dangerous. Therefore, even with the necessary money, it is not clear how much could be accomplished in a short time period, simply from a workforce standpoint.[107] Undergrounding lines has also gained attention as a potentially long-term solution to reduce risk, particularly in fire-prone or urban environments. However, they are still vulnerable to events like earthquakes and the costs can be exorbitant, rising from $3 million per mile. Therefore, for PG&E to bury all of its distribution lines – let alone high-voltage transmission lines – it would cost $15,000 per customer. That is part of the reason why utilities have generally undergrounded lines at a slow rate and why it will likely only play a targeted role going forward.[108]

Potential reforms to the grid largely revolve around decentralization, creating microgrids, installing batteries, or investing in local renewable capacity. This would reduce the number of impacted customers from PSPS events, making that a more acceptable strategy for reducing risk going forward.[109] In 2019, the CPUC approved $100 million to deploy energy storage systems to high fire risk areas, which would create backup generation in the event of power shutoffs.[110] However, because they currently cost more per kilowatt-hour than traditional generation, the use of distributed energy resources (DERS) like microgrids has lagged in most states, which have often not properly incentivized them.[111] This year, California is planning to add 1.7 gigawatts of battery capacity to its grid in a bid to avoid blackouts, a marked increase from a few years ago.[112] Investments like this indicate that decentralizing the grid may prove a key strategy to alleviating hardship from blackouts, but the state could consider other policies to hasten their deployment beyond allocating more funding. Since the location of DERS is important to provide the most

strategic benefits, Burger et al. argue for the adoption of locational rate design, allowing some individuals to earn more for the energy they produce for the grid.[113] While challenges persist, a less centralized grid would allow utilities to reduce fire risk with fewer disruptions for consumers, making these reforms an important part of the state's mitigation strategy.

Ultimately, a big part of the problem has been that the incentive structure for utilities is not one that supports the long-term provision of reliable electricity.[114] Utilities' rates are set by the CPUC, which approves increases that allow the utility to recoup costs from investments in grid infrastructure. But, oftentimes, this encourages overbuilding and cutting corners in order to maximize profits. Therefore, the state may want to consider regulatory changes that shift from compensating utilities for building to assessing on a series of performance-based metrics.[115]

Addressing the vulnerabilities of California's electrical grid is a politically fraught prospect. Utilities like PG&E are powerful political players, as are many of their investors, so efforts that cut into their profits are difficult to attain.[116] Meanwhile, in the aftermath of the recent deadly fires that were caused by the utilities' infrastructure, public sentiment has turned against them.[117] Therefore, proposals that require using public dollars to make up for decades of mismanagement could pose serious repercussions for policymakers. With that said, the grid poses a large enough fire risk that action is desperately needed, so the political landmines may not be a significant enough deterrent.

Recommendations

Wildfires are one of the most pressing issues facing California and stand to get worse over time without aggressive intervention. They have been driven by a combination of climate change, housing sprawl, decades of land management policies that have left the state's forests and grasslands primed to burn, and a vulnerable electrical grid which has sparked many of the state's most destructive fires. Due to the global nature of climate change and the intractability of California's housing crisis, the first two are difficult to address. Therefore, the state must seriously look at scaling up other solutions. I assess the viability of the previously described alternatives and summarize their viability in a criteria alternative matrix, which ranks alternatives on a scale of 1 to 5 (Table 1). Ultimately, I conclude that there is no silver bullet solution to this problem, so it will take a multi-faceted approach to properly mitigate.

While expanding Cal Fire's firefighter ranks and investing in new technologies has been one of the primary responses, this does not get to the root of the problem and will be prohibitively costly going forward. Therefore, the state should refocus its efforts on a combination of scaling up controlled burns and thinning operations to promote healthier forests, enforcing stricter building methods and defensible space requirements for homes in fire-prone areas, and improving the electrical grid by investing more in overdue maintenance and promoting more decentralized power generation. These all carry very real costs, implementation challenges, and political sticking points. They also will not entirely solve the state's wildfire problems, but they would help minimize future damages.

Table 1. *Criteria Alternative Matrix*

	Criterion 1: Cost-effectiveness	Criterion 2: Administrative Feasibility	Criterion 3: Political Acceptability	Total Score
Firefighting Response	Rating: 1 Weight: .5 Total: .5	Rating: 3 Weight: .3 Total: .9	Rating: 5 Weight: .2 Total: 1.0	2.4
Forest Management	Rating: 4 Weight: .5 Total: 2.0	Rating: 3 Weight: .3 Total: .9	Rating: 3 Weight: .2 Total: .6	3.5
Home Hardening	Rating: 5 Weight: .5 Total: 2.5	Rating: 3 Weight: .3 Total: .9	Rating: 4 Weight: .2 Total: .8	4.2
Electric Grid Upgrades	Rating: 4 Weight: .5 Total: 2.0	Rating: 2 Weight: .3 Total: .6	Rating: 2 Weight: .2 Total: .4	3.0

There is a growing body of research that disaster preparedness carries high financial returns. The National Institute of Building Sciences estimates that every dollar invested in disaster mitigation saves $6 overall.[118] Meanwhile, according to Richards, the ratio is smaller, but every dollar still corresponds to a savings of four dollars in response and recovery costs.[119] He cites the cases of Silverthorne, Colorado, where spending a few million dollars on fire breaks and prescribed burns helped protect nearly $1 billion worth of property during a fire in 2018, and Rancho Santa Fe, California, where fire-safe building practices reduced the damage sustained during a fire there. The big question with these preventative and mitigation measures is whether the state has the ability and the political inclination to implement them on the scale necessary to reduce the impact of future wildfires.

So far, while California has begun making serious strides to invest money in fireproofing homes, expanding forest management, and attempting to reduce the risk from the electrical grid, most money continues to go toward wildfire response efforts. Fire suppression has historically worked to protect communities, but, with changing fire intensity and behavior, it is often impractical. Moreover, it has proven extremely costly and its feasibility from a human resources perspective is in serious doubt. So, while protecting communities through these means is a logical response and certainly enjoys strong political support, it is a suboptimal option for reducing the destructiveness of the wildfires, particularly over the long-term. Recent efforts like the Legislature's and Governor's $536 million wildfire prevention deal indicate this may be changing and other investments may be gaining tractions.

Home hardening and other remedies focused on the individual structure and neighborhood are likely the most cost-effective ways to reduce damage, especially when entire

communities take those steps. This last point presents the biggest hurdle because, while one homeowner may invest in fire safe practices, their success also relies on their neighbors. Low-income individuals have been less likely to adopt such practices, so helping them defray costs could go a long way toward making up this difference. While there is some evidence of political resistance to these methods, it is difficult to imagine that being as big an impediment given the high-profile nature of wildfires. Better enforcement is a potential administrative barrier, but that, too, is likely surmountable and providing additional resources inspections could help get past the barrier of not having universal adoption. Given how homes built to stricter codes have been much likelier to survive recent fires, this will continue to be an important area for investments.

Improving California's forest management practices by scaling up controlled burns and doing more thinning work would help reduce the intensity of future fires. However, in terms of its administrative feasibility, this will be extremely difficult to accomplish and meet the state's goals, facing a number of regulatory and technical barriers like continued issues around smoke, liability, and watershed impacts. That said, increased investment in projects and workforce development, as well as changes to the permitting process, may allow management work to play an important mitigative role. Landownership also presents a barrier, so taking a more local or regional approach to do outreach in fire risk communities could promote greater cooperation and allow more projects to be realized. The biggest question mark is whether there will be the political will and if the public will grow more accepting of some impacts.

Finally, improving the electric grid stands to be politically perilous, but improvements would reduce the wildfire threat during red flag warnings and thus likely damage structures. California's utilities are beginning to spend more money on wildfire prevention, but the backlog of work, particularly for PG&E, means they will continue to struggle to make meaningful headway. That begs the question of how likely these changes are from an administrative perspective, especially since the pace of implementation will be slow. However, the large upsides in preventing fires make this an option on the policy agenda. Especially given the high-profile nature of past PSPS events and their public costs, highlighting the need to create a more resilient grid could build support for reforms and investments. Therefore, the state may want to consider electricity rate reforms to incentivize better performance, as well as continuing to invest in decentralizing the grid through battery deployments and the creation of microgrids.

Ultimately, though, while a combination of increasing funding for forest management, home hardening, and electrical infrastructure upgrades would help to minimize losses from wildfires, California will continue to experience ongoing disasters. In order to more completely address the problem, the state would need to contend with climate change and the location of housing in the WUI. At present, meaningful action on these fronts at a requisite scale to move the needle appears far off. However, that could change as the wildfire crisis deepens. If so, the state could consider other options like moratoriums on new construction in fire hazard zones, but that would be very politically difficult in light of the statewide housing shortage and local control.[120] However, in the meantime, it will need to move swiftly on mitigation to prevent escalating destruction and the upending of countless lives in California's exurban and rural communities.

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