THE BURNING ISSUE

MANAGING WILDFIRE RISK

After the wildfires of 2017 and 2018, some have asked whether we have entered a fiery new normal. However, a changing climate and growing numbers of people and assets in fire-prone areas suggest little chance that wildfire risk will stabilize in the foreseeable future.

MARSH & McLENNAN INSIGHTS

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EXECUTIVE SUMMARY

Concern about wildfire risk is growing around the world. Recent years have seen unusually severe fires in countries such as Canada, the US, Spain, Portugal, Greece and Chile, claiming hundreds of lives and causing billions of dollars of economic damage.

Wildfires have also broken out in countries unaccustomed to the problem. In 2018, for example, northern European countries experienced between 20 and 200 times more area burned than normal.

UNDERLYING DRIVERS POINT TO INCREASING RISK

Two underlying trends are contributing to wildfire risk around the world, either in isolation or in combination, depending on the location.

In many regions, climate change is increasing the likelihood of hot and dry conditions in which wildfires thrive. Fire seasons have already lengthened around the world and modeling predicts significant increases in fire activity in high-risk areas such as southern Canada, western US and southern Europe.

Meanwhile, urban expansion into wildlands is exposing more people and assets to wildfire. It also introduces a new cause of ignition—people—into fire-prone areas. For instance, in densely populated Europe, nearly all wildfires are started by people.

Globally, urban area is growing at twice the speed of urban population and is expected to triple in size between 2000 and 2030. As urban developments around the world creep further into wildlands, the number of people and value of assets exposed to wildfire will increase. This is compounding risk in regions already prone to wildfires and creating new risks where wildfire activity is not yet a problem but may become one as climate change progresses.

Exhibit A highlights regions of future wildfire risk. It identifies areas with a 'Negative Outlook', which are characterized by high levels of current risk and well-established trends in underlying climate and exposure drivers (shown in red). There is high confidence that these regions will face greater wildfire risk in the coming decades. The map also marks areas under 'Watch', where there is lower confidence in the extent of future risk but where climate and/or exposure trends provide cause for concern and where there may be early indications of deteriorating risk (shown in orange).

WILDFIRES CAN CAUSE SIGNIFICANT DAMAGE, BUT THE FULL COSTS ARE OFTEN MUCH GREATER THAN IMMEDIATELY APPARENT

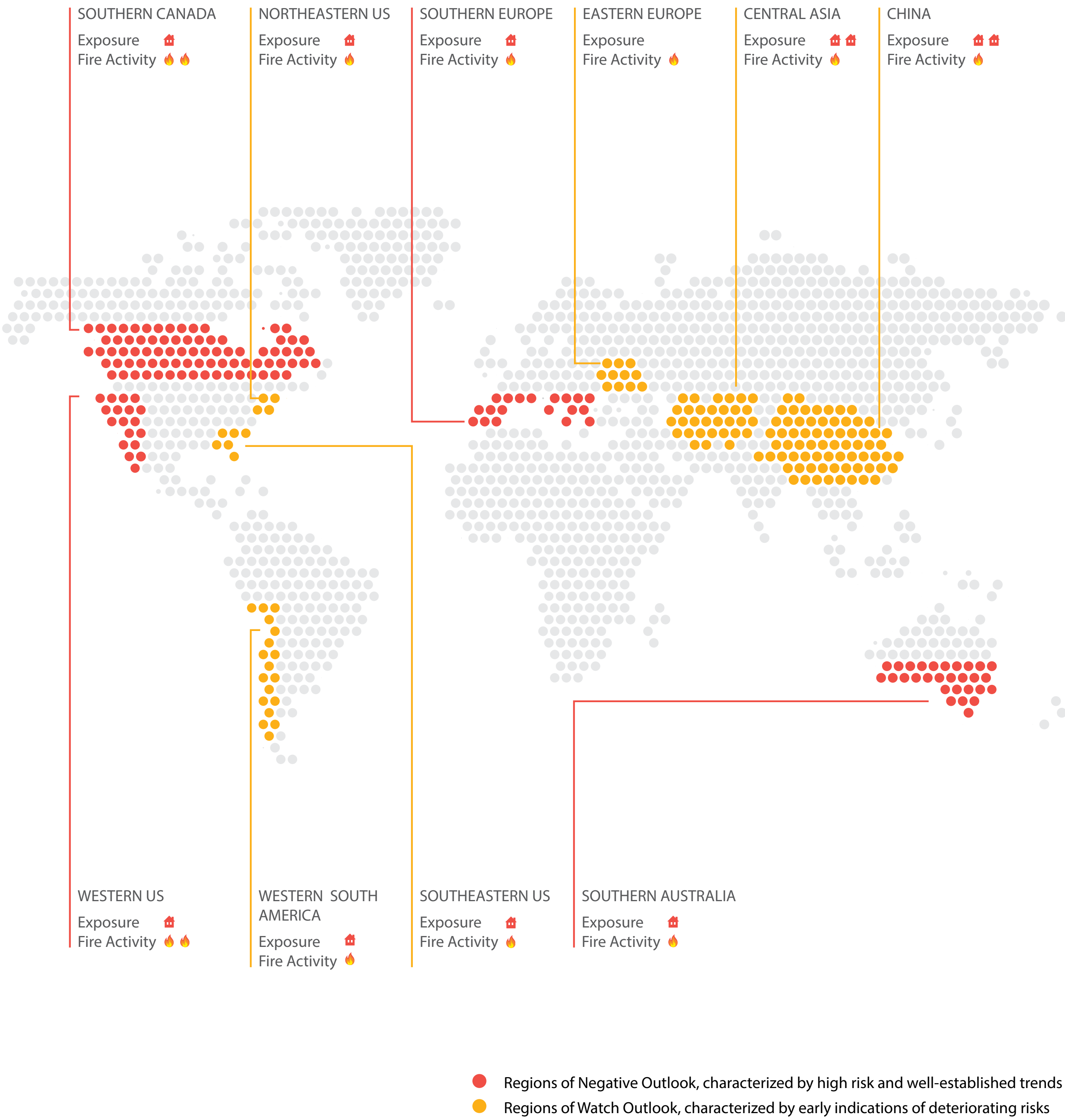
Both 2017 and 2018 witnessed record-breaking economic losses from wildfires – over $20 billion annually, driven by catastrophic fire seasons in California. However, these direct losses are likely to be only a fraction of the full costs, as they exclude firefighting costs and wider societal and environmental damage.

Available data indicates that firefighting costs, which are predominantly borne by the public sector, are increasing in many parts of the world and may become unsustainable if current trends continue. Governments are falling into the 'firefighting trap', in which spiraling fire suppression costs consume budget for investment in fire prevention, therefore contributing to increased fire risks.

Furthermore, the costs of wildfire-caused air pollution can dwarf losses resulting directly from wildfires. For example, long term exposure to fine particulate air pollution from wildfires is estimated to cost the US between $76 to $130 billion a year. Worldwide, over 1,000 times more people die prematurely from wildfire-related air pollution each year than are killed in fires. Costs in fire-affected communities due to post-traumatic stress disorder, depression, substance abuse, and domestic violence can also be significant.

Wildfires are also a significant source of greenhouse gas emissions. Indonesia's 2015 peatland forest fires, for example, are estimated to have emitted over a gigaton of carbon dioxide

EXHIBIT A: REGIONS OF FUTURE WILDFIRE RISK



Source: Marsh & McLennan Insights

equivalent – more than twice the aggregate emissions of the UK for that year.

THE RISKS CAN BE SIGNIFICANT FOR BUSINESSES OPERATING IN FIRE-PRONE AREAS

Damage to residential property often accounts for the majority of direct losses resulting from wildfires. However, businesses operating in risky areas face damage to assets and losses from business interruption. Commonly affected sectors include:

- Forestry, where fires can destroy timber, close down sawmills, and disrupt supply chains;
- Agriculture, where fires can kill livestock, damage crops, and destroy property;
- Tourism and leisure, which can suffer from lost revenues when parks and resorts are closed or evacuated, and when tourists are dissuaded from visiting due to wildfire concerns;
- Extractive industries, which may be forced to suspend activities in the vicinity of wildfires and face serious risks should fires reach production sites;
- Power companies, which may be particularly exposed to liability risks if their assets are found to be responsible for starting a fire.

LAND CHOICES MATTER

The adoption of modern agriculture practices in developing countries can reduce wildfire activity by dividing the landscape into large fields and pastures that introduce fuel breaks[1] and limit the ability of fires to spread. The construction of roads and other infrastructure can have a similar effect, albeit by placing economic assets at risk. Fuel breaks can also be designed into landscapes, for example, by keeping certain areas free of trees and shrubs.

Forests can be managed to reduce the accumulation of fuel and to increase resilience to fire. Practices include prescribed burns, and the selective removal of flammable deadwood, small trees, and brush. Where new forests are introduced—for timber or for carbon sequestration—careful consideration should be given to wildfire risk. Planting monocultures of fast-growing flammable trees such as pine and eucalyptus can significantly increase the risk of severe fires.

Ultimately, the simplest and most effective thing that can be done to reduce wildfire risk is to prevent urban development in high-risk areas, however, short-term economic and political imperatives may prevent this from happening. Population growth and rising housing costs drive expansion into wildlands and, even after developments have been destroyed by fire, pressure to rebuild on the same ground is often high.

PREPARING FOR INCREASED WILDFIRE RISK

Wildfire risk is not a new development, and there is extensive experience of dealing with it in different countries and contexts. This provides a rich source of lessons and insights that can be applied in regions witnessing increasing risk. Priorities include:

- Adopting a risk-based approach to fire management. Many wildfires present minimal risk to populations and therefore do not need to be suppressed. In fact, aggressive suppression can result in the long-run accumulation of fuel and increased risk of severe fires. Authorities should, therefore, consider allowing low-risk fires to burn as an opportunistic way to naturally reduce fuel loads at minimal cost. Increased use of prescribed burning may also be appropriate in many areas.
- Breaking out of the firefighting trap. In certain locations, the twin trends of climate change and urban sprawl create the prospect of governments getting caught in the trap of escalating suppression costs and declining investments in fire prevention. Allowing more fires to run their course will help, but governments will also require sufficient, ring-fenced funds for prevention. Options include raising new funds by charging homeowners in high-risk areas, and using insurance to cover extreme suppression costs, thus making it easier to plan investment in prevention. Innovative risk financing arrangements such as pay-for-performance bonds and resilience bonds can also help mobilize private capital for prevention.
- Building resilient communities. If urban development is to take place in high-risk areas, then everything possible should be done to increase communities' resilience to wildfires. Strategies to encourage communities to invest in their own resilience include education programs and economic incentives or behavioral nudges to help homeowners maintain safe properties. Building codes should stipulate the use of fire-resistant materials and zoning can be used to limit development in the riskiest areas.
- Getting incentives right. Homeowners need to purchase market-based insurance if they are to be properly rewarded for risk-reducing behavior and discouraged from building

in fire-prone areas. Government interventions to subsidize insurance or suppress market premiums may crowd out private insurers and create a moral hazard as homeowners are less incentivized to reduce fire risks on their property; such interventions may also promote expansion in fire prone areas by shielding homeowners from the true cost of wildfire risk.

- Leveraging risk transfer. In a future of increasing wildfire risk, governments and businesses may need to draw upon the full range of risk transfer solutions available to them. Conventional insurance, parametric insurance, and CAT bonds can all be used to transfer wildfire risk. In certain circumstances, it may be appropriate to establish pools to aggregate and diversify risks. Opportunities include establishing insurance pools to provide cover to homes no longer able to access insurance; pools to establish collective self-insurance for power companies against liability risks where private insurance capacity is limited; and inter-governmental risk pools to cover suppression costs in extreme years and exploit the geographical diversification of wildfire risk.

INTRODUCTION

In 2018, the world seemed to catch fire. California suffered its most costly and deadly fire season to date. The Mendocino Complex Fire burned 186,000 hectares of land,[2] making it the largest in California's history, while the Camp Fire killed 85 people,[2] razed a town to the ground, and resulted in $16.5 billion of economic losses,[3] making it the most destructive. To the north, in Canada, the province of British Columbia declared a state of emergency as its worst wildfire season in history burned 1.4 million hectares[4] of forest—an area larger than England—sending choking fumes across the border to Seattle in the US.

In Europe, in the same year, more than 100 people died in horrific wildfires in Greece. In the north of Europe, countries experienced between 20 and 200 times the average area burned,[5] with fires raging as far north as the Arctic Circle.[6] In the southern hemisphere, in Australia, bushfires burned along Sydney's perimeters, enveloping the city in smoke and ash.

Many of the records broken were only a year old. 2017 had been the worst fire season in California and British Columbia. That same year, more than 100 people were killed as wildfires ravaged Portugal and Spain, and in Chile the government declared a national emergency after fires killed 11 people and consumed the town of Santa Olga.

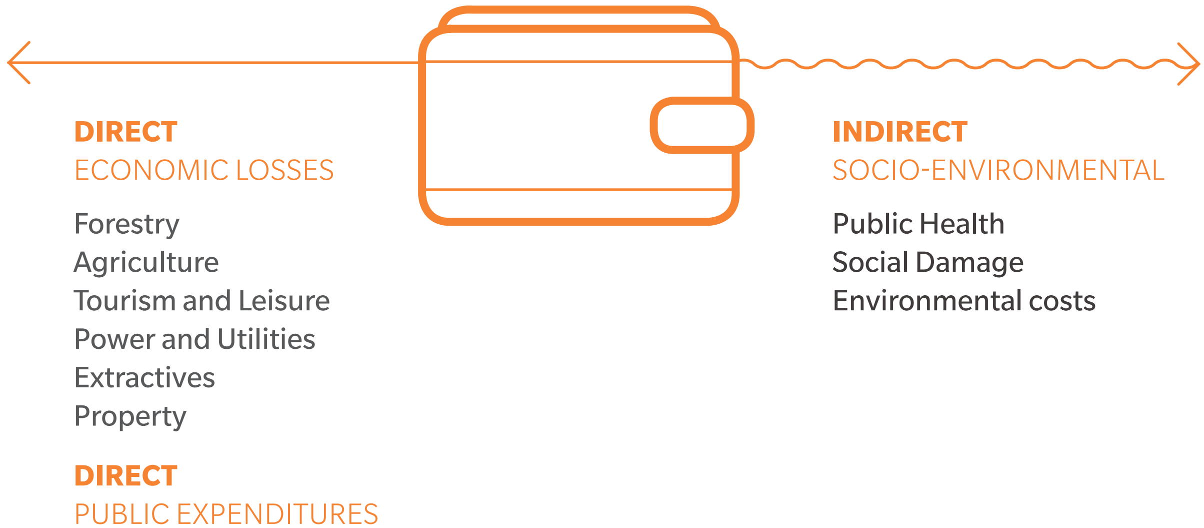
Recent years have seen major wildfires in other countries including Russia, Mexico, China and South Africa. The apparent surge in wildfire activity has led some to ask whether large and destructive megafires are becoming more common.

This paper examines the global outlook for wildfire risk in the context of climate change and the spread of urban areas into fire-prone wildlands. It begins by considering the cost of wildfires before discussing the drivers of wildfire risk and the outlook in key regions of the world. It concludes with a series of recommendations for how wildfire risk should be managed.

THE COST OF WILDFIRES

The costs of wildfires include economic losses in the form of damages to property and business interruption; public expenditure related to preventing and extinguishing fires; and a range of social and environmental costs that are rarely considered in the damage equation but are often significant (Exhibit 1).

EXHIBIT 1: THE FULL COSTS OF WILDFIRES



Source: Marsh & McLennan Insights

ECONOMIC LOSSES

Historically, direct economic losses from wildfires have been of the order of several billion dollars a year globally. In the EU, wildfires are estimated to have caused €54 billion ($65 billion) of economic losses between 2000 and 2017 – roughly €3 billion ($3.6 billion) a year on average.[7] In the US, overall losses over the same period due to wildfires and heat wave events amounted to approximately $42 billion, averaging $2.3 billion annually.[8]

Until recently, wildfire losses were considered by reinsurers to be low and predictable in the context of overall catastrophe losses. In industry terms, wildfire losses were attritional.

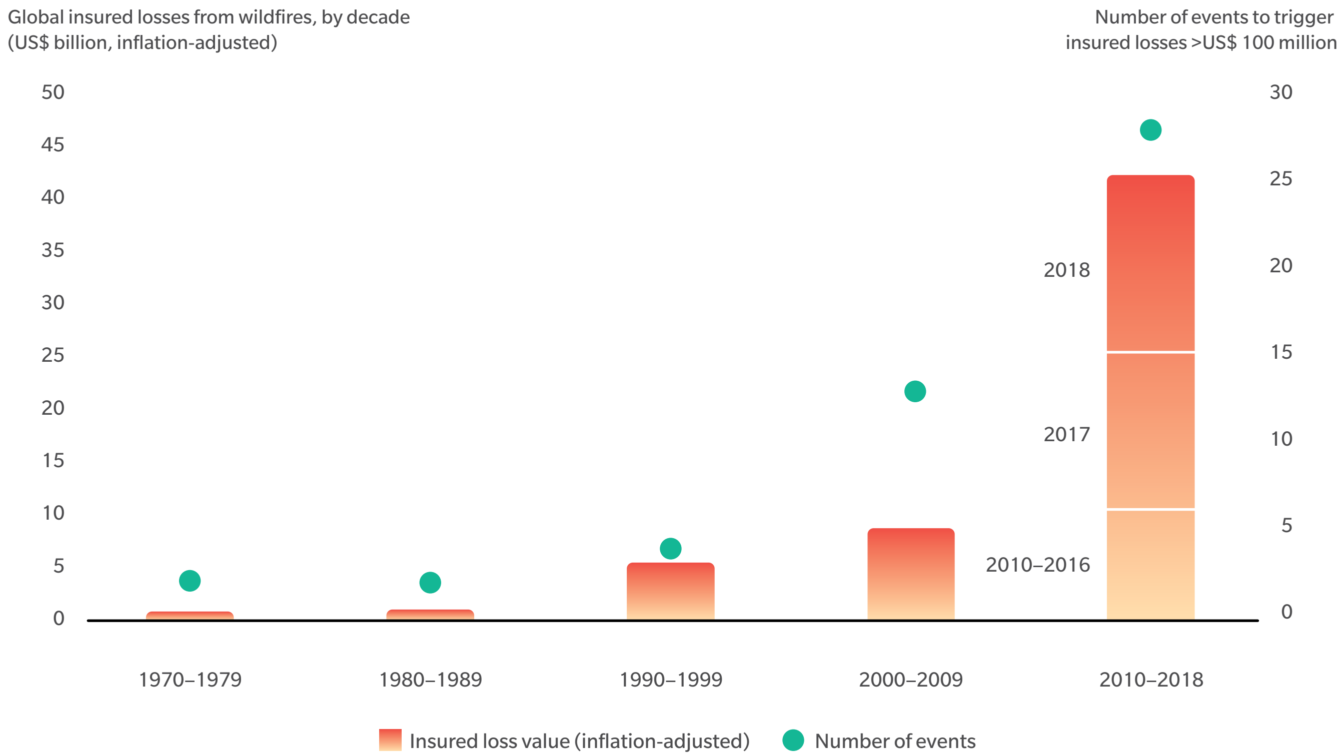
This view may need to change. Driven by California's catastrophic wildfires in 2017 and 2018, insured losses due to wildfires have soared in recent years – from a little more than $1billion a year between 2010 and 2016, to more than $15 billion in both 2017 and 2018 (see Exhibit 2).[9] This is well beyond the bounds of historical variability. Insured losses from the Camp Fire alone totaled $12.5 billion, eclipsing Hurricane Michael and Typhoon Jebi to become the insurance industry's most costly event in 2018.[10]

Losses arise from damage to property and infrastructure, and interruption of business activities located within or on the frontiers of fire affected wildlands. Residential property has often constituted the majority of losses in the costliest wildfires, although businesses operating within affected communities or in fire-prone areas—such as those from the forestry, agriculture, power, tourism and leisure, and extractive industries—can also experience significant losses.

FORESTRY

Forest fires can destroy timber, disrupt timber supply and damage logging infrastructure, creating costs for forestry companies and knock-on effects for sectors such as pulp and paper and construction. The 2009 Black Saturday Fires in Australia, for example, were estimated to have destroyed

EXHIBIT 2: WORLDWIDE INSURED LOSSES FROM WILDFIRES



Source: Guy Carpenter

A$600 million of timber,[11] and the record-breaking 2017 wildfires in British Columbia in Canada, which is the world's largest exporter of softwood lumber, burned 1.2 million hectares (about 8 times the 10-year average) and destroyed 53 million cubic meters of timber, equating to a year's worth of allowable production. Although no sawmills were lost to the fires, many were shut down initially for safety reasons, then remained shut due to a lack of timber supply exacerbated by the wildfires, prompting a surge in international lumber prices. The province's Forest Ministry estimated the industry would take at least five years to recover. Unfortunately, records were broken again the following year, when 1.4 million hectares were burned.[12]

AGRICULTURE

Agriculture and farming often occur close to fire prone wildlands, and damage to livestock, crops and buildings from wildfires can be significant. For example, the 2009 Black Saturday Fires in Victoria, Australia caused A$733 million of agricultural losses.[13] More recently, the 2018 Sherwood bushfire in Australia killed 2,000 livestock and burned 12,000 hectares of land in a day.[14]

California's 2017 and 2018 wildfires destroyed rangelands, fruit and vegetable crops, damaged soils and affected a number of wineries. The 2017 Thomas Fire was estimated to have caused over $170 million of agricultural damages to the Avocado, Citrus, and Cattle industries in Ventura county.[15,16]

TOURISM AND LEISURE

Wild areas of natural beauty visited by tourists may also be prone to fires. In recent years, wildfires in popular tourist destinations in the Mediterranean region of Europe have made headlines and necessitated tourist evacuations.[17] Fires have also forced the closure of parks and resorts, resulting in significant revenue losses. In 2018, for example, the Ferguson

Fire resulted in the closure of Yosemite Valley in the US, one of the most popular destinations in the Yosemite National Park, for three weeks during peak tourist season. Years earlier in 2002, Colorado's tourist sector lost $1.7 billion in a record-breaking fire season.[18] Worries around the risk of fire can lead to lower rates of bookings and trip cancellations. One survey of would-be visitors to California in 2018 found that 11 percent had cancelled their trips due to fire concerns,[19] again underlining how wildfire risk can adversely impact tourism revenues.

POWER

Wildfires can damage power infrastructure, destabilizing grids and leading to power cuts for homes and businesses. The 2007 Tatong bushfire in Victoria, Australia resulted in the loss of 7,100,000 kWh to over 620,000 households and almost 67,000 businesses, costing the economy A$234 million.[20] But history shows that electricity utilities' largest wildfire exposures arise not from damage to their assets, but from the liabilities they may incur if these assets are found to have been responsible for igniting a fire.

High winds are a key risk factor for utilities because they not only increase the chance of power line sparks (for example, from falling trees or clashing lines) that can start a fire, but also encourage fires to spread rapidly. Periods of extreme fire weather (characterized by high temperatures, high winds, and low humidity) are therefore especially risky for utilities, as optimal fire conditions coincide with high chances of power line sparks. Unsurprisingly, the proportion of wildfires ignited by powerlines is significantly higher on days of extreme fire weather. For example, in Australia, half of the fires during the disastrous Ash Wednesday fires in 1983, and a similar proportion of those during the 2009 Black Saturday Fires, were started by electricity power lines (see Box 1).[21] The same happened in 2011 in Texas, when trees falling on power lines during a day of high winds and high temperatures resulted in the state's worst wildfires in history.[22]

BOX 1: INDUSTRY IN FOCUS – POWER UTILITIES AND WILDFIRE LIABILITY RISKS

Power utilities' exposure to wildfire liabilities was thrown into the spotlight in early 2019, when, faced with class actions and potential liabilities of $30 billion in the wake of two devastating wildfire seasons, the Californian utility company PG&E entered into Chapter 11 bankruptcy.

In California, an inverse condemnation regime, whereby a utility company can be liable for starting a fire without being negligent, means the risks utilities face are higher than elsewhere. Nevertheless, power companies in other parts of the world, most notably in Australia, also face similar risks.

One such example is Australia's Black Saturday bushfires. In February 2009, a series of fires across the state of Victoria during a period of extreme fire weather caused 173 fatalities, 414 injuries, and destroyed 2,029 homes.[23] Economic losses were estimated at A$4.4 billion resulting in A$1.07 billion of insured losses.[24] The subsequent Victorian Bushfire Royal Commission found that electrical faults had caused five of the 11 major fires.[25]

A series of class action lawsuits against electricity companies were initiated by victims of the fires, culminating in the largest class action settlement in Australian history. SP AusNet, the Department of Sustainability and Environment, and the line maintenance contractor agreed to pay the victims of the Kilmore East Fire almost A$500 million without admission of liability.[25]

In some instances, liability risks may extend beyond electrical utilities to other companies. For example, after the 2007 San Diego fires, the utility company San Diego Gas & Electric (SDG&E) received contributions to the cost of its liabilities from the cable provider Cox Communications, without admission of liability, when investigations concluded that a Cox wire had clashed with a power line. Further contributions were also received from a tree-trimming company and an electrical contractor.[26]

In the future, utilities may face greater liabilities for starting fires as scientists become more confident in attributing excess deaths from air pollution to particular fire events. For example, records indicate that about 105 additional people died owing to a spike in air pollution during the 2017 Atlas and Tubbs Fires in California, closely corresponding with model predictions.

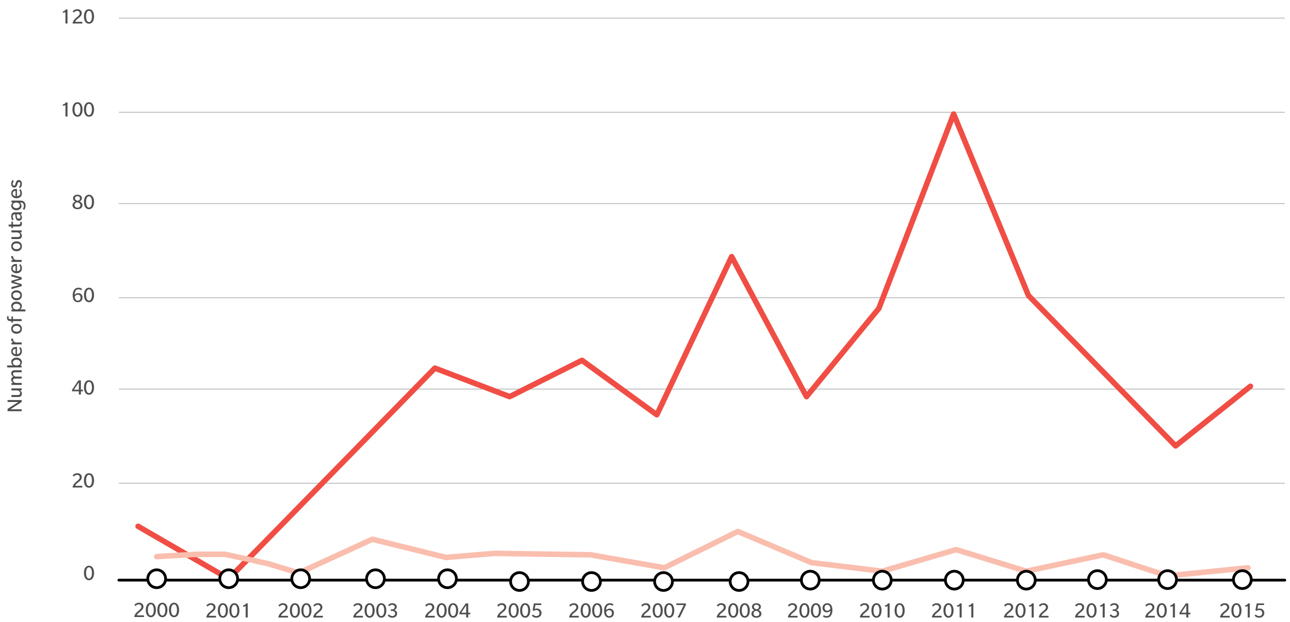
The challenge of safely providing electricity in fire-prone areas such as California and Victoria is increasing. More people are living in these areas, necessitating more connections and power lines, while exposing more homes and lives to fire. Meanwhile, climate change is increasing the chance of severe fire weather.

Insurance can help to cover some of the liability risks faced by utilities, but following recent events, carriers are reducing their capacity for wildfire liability and increasing premiums. **The ratio of Californian utilities' premiums to coverage was reported to have quadrupled between 2017/18 and 2018/19.**[27] If this trend continues, utility companies operating in fire-prone areas will need to examine alternative risk transfer solutions such as CAT bonds or establishing risk pools, or work with governments and regulators to find equitable solutions to financing their liability risks.

Utility companies will also need to minimize the risks of their equipment starting fires. But building resilience of the grid to extreme fire weather requires substantial investment. Californians are bracing themselves for higher electricity bills following utilities' application to increase rates to fund wildfire mitigation. In Victoria, a A$750 million fund to finance resilience measures was established through levies on electricity bills, with an additional A$250 million provided by the state government.[26] This has allowed laying underground power lines in high-risk areas and the rollout of new technologies such as Rapid Earth Fault Current Limiters (REFCL) which can identify when and where a power line touches ground or vegetation and reduce the voltage at this location within milliseconds. However, the full costs of upgrading the grid are likely to be more than planned, as the costs of REFCL installations alone are expected to exceed A$500 million.[26]

In periods of extreme fire weather, utilities may choose to minimize their liability risks by cutting off power to communities in risky areas. However, this raises concerns about the potential impacts on vulnerable individuals and people with disabilities, and the possibility of further litigation should there be adverse consequences for people's health and wellbeing as a result of power being cut off.

EXHIBIT 3A: MAJOR WEATHER-RELATED POWER OUTAGES IN THE US ARE INCREASING



Source: Purdue University, Major Power Outage Risk in the US.

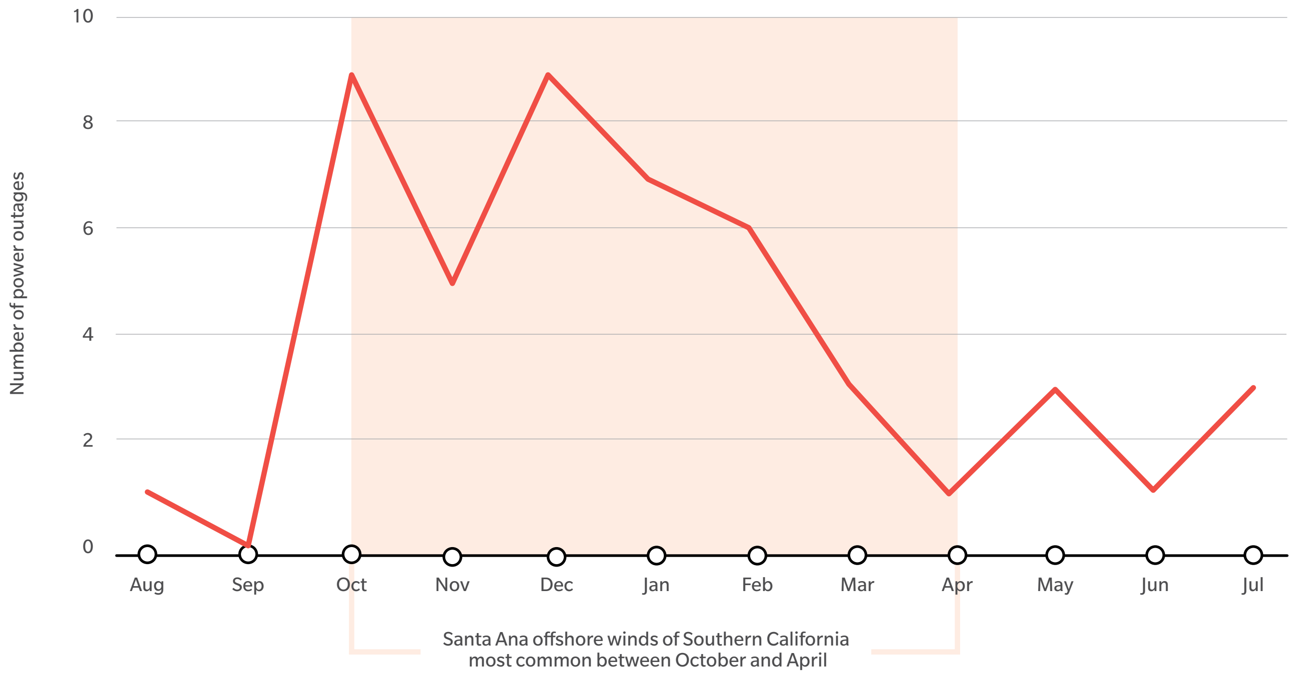
Since climate change is expected to increase the incidence of extreme fire weather in many regions of the world (see Section 3), it is likely to increase the liability risks faced by utility companies. With increasing regularity, utility companies can expect days when powerlines are more likely to spark and sparks, in turn, are more likely to develop into severe wildfires. An examination of national power outage data for the US,[28] for example, reveals that weather-related outages (which are likely to be associated with events that may cause sparks, such as trees falling on power lines) are on a strong upward trend, whereas those caused by other factors essentially remain flat (see Exhibit 3A).

The same data shows how, in California, weather-related power outages cluster during the Santa Ana fire season from October to April (see Exhibit 3B). Between 2000 and 2015, 83 percent of major weather-related outages occurred during this period, when warm, dry winds pick up after the hot summer, creating optimal conditions for fast moving, destructive wildfires such as the 2018 Woolsey and Camp Fires, and the 2017 Tubbs and Thomas Fires. This concentration of weather-related power outages during the fire season strongly indicates that the weather is causing power lines to spark most when the risk of destructive wildfire is greatest. It is therefore no surprise that over 80 percent of wildfire losses in California occur during the Santa Ana months.[29]

EXTRACTIVE INDUSTRIES

Extractive companies often operate in wildlands where fires may occasionally threaten infrastructure and force them to suspend operations. This can have knock-on consequences for economic activity and resource markets, and serious localized impacts if fires reach extraction sites.

EXHIBIT 3B: SUMMARY OF WEATHER-RELATED POWER OUTAGES IN CALIFORNIA FROM 2000 TO 2015



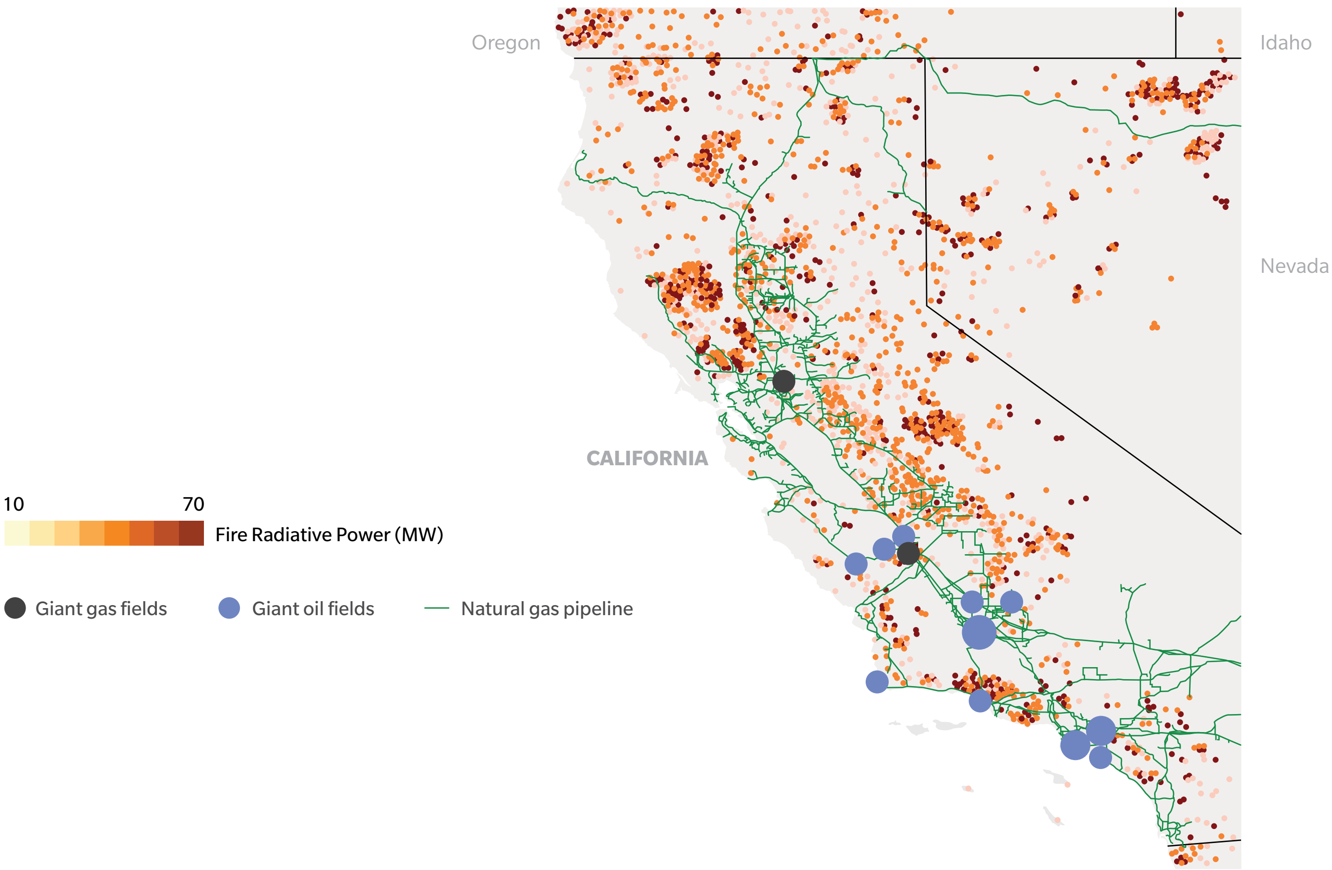
Source: Purdue University, Major Power Outage Risk in the US

The 2016 Fort McMurray fire in Alberta, Canada had a material impact on Canada's economy and international oil markets. It resulted in the evacuation and temporary shutdown of a number of oil production sites, resulting in C$3.7 billion of insured property damage and almost C$10 billion in total direct and indirect costs, contributing to a sharp decline in monthly GDP and making it the country's costliest ever disaster. Around 40 million barrels of production were deferred, pushing up international oil prices.

Where wildfires reach production sites, there can be serious risk of environmental damage. In 2014, embers from a bushfire in Victoria, Australia set the Hazelwood open cut brown coal mine on fire for 45 days, spewing smoke and ash over surrounding areas and the town of Morwell, resulting in a localized public health crisis and serious economic impacts. Subsequent inquiries estimated the costs of the disaster to be in excess of A$100 million ($70 million) and found it likely that air pollution from the fire contributed to an increase in mortality in the surrounding area.[31]

Wildfires have also reached oil and gas fields in California in the past, many of which are located in, or close by, areas of high fire risk (see Exhibit 4), placing production sites and pipelines at risk. For example, the 2017 Thomas Fire ignited flammable and hazardous chemicals, making some fields too dangerous for fire fighters to access. Multiple sites were shut in and evacuated, and oil seeps in the area were reported to have remained burning for weeks.[32]

EXHIBIT 4: MAP OF 2018 WILDFIRE RISK ZONE IN CALIFORNIA OVERLAY WITH OIL FIELDS



Source: Marsh & McLennan Insights and datasets from NASA FIRMS, California Natural Resources Agency, and AAPG Datapages

PUBLIC EXPENDITURES

The costs of fighting wildfires are largely borne by the public sector. Available data indicates that wildfire suppression costs are increasing in a number of regions and may become unsustainable. In 2018, US Federal Forest Service suppression costs exceeded $2.6 billion,[33] representing 55 percent of the service's total discretionary budget,[34] up from 11 percent in 2010 (see Exhibit 5). The sharp increase in suppression expenditure suggests that funds intended for fire prevention were increasingly diverted to fighting fires, since the overall discretionary budget has declined over the past decade.[35]

One analysis of Canadian suppression costs found a 176 percent increase in 10-year average annual costs from 1970 to 2010.[36] The Canadian government, meanwhile, has forecast that forest fire protection costs could double between 2000 and 2040.[37]

National government expenditures are only part of the story in countries where state or provincial governments also have responsibility for firefighting. In Canada, for example, each province and territory is responsible for wildfire management. Meanwhile, in the US, the federal government is responsible for fire suppression on federal lands, while state governments are mostly responsible for fire suppression on non-federal lands. In the western states, governments typically spend less than 1 percent of their general fund (comprising unrestricted state revenues) each year on suppression, but in severe fire years, this can increase to above 2 percent which can have a material impact on the overall fiscal position, especially in years with tight budgets.[38] For example, after a severe fire season in 2017, Montana was forced to make deep budget cuts when firefighting costs came in at 250 percent above the decadal average.[39]

Suppression cost data compiled for eight western US states from 2005 to 2015 reveals the extent of cost volatility and the challenge this creates for budgeting (see Exhibit 6). Apart from considerable variation from one year to the next, it also shows strong variation among states in any given year. Typically, when some states are spending more than average on fire suppression, others are spending less. This suggests the potential for a diversification benefit if states were to pool their risks. For example, in only two years (2013 and 2015) did more than one state experience an extreme year (spending more than twice the average on suppression).

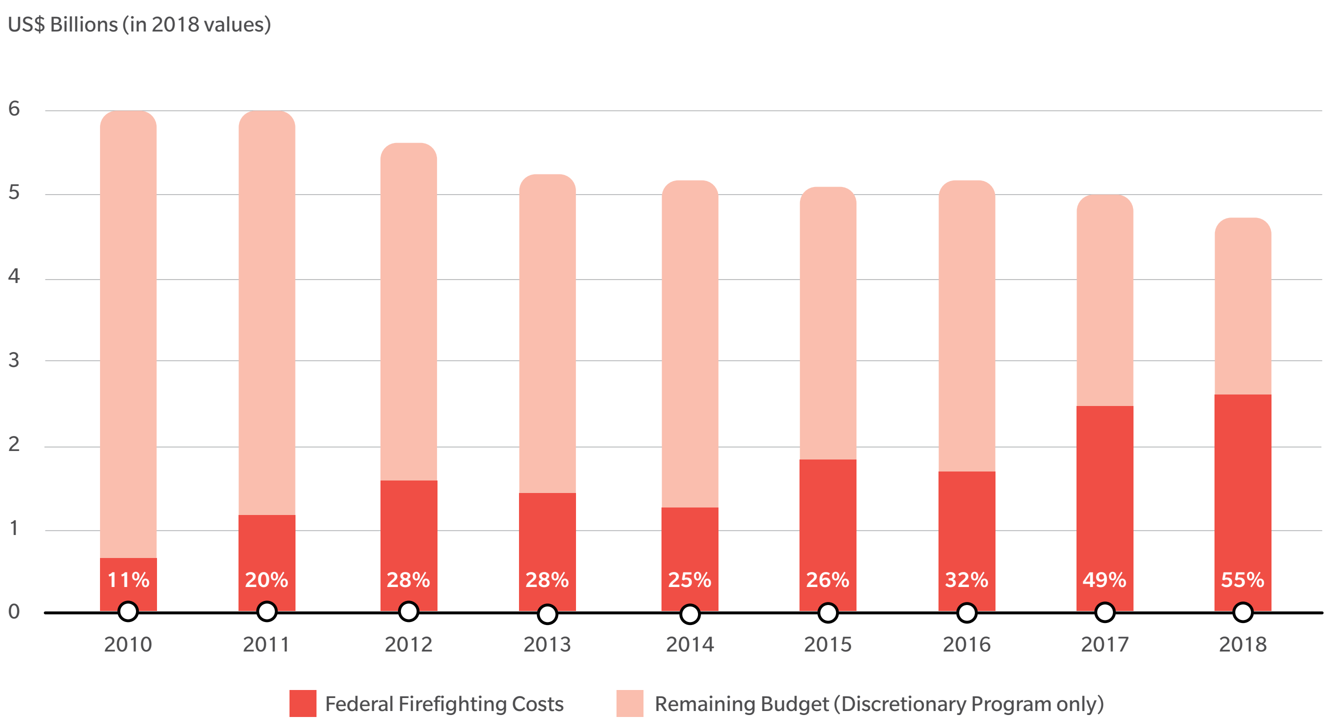
OTHER COSTS

The true cost of wildfires extends beyond economic losses and public expenditures, and incorporates a range of indirect and unpriced impacts on people and the environment. Although these can be hard to estimate, they are significant. For example, an analysis of the Black Saturday bushfires in Australia found the intangible costs of the fires exceeded the tangible costs by around 30 percent.[40]

FATALITIES

Although air pollution from wildfires is estimated to kill hundreds of thousands of people every year (see Exhibit 7), direct fatalities from wildfires are small compared to other natural disasters such as floods and hurricanes, and appear to be stable at the global level.

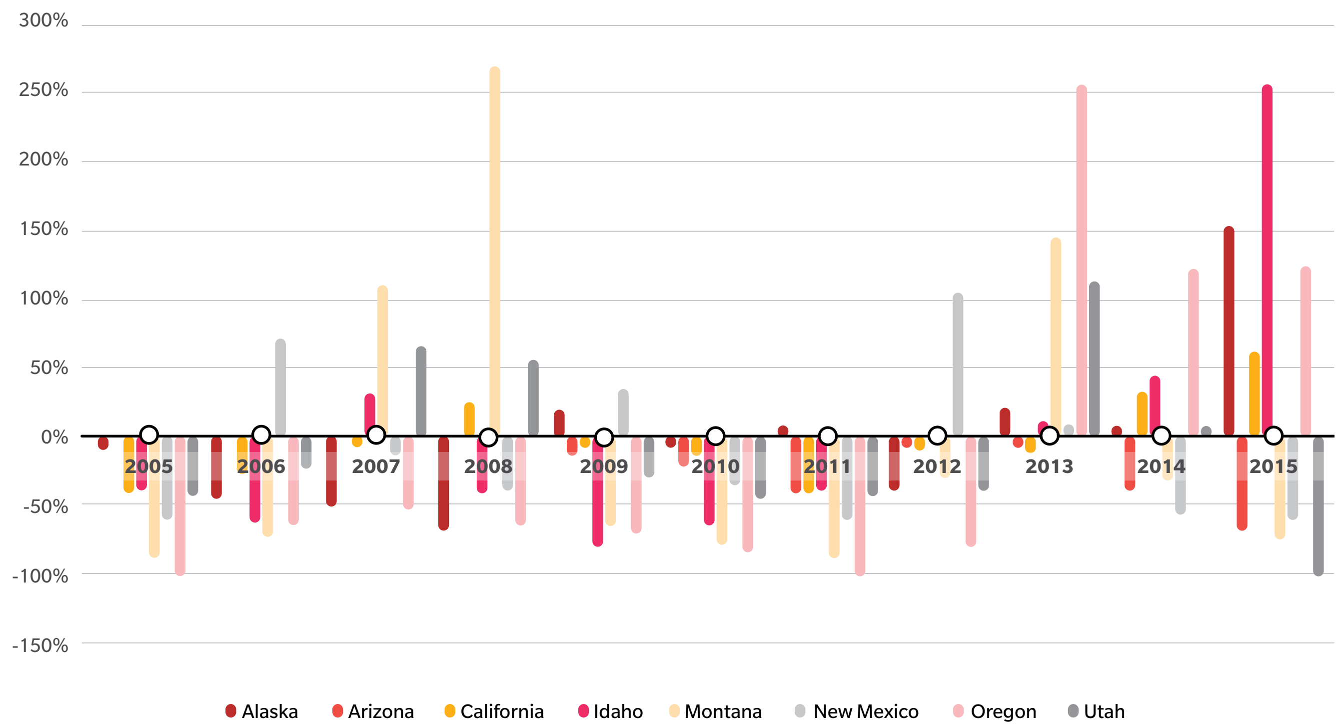
EXHIBIT 5: STEADY INCREASE IN FIREFIGHTING COST TO THE US FOREST SERVICE BUDGET



Source: USDA and authors' own analyses

EXHIBIT 6: SUPPRESSION COST SPENDING FOR EIGHT WESTERN US STATES

Suppression costs relative to mean



Source: Cook P S, & Becker D R. (2017)

PUBLIC HEALTH

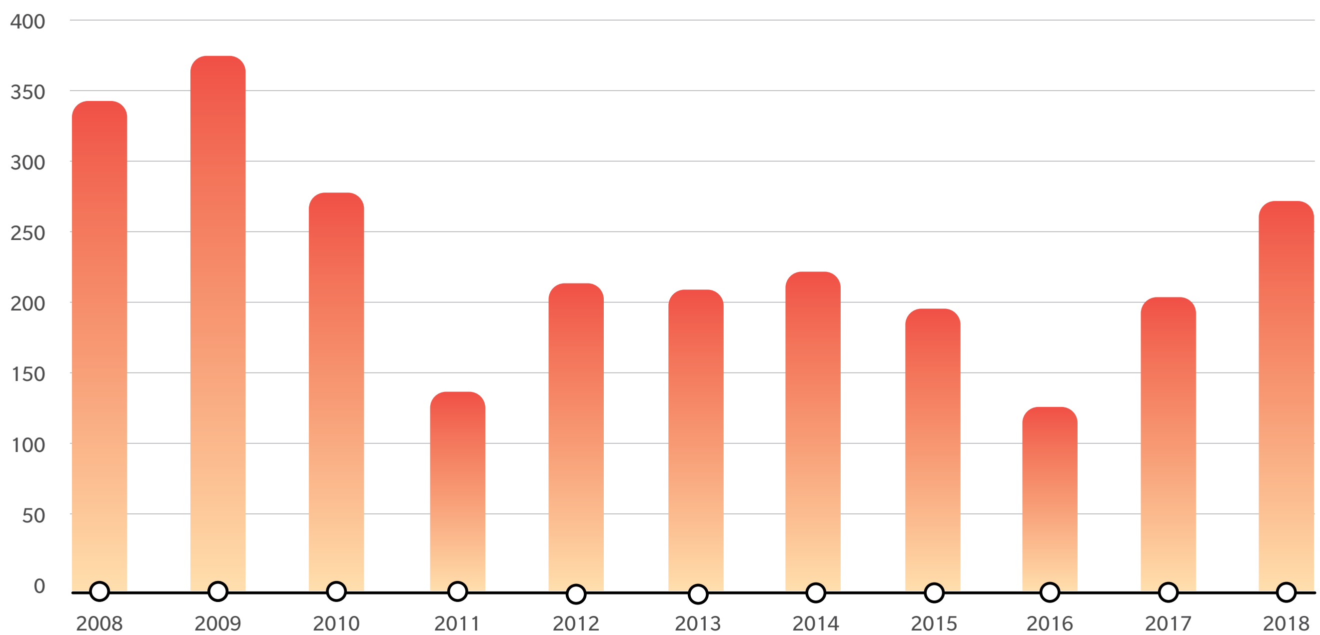
Smoke from wildfires can be a source of serious air pollution. Globally, on average, air pollution from wildfires is estimated to cause 339,000 excess deaths a year, on par with pollution from transport.[41]

When wildfires occur near highly populated areas, the impacts can be stark. In July and August 2010, smog from nearby wildfires, in combination with a severe heat wave, contributed to 56,000 excess deaths in Moscow, Russia.[42] But some of the most severe impacts in recent years have occurred in Southeast Asia, where forest fires in Indonesia have created a toxic haze, estimated to have killed over 100,000 people across Indonesia, Malaysia, and Singapore in 2015.[43] The healthcare costs associated with wildfire air pollution can dwarf economic damages. Mortality and morbidity costs due to exposure to fine particulate air pollution from wildfires in the US are estimated to be between $11 billion and $20 billion a year for short-term exposures, and $76 billion to $130 billion a year for long term exposures.[44]

SOCIAL DAMAGE

In addition to all the economic and health consequences, wildfires can have devastating social consequences for affected communities. People can lose loved ones, homes, and jobs, and witness terrifying and horrific events. This can have serious consequences for mental health, resulting in higher incidences of depression, post-traumatic stress disorder, and alcohol use. Domestic violence may also increase. In the aftermath of the 2009 Black Saturday fires in Australia, the costs of these factors were estimated to have exceeded A$2 billion – around 40 percent of direct economic damages.[45]

EXHIBIT 7: GLOBAL WILDFIRE FATALITIES



Source: GFMC, Swiss Re and authors' own research

ENVIRONMENTAL COSTS

Forest fires can be a major source of carbon dioxide emissions, thereby contributing to climate change. For instance, unprecedented wildfires in the Arctic Circle during the summer of 2019 emitted 50 megatons of carbon dioxide a month.[46] Indonesia's 2015 peatland forest fires are estimated to have emitted over a gigaton of carbon dioxide equivalent – more than twice the annual emissions of the UK at that time. During September and October alone, the 2015 fires' emissions rate exceeded that from fossil fuel combustion across the whole of the EU.[47]

In addition to climate impacts, wildfires can curtail a range of environmental benefits and services. For example, fires can pollute watersheds, while loss of upland forests can leave communities more vulnerable to flash floods and landslides (see Box 2).

BOX 2: NATURAL HAZARDS IN FOCUS – WILDFIRES AND RESULTING LANDSLIDE IMPLICATIONS

The risk of flash floods and landslides often increases after forest fires. Fires create large amounts of debris and ash. The ash can act as a lubricant, making it easier for debris to slide downhill. Charred earth is also less permeable to water, so when the rains come, water skims along the surface and washes debris and mud quickly downhill. Moreover, if vegetation has been destroyed in the fire, there is little to impede the flow and prevent materials being picked up. The increased risk of landslide can persist for years after a fire.

The results can sometimes be more disastrous than the preceding fire itself. After being narrowly missed by the Thomas Fire, the Californian town of Montecito was inundated by a mudslide following a period of heavy rains in January 2018. Twenty-three people were killed and damages were estimated at around $200 million.

DRIVERS OF WILDFIRE RISK

Wildfire activity is shaped by three fundamental factors:

WEATHER and climatic conditions such as temperature, wind, humidity and preceding periods of rainfall (which can increase vegetation), and drought (which can dry out fuels) are major determinants of fire likelihood and fire intensity.

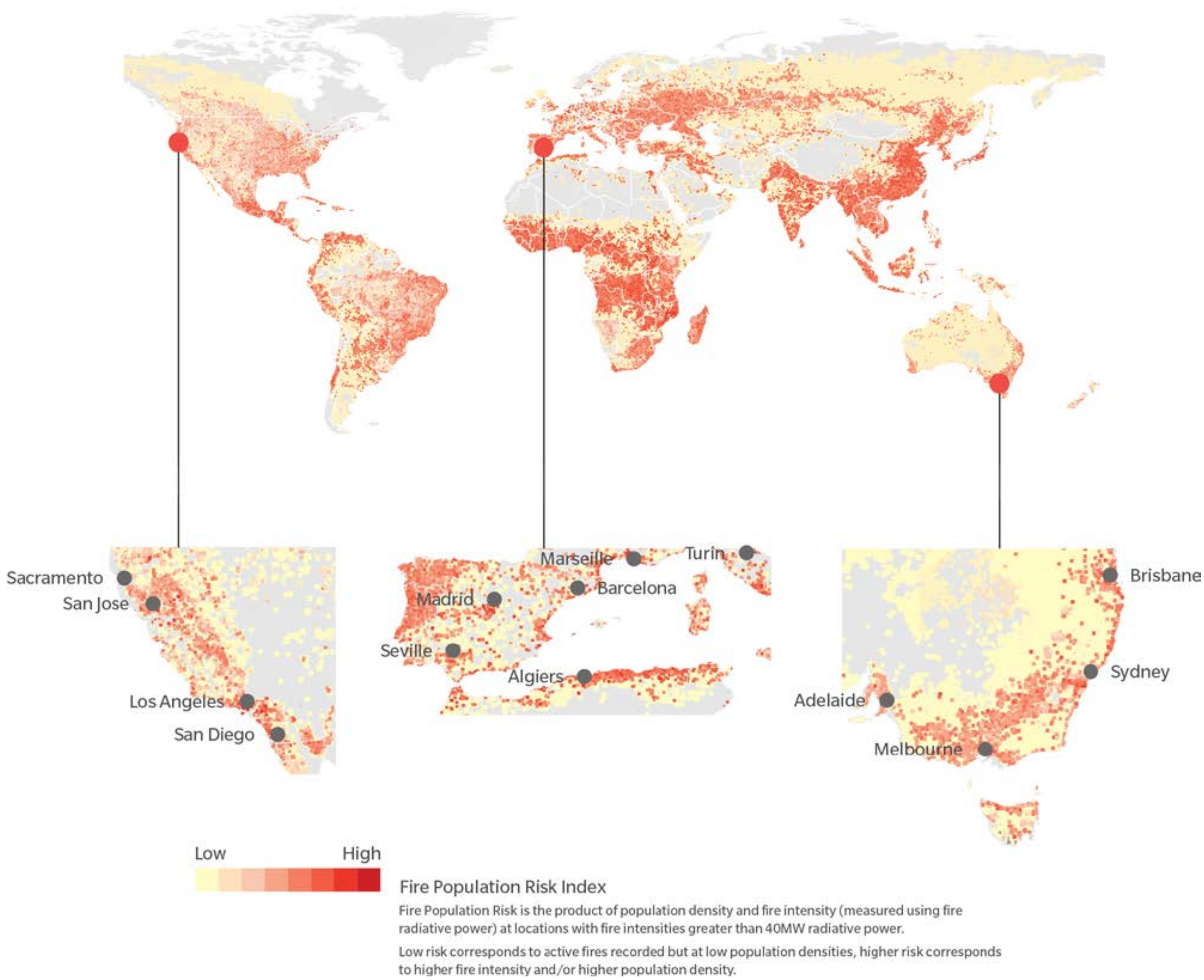
FUEL of sufficient quantity, flammability, and continuity is necessary for a wildfire to take hold and spread. The moisture content of fuels is critical, as is their nature and structure. For example, certain species of tree are more flammable than others; and dead trees, small trees, and underbrush are more susceptible to fire than mature trees.

IGNITION is necessary for a fire to start. In remote areas, lightning usually provides the necessary spark, but where wildlands come into contact with human populations, the overwhelming majority of fires are caused by people.

Fires are not confined to prominent fire-prone regions such as the western US, Victoria or the Mediterranean. Wildfires are far more pervasive. Although most pose little risk because they burn in remote areas, the risk increases where wildfires and populations meet (see Exhibit 8). This is apparent in regions such as the western US and southern Europe, but also in many other parts of the world.

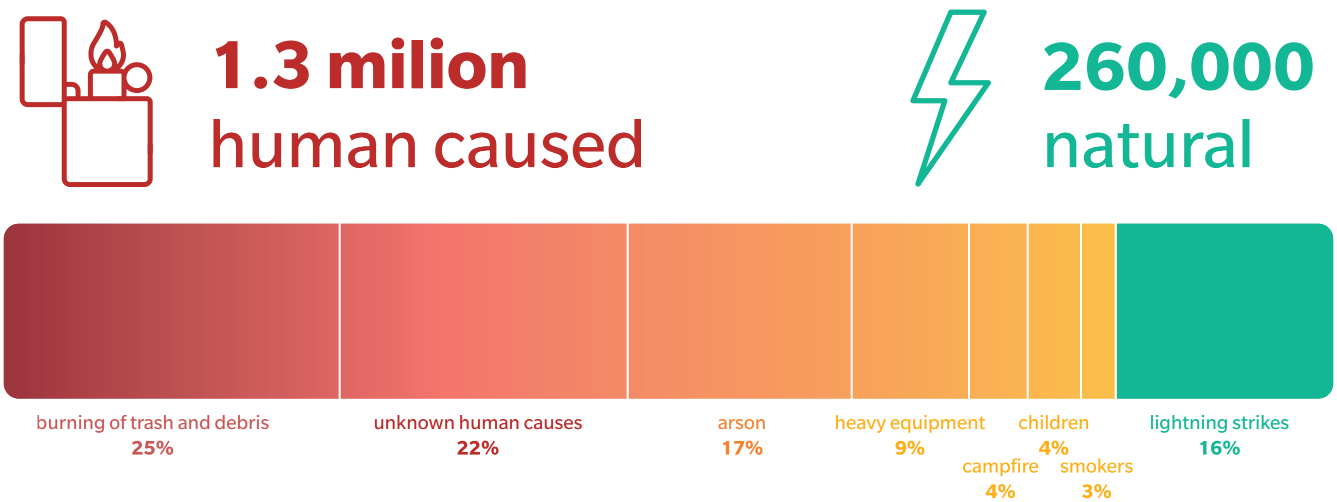
Although they may seem catastrophic, fires are an integral characteristic of many natural wildlands that stimulate regeneration of vegetation and promote biodiversity. Wildlands are adapted to fire, resulting in distinct fire regimes[48] in different regions of the world that maintain a natural balance between wildfires and landscapes. However, this balance is delicate, and it is easily destabilized by humans and climate change.

EXHIBIT 8: MAP OF GLOBAL POPULATION DENSITY AND WILDFIRE ACTIVITY COMPOSITION (2009 TO 2018)



Source: Marsh & McLennan Insights and datasets from European Commission Global Human Settlement and NASA FIRMS

EXHIBIT 9: CAUSES OF US WILDFIRES FROM 1992-2013



Source: John Upton (2017). Humans Blamed for Starting Most Wildfires in the US. Climate Central

HUMAN DRIVERS OF WILDFIRE RISK

Fire regimes change as human populations expand into wildlands. People provide a new source of ignition that can dramatically increase the occurrence of fires. They also alter the landscape in different ways that can, for example, affect the accumulation of fuel, reduce the resilience of landscapes to fire, and change the potential for fire to spread over large areas. Finally, the accumulation of more people, property, and infrastructure in fire-prone areas is increasing exposure to wildfires that would once have posed no risk.

EXPANSION INTO WILDLANDS

Patterns of urbanization mean the boundaries between urban and wildland areas are becoming increasingly blurred in many parts of the world. The wildland-urban interface (WUI) has become the frontline of wildfire disaster, and it is growing rapidly.

Increasing ignitions

In natural wildfire regimes, the primary ignition source is lightning. However, increasing human presence at the wildland interface means that anthropogenic ignitions have eclipsed lightning in many parts of the world. Common causes include vehicles, arson, debris burning, discarded cigarettes, and unattended campfires. Sparks from infrastructure, such as railways and power lines, can also start fires.

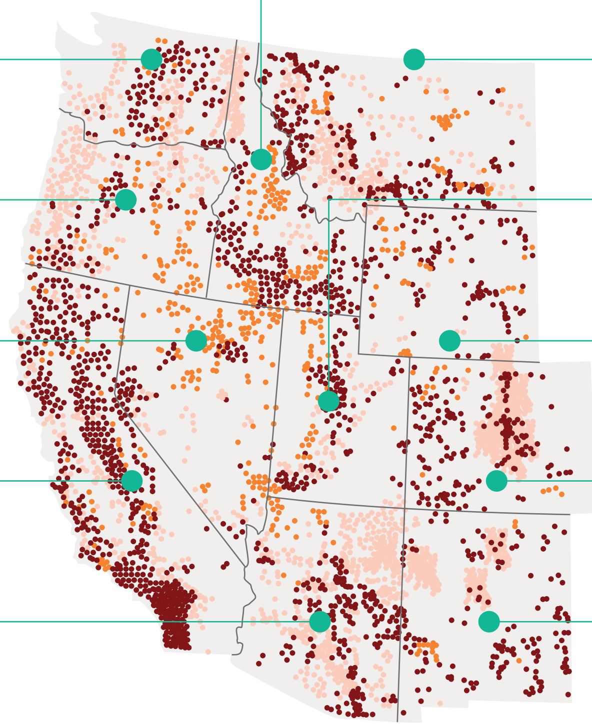
A recent study of 20 years of wildfire data in the US found that 84 percent of fires had been caused by people. In less densely populated British Columbia, Canada, the Wildfire Service estimates that around 40 percent of forest fires have been started by people.[49] An analysis of bushfires in southeastern Australia, meanwhile, found that 87 percent of fires with known causes were due to humans, and that population density was the principal driver of fire ignitions.[50] In Europe, over 95 percent of fires are caused by humans.[51]

Increasing exposure

The US WUI expanded by a third between 1990 and 2010 in terms of land area, and saw a 41 percent growth in houses to over 43 million.[52] Some of the most rapid expansion has occurred in fire-prone areas. Since 1970, the WUI has expanded by 60 percent in the western US. California has 4.5 million homes in the WUI, Arizona has 1.4 million, and Washington state has 1 million.[53]

The WUI also accounts for a significant share of area burned in western US (see Exhibit 10). Since 2000, 35 percent of California's burned area was within the WUI; the share was 30 percent for Colorado and 24 percent for Washington.[54]

EXHIBIT 10: WILDFIRE AND THE WESTERN US WUI, 2000 TO 2016



Source: Schoennagel et al. (2017)

There is significant potential for further increases in exposure in the western US WUI, where 70 percent of land is privately owned but only 14 percent has been developed.[55]

Increasing exposure to wildfires in the WUI is best documented in the US, where the concept of the wildland-urban interface originated. However, data indicates it is an issue in other fire-prone regions too. In Europe, for example, areas of WUI have expanded due to urbanization and the encroachment of shrubland into peri-urban areas, creating particular wildfire exposures in the Mediterranean region.[56] Expansion of WUI areas is also happening in Canada and Australia.[57]

At the global level, the expansion of the WUI is an inevitable consequence of the double trend of urbanization (more people and assets in urban areas) and urban de-densification (urban areas becoming less densely populated). The result is urban sprawl. Globally, urban land area is expanding twice as fast as the urban population. Based on current trends, global urban land area is expected to triple between 2000 and 2030.[58]

Much of this expansion is expected to occur in developing countries, particularly in China, India, and Africa, where notable fire-prone areas exist (see Exhibit 8). Urban sprawl, coupled with rapid economic growth in these regions, is likely to increase exposure significantly, although increases in risk are likely to be tempered by agricultural development and declines in rudimentary 'slash and burn' practices that act to reduce wildfire activity. The outlook in these countries is therefore uncertain, and the impact of climate change may prove to be a decisive factor.

Even in developed regions where exposure in fire-prone areas is already high, urban land cover is still expected to increase significantly – by more than 100 percent in North America from 2000 to 2030, and 160 percent in the Mediterranean basin.[58]

LANDSCAPE MANAGEMENT

Human populations shape the surrounding landscape in various ways that may have implications for wildfire risk.

Agriculture

Agricultural practices influence wildfire risk. In many developing countries, wildfires are started accidentally by 'slash and burn' farming. This is thought to account for a significant share of fires in Africa and South America, for example (see Exhibit 8), while Indonesia's forest fires are often started by farmers to clear land for palm oil cultivation. But as modern farming practices have expanded in developing countries, the total area burned has steadily decreased.

Fuel fragmentation

Modern agriculture also reduces wildfire risk by dividing the landscape into large scale fields and pastures which break up wildlands, creating discontinuities in the fuel source such as trees or shrubs, and limit the potential for wildfire to spread. Construction of roads and other infrastructure can have a similar effect. However, while the net effect may result in reduced burn area, this is essentially achieved by placing economic assets in the path of fire. Consequently, this does not necessarily translate to reduced risk.

Forest management

The ways in which forests are utilized and managed has important consequences for fire risk. In certain natural forests, wildfires are an important ecological process that clear dead trees, return nutrients to the soil, and help maintain biodiversity. In these contexts, efforts to suppress all fires can lead to the accumulation of fuel and larger, more intense fires that would occur less frequently in an undisturbed system. This has been the case in the western US following decades of aggressive fire suppression,[54] and has been identified as a factor in the recent trend towards more megafires in the region. California's forests may now have up to 100 times as much flammable underbrush and small trees as they had prior to European settlement.[59]

The obvious solution is to take an opportunistic approach to wildfires and allow those considered as non-threatening to run their course. However, this can be a hard sell to the public in fire-prone regions, especially in the wake of catastrophic megafires. The practice of prescribed burning—in which a planned fire is used to reduce fuel load under controlled circumstances—may also be unpopular. Concerns include increased air pollution and the chance of a prescribed fire going out of control, though in practice very few prescribed burns escape;[60] and assuming they are managed appropriately, controlled fires tend to generate less harmful pollution than wildfires.

Despite a strong evidence base supporting the use of prescribed burning as a fire mitigation strategy, the approach is heavily underutilized in California and in other parts of western US, where the annual extent of prescribed fires has declined or remained flat for the last two decades. During the same period, southeastern US utilized twice as much prescribed fire as the rest of the US combined, and that could be one of the reasons why the region has experienced relatively few wildfire disasters despite high exposure at the WUI and significant wildfire activity.[61]

Prescribed burning also appears to be underutilized in British Columbia, Canada where it has declined significantly since the 1980s as wildfire activity has increased (see Exhibit 11).

Prescribed burns are inexpensive compared to the costs of suppressing wildfires, which data indicate are increasing. Rising suppression costs raise the prospect of a 'firefighting trap', in which governments fall into a pattern of allocating more funds to suppression in the wake of severe fires, undermining prevention efforts and perversely creating conditions for worse fires in the future as tinder and deadwood accumulate.[62] In Portugal, almost three times as much is spent on suppression as is invested in prevention.[63] And in the US, spiraling suppression costs have eaten into funding for prescribed burning, which has received a declining share of federal budgets.[64]

As the US Secretary of Agriculture noted in 2017:

"We end up having to hoard all of the money that is intended for fire prevention, because we're afraid we're going to need it to actually fight fires. It means we can't do the prescribed burning, harvesting, or insect control to prevent leaving a fuel load in the forest for future fires to feed on."

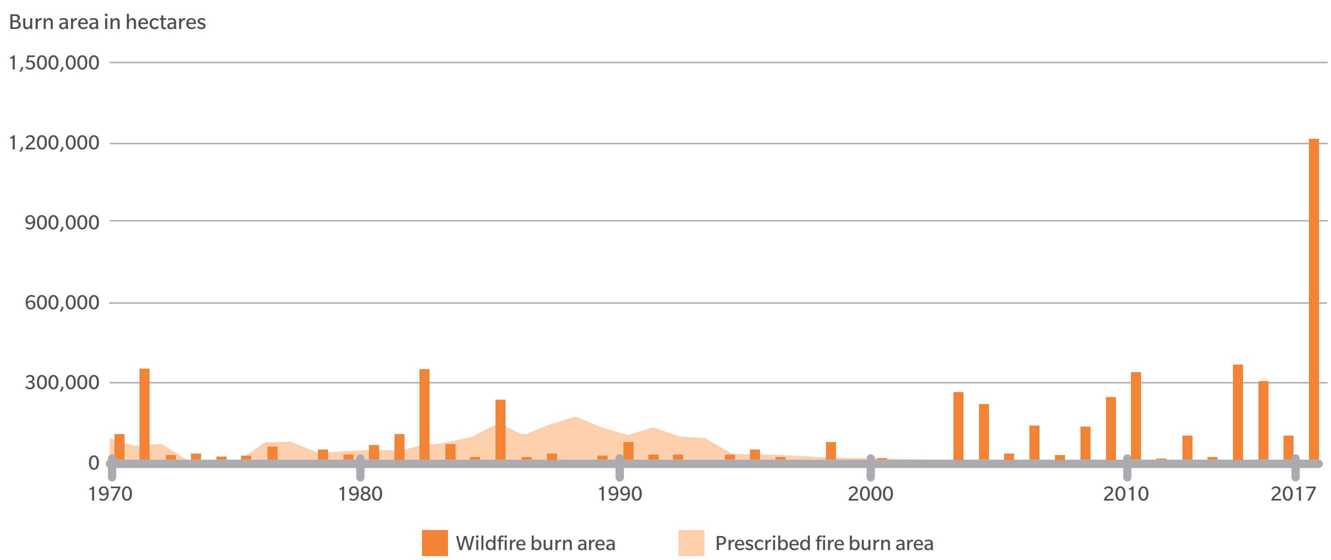
Fuel loads can also be reduced through forestry practices such as thinning of dead or small trees that burn more easily, and collection of forest residues. The timber harvested can provide feedstock for bio-energy or be used to manufacture low-carbon construction materials such as cross-laminated timber. However, harvesting must be carefully managed to avoid damaging forest ecosystems or increasing fire risks. Careful selection of deadwood, small trees, and brush is very different to clear cutting, which may be more economical for a timber company, but can impose significant ecological damage and removes large, more fire-resistant trees, potentially increasing susceptibility to fire. Logging can also increase wildfire risk through accidental ignitions and by thinning the protective forest canopy.[65]

Manmade forests

Fires occur not only in natural forests, but also in managed plantation forests, and the effects can be quite different. For example, a study of wildfire in Oregon found that privately owned and managed forests burned with greater severity than publicly owned forests.[66] Fast growing varieties such as eucalyptus and pine are often favored by forestry companies. However, these species burn rapidly and can spread sparks and embers over large distances, creating fast moving fires as seen recently in Chile and Portugal (see Box 3).

The susceptibility of new forests to fire (whether monoculture plantations or restored natural forests) needs to be considered carefully in the context of climate change. This is because climate change is expected to increase the risk of fire in some areas, but also because massive tree planting programs are needed to meet climate change objectives. If afforestation and reforestation were to deliver the carbon sequestration needed to keep global temperature increases below 2˚C, then as much as 970 million hectares of new forest—an area about the size of Canada—could be needed.[67] A global map of forest restoration opportunity reveals that many of the regions with most potential have high susceptibility to wildfire (see Exhibit 12). Where new forests are planted, and with what species of trees, will have important implications for fire risk, and ultimately the efficacy of carbon sequestration efforts.

EXHIBIT 11: THE GOVERNMENT OF BRITISH COLUMBIA HAS REDUCED PRESCRIBED BURNING AS WILDFIRE ACTIVITY HAS INCREASED



Source: Government of the British Columbia (2018). Addressing the New Normal: 21st Century Disaster Management in British Columbia.

BOX 3: LANDSCAPE MANAGEMENT IN FOCUS – FIRES IN PINE AND EUCALYPTUS PLANTATIONS

Forest plantations supply a growing demand for industries such as pulp and paper, timber, and bio-energy. Economics dictate a preference for fast-growing trees such as eucalyptus and coniferous species. However, the resins in coniferous trees such as pine and the oils in eucalyptus are highly flammable, supporting fast moving wildfires. Eucalyptus trees have actually evolved to propagate fires – dropping flammable leaves, shedding bark, and raising fire to the canopy where burning leaves can project fire hundreds of meters further. While burning, the trees release seeds which then germinate in soils fertilized by fire.

Recent wildfires in Chile occurred in large scale plantations of pine and eucalyptus that had replaced natural forests for the timber, and pulp and paper industries. After a decade long drought, fires near Valpariso and Santiago triggered the evacuation of more than 10,000 people and destroyed thousands of homes in 2014.[68] In 2017, the country's worst fires in history led the government to declare a national emergency after 11 people died and the town of Santa Olga was consumed by fire.[69]

In Portugal too, eucalyptus trees steadily replaced native species during the latter half of the twentieth century to supply the timber, and pulp and paper industries.[70] It is now Portugal's most common tree, covering a quarter of its forested area. But as Portugal has urbanized and people have left rural areas, the eucalyptus forests have become increasingly unmanaged. The majority of trees are owned by elderly smallholders, or by people living in remote cities, who do not manage the accumulation of fuel in their plantations.

As a result, fires have become an increasing problem, compounded by more smallholders switching to fast-growing eucalyptus after each fire in a bid to recover their losses. The worst fire so far occurred in 2017, when a deadly combination of drought, high temperatures, and high winds led to a forest fire that swept through the Pedrógão Grande area in Portugal and claimed 66 lives.

"Where new forests are planted, and with what species of trees, will have important implications for fire risk, and ultimately the efficacy of carbon sequestration efforts."

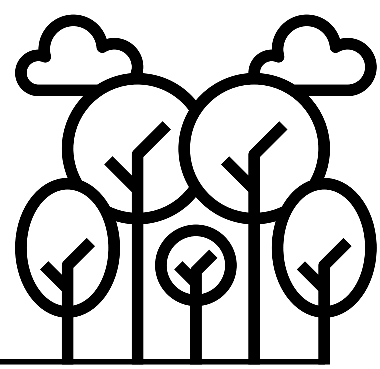
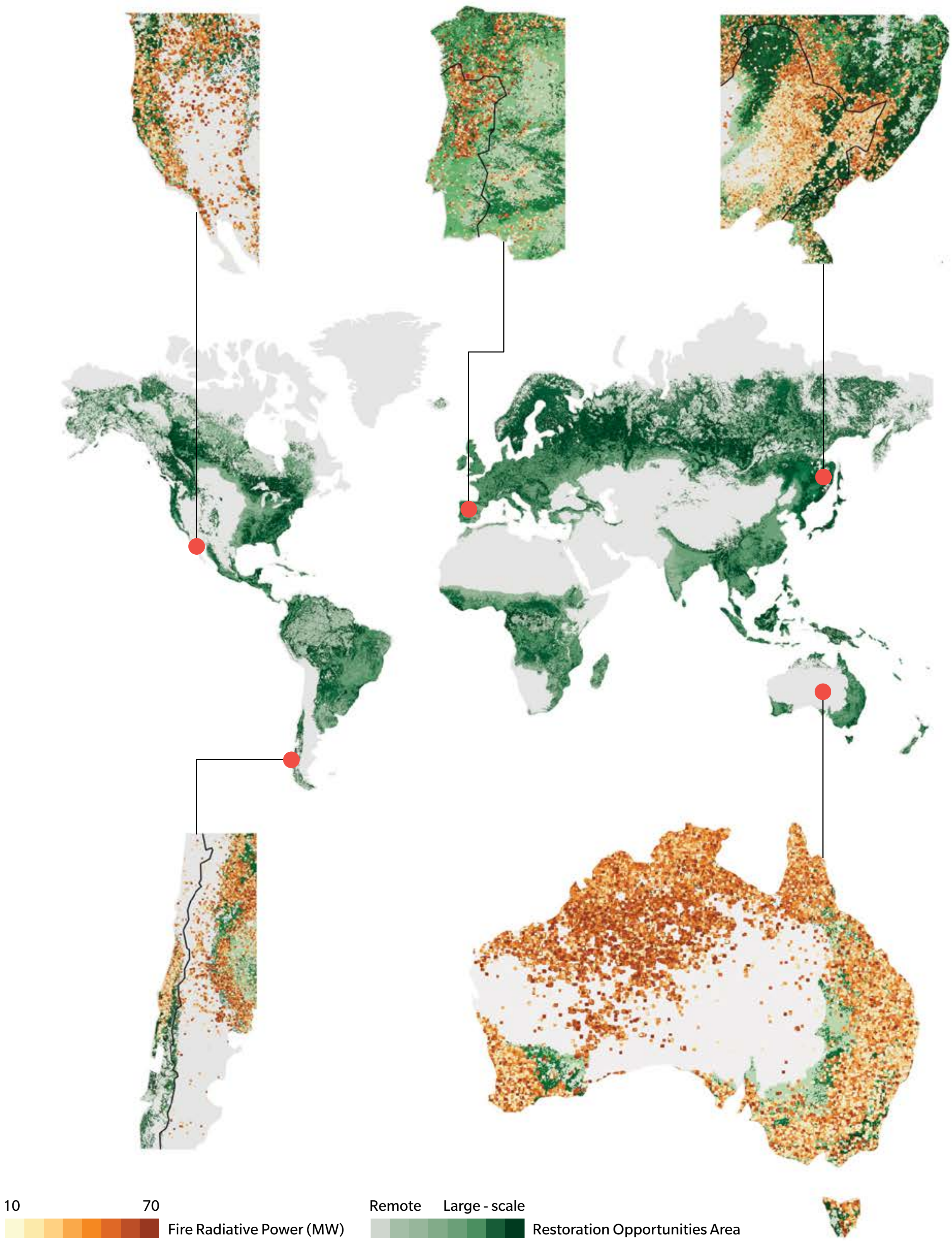


EXHIBIT 12: GLOBAL FOREST RESTORATION OPPORTUNITIES AND 2018 WILDFIRE ACTIVITY FOR SELECTED REGIONS



Source: Marsh & McLennan Insights and datasets from Global Forest Watch and NASA FIRMS

CLIMATE DRIVERS OF WILDFIRE RISK

Climate change is expected to increase wildfire risk through a number of different channels.

HIGHER TEMPERATURES

Climate change is increasing average temperatures around the world and the frequency and severity of heat wave events. A recent review of scientific studies of heat waves revealed that climate change had made the event in question more likely or more severe in 95 percent of cases.[71] Higher temperatures lead to drier fuels that burn more easily, making it easier for fires to catch and spread. Higher temperatures can also lead to more intense fires.[72] For instance, the Black Saturday Fires in Australia, which occurred during record breaking temperatures, released as much energy as 1,500 atomic bombs.[73]

DROUGHT

Climate change may increase the incidence of drought in certain regions. Almost two-thirds of attribution studies examining droughts found climate change to have increased the likelihood or severity.[71] Prolonged drought has preceded recent megafires such as the ones in California (2017 and 2018), Chile (2017), Portugal (2017) and Australia (2009).

SNOWMELT

Climate change is associated with changing seasonal patterns in many parts of the world, in particular the earlier arrival of spring in temperate regions. This means that snow is melting earlier and leaving soils drier for longer, increasing susceptibility to fire. New evidence also indicates that wildfires can increase snowmelt by clearing the forest canopy, exposing more snow to sunshine, and by darkening the snow with ash, causing it to absorb more solar energy. This raises the prospect of a vicious cycle in which earlier snowmelt contributes to more fires, in turn accelerating snowmelt.[74]

LIGHTNING

Climate change is expected to increase lightning activity, leading to more ignitions of wildfires. One study predicted that increasing temperatures mean lightning strikes in the US could increase by 50 percent over the course of the century,[78] and this could increase instances of wildfire ignition.

WIND

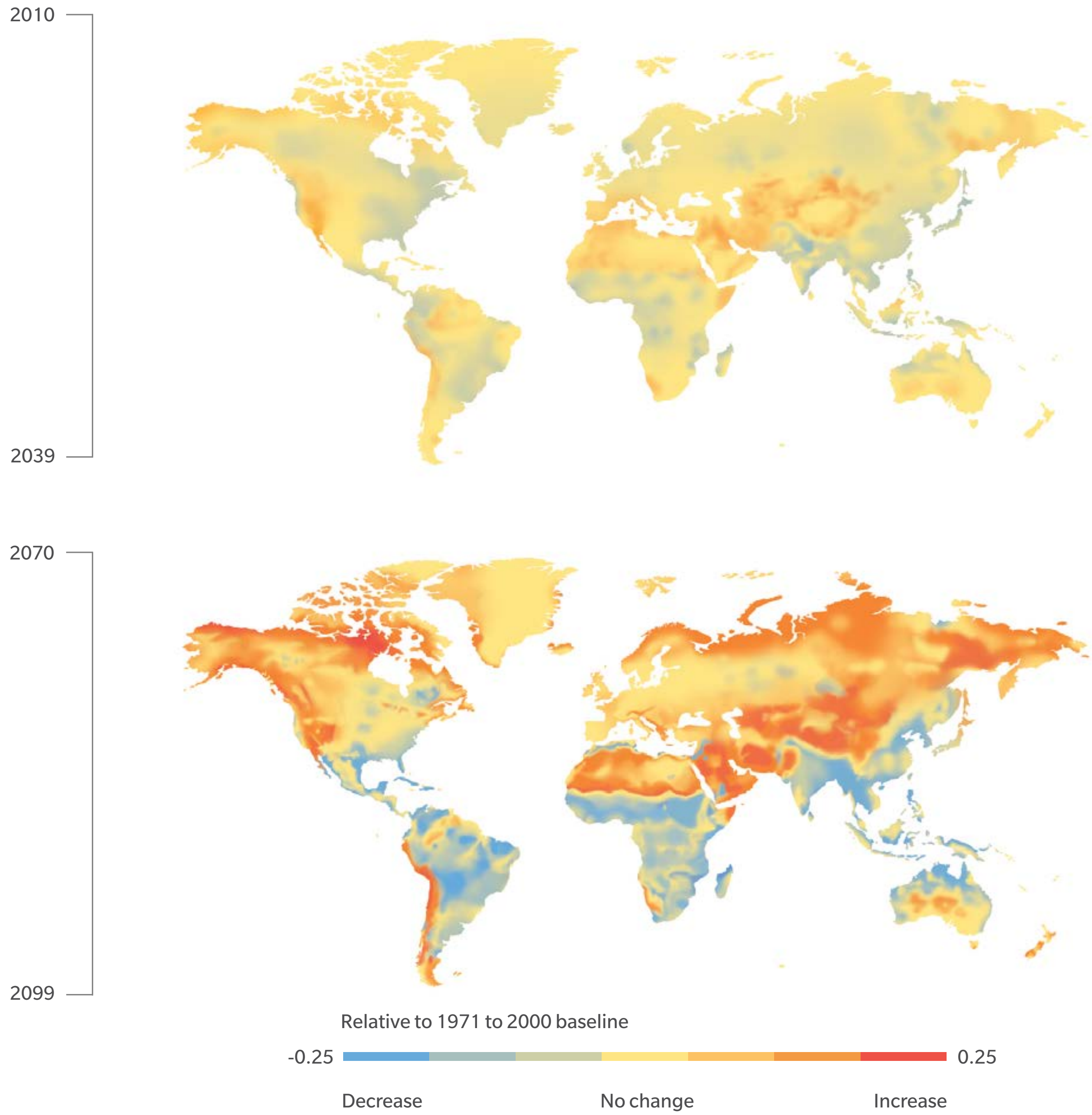
Winds can dry out forests, shrublands and grasslands and spread fire rapidly. The implications of climate change for winds in fire-prone regions are unclear. At the global level, modeling of wind speeds under climate change generates results with considerable regional variation and uncertainty, and most studies have focused on wind power potential rather than wildfire risk. One such study did, however, predict a significant increase in wind speeds for eastern Australia, where wildfire risk is already high.[75]

A 2015 study of California wildfires found that the Santa Ana winds, associated with the most destructive fires, are likely to become more intense with climate change, resulting in a 64 percent increase in the area burned by Santa Ana fires by mid-century relative to a 1981-2000 baseline.[76] A different analysis predicted that the Santa Ana winds may become less frequent by the end of the century, although it did not address the possible impact on fire activity.[77]

PESTS AND DISEASES

Climate change is expected to affect the distribution of pests and diseases, contributing to increased tree death and the accumulation of deadwood in forests, increasing susceptibility to fire. It is also thought to have facilitated the spread of bark beetles throughout North America and contributed to a sustained explosion in their numbers as warmer winters result in reduced larvae die-off. Higher temperatures and drought are also stressing trees, making them more susceptible to infestations. The result has been catastrophic tree mortality over wide areas of forest. Beetles have devastated 22 mega hectares of US forest (an area the size of Utah) since 2000, and 17 mega hectares of forest in British Columbia, Canada.[79] Climate change is also thought to have contributed to a serious bark beetle outbreak in Central Europe's conifer forests.[80]

EXHIBIT 13: EXPECTED CHANGE IN WILDFIRE PROBABILITY UNDER CLIMATE CHANGE

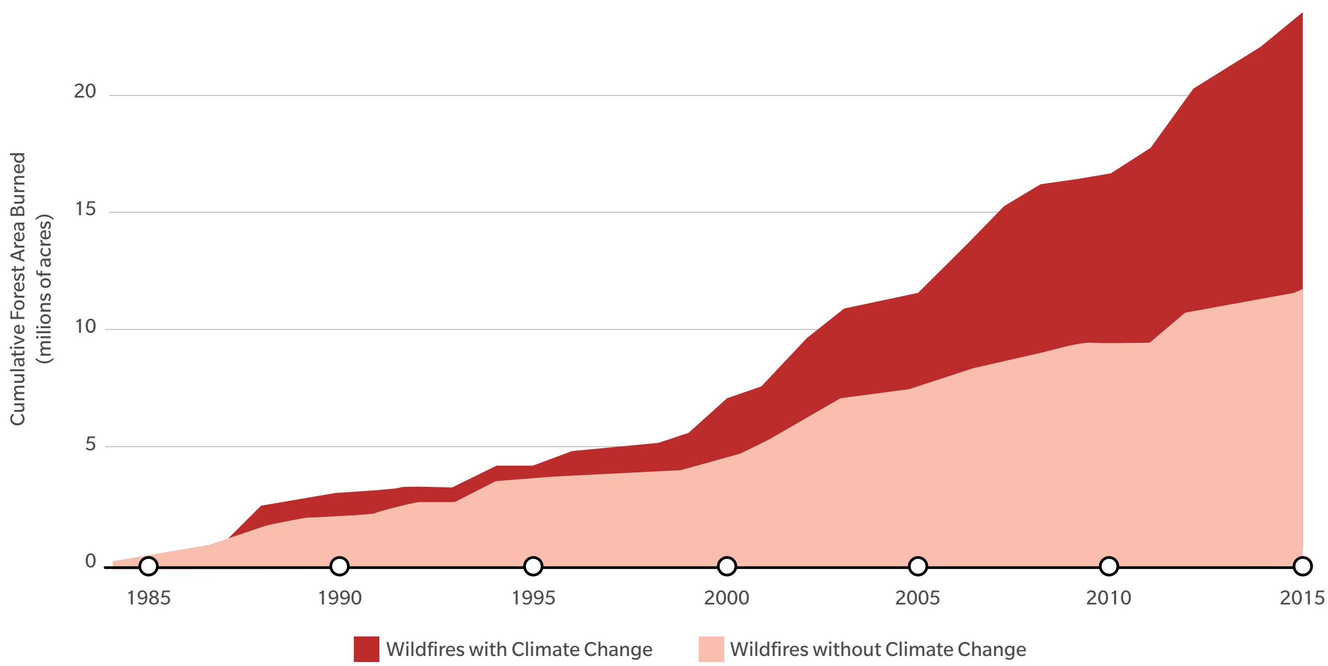


Source: Moritz et al. (2012)

In sum, there is widespread scientific consensus that climate change will increase wildfire risk in many regions of the world.[81] One study, using an ensemble of climate models, predicted increases in fire probability across 37.8 percent of global land area for the 2010-2039 period – rising to 61.9 percent by the end of the century. Regions with increasing probability were concentrated in the mid to high latitudes, including many of today's fire prone areas. Conversely, many tropical regions are expected to experience a reduction in risk (see Exhibit 13).[82]

Many forecasts of the impact of climate change on wildfire risk take a long-term view, but a growing body of evidence indicates it is already having a discernible impact in certain regions. Climate change is thought to have lengthened fire seasons (the period each year during which wildfires occur) across

EXHIBIT 14: EFFECT OF CLIMATE CHANGE ON CUMULATIVE FOREST AREA BURNED IN WESTERN US FROM 1985 TO 2015



Source: Abatzolgou and Williams (2016)

a quarter of the world's vegetated land surface, resulting in an 18.7 percent increase in global mean fire season duration since 1979.[83] The latest US National Climate Change Assessment cited research which found that climate change had almost doubled the area of forests burned in western US between 1985 and 2015 (see Exhibit 14).

COST IMPLICATIONS OF CLIMATE CHANGE

In certain adversely affected regions, climate change is expected to increase the area burned (see next section and Exhibit 14), but it may also lead to more severe megafires that are even more damaging, have higher suppression costs per hectare, and are more likely to overwhelm firefighting capabilities.[84, 85] In such instances, there may be diminishing returns from fire suppression. Modeling of forest fires under climate change in Ontario found that it would require a doubling of resources to deal with a comparably modest 15 percent increase in fire load.[86] These dynamics will present a challenge for governments already struggling to contain fire expenditures, particularly in areas of continued urban sprawl and increasing exposure. Ultimately, spiraling suppression costs and increasingly unsuccessful attempts to contain large fires may force a fundamental change in approach to wildfire management – away from suppression and towards accommodation.

The cost of wildfires is far greater than suppression expenditures. Analysis of data in the US, for example, suggests that total wildfire costs, including economic, social, and environmental damages, are 10 to 50 times greater than suppression costs.[84] Forecasting global wildfire costs under climate change is extremely difficult, due to a lack of data on wildfire losses for many countries, differences in fire regimes and exposure, and the challenge of forecasting how these are likely to evolve. One estimate for the US found that total wildfire costs could increase from an average of around $45 billion a year to $67.5 billion by 2050 due to climate change alone.[84] In reality, the increase will be significantly more if exposure at the WUI continues to increase on current trends.

WILDFIRE RISK OUTLOOK

Climate change is expected to increase wildfire activity in regions where risk is already high: southern Canada, western US, southern Europe, and southern Australia. However, different patterns of urban expansion and climate change are unfolding all around the world, leading to fast-changing exposures and potentially rapid shifts in fire regimes. While it is relatively straightforward to predict the continuation of well-documented trends in high-risk areas, it is harder to anticipate where new hotspots will emerge. There will be surprises.

This section highlights regions of future wildfire risk. It identifies areas with a 'Negative Outlook', which are characterized by high levels of current risk and well-established trends in underlying climate and exposure drivers. There is high confidence that these regions will face greater wildfire risk in the coming decades. The section also marks areas under 'Watch', where there is lower confidence in the extent of future risk but where climate and/or exposure trends provide cause for concern and where there may be early indications of deteriorating risk.

OUTLOOK: NEGATIVE

OVERVIEW

WESTERN US

The highest risk region in the world due to high levels of exposure at the WUI, high levels of accumulated fuel, and climate change. California is the epicenter of US fire risk – the 10 most costly wildfires in US history have all occurred there.

SOUTHERN CANADA

Wildfires burn 2.5 mega hectares in an average year, although recent years have seen considerably larger burn areas. A small number of large fires are responsible for nearly all the area burned. Fires are often in remote areas, but may threaten forestry and extractive industries, and cause serious air pollution for nearby urban populations.

CURRENT SITUATION

WESTERN US

EXPOSURE The WUI has expanded by 60 percent since 1970. California now has 4.5 million homes in the WUI. Since 2000, 35 percent of California's burned area has been within the WUI. The share is 30 percent for Colorado and 24 percent for Washington state.[87]

FIRE ACTIVITY Western US is experiencing increased burned area driven by increasing numbers of megafires. Large fires are almost seven times more frequent than they were three decades ago, driving an increase in area burned by large fires of 1,200 percent. The fire season has lengthened by almost three months since the 1970s.[88] Additionally, climate change is estimated to have doubled the area burned since the 1980s.[89]

EXPENDITURES Western state suppression expenditures have increased by more than 5 percent a year over the last decade, approaching $2 billion.[90] This is in addition to federal expenditures on fire suppression, which in 2018 exceeded $630 million for California alone.

SOUTHERN CANADA

EXPOSURE Canada has pronounced urban sprawl, with population growth in peri-urban areas outstripping that in urban centers. The WUI covers 32.3 mega hectares, with additional infrastructure and industry interfaces covering 10.5 mega hectares and 109.8 mega hectares respectively. The total wildland interface amounts to more than one-fifth of the wildland fuel area. The majority of this exposure is concentrated in the south, in Quebec, Alberta, Ontario, and British Columbia – which between them account for 80 percent of fire management expenditures.[92] These provinces are also experiencing some of the highest rates of population growth and urban expansion.

FIRE ACTIVITY Area burned is increasing, along with the number of large fires and the size of the largest fires. Annual area burned has tripled since the middle of the last century, since when the number of large fires has increased by three fires per year and the largest fires (95th percentile) have increased in size by 57 percent. The fire season has lengthened by over two weeks[92]

EXPENDITURES Fire management costs fluctuate between C$500 million and C$1 billion a year, and have been rising at a rate of around C$120 million a decade.

WORST YEAR

WESTERN US

2018 Following the previous record set in 2017, California's 2018 fires caused $24 billion of damages and killed over 100 people.

SOUTHERN CANADA

2016 The Fort McMurray fire was the costliest disaster in Canadian history, resulting in almost C$10 billion of losses.

OUTLOOK

WESTERN US

EXPOSURE WUI expansion is expected to continue due to high levels of undeveloped, privately held land in the WUI, population growth in western states, and rising housing costs.

FIRE ACTIVITY Climate change is expected to increase fire activity significantly. By 2039, it is forecast to have more than doubled the area burned in California's Sierra Nevada, and parts of Oregon and Washington, and to have more than quintupled area burned in parts of Montana, Colorado, New Mexico, and Arizona.[91]

SOUTHERN CANADA

EXPOSURE WUI expansion is expected to continue due to population growth and high urban living costs although policies to increase urban density may slow the rate of growth.

FIRE ACTIVITY Climate change is expected to increase fire activity significantly. Area burned is forecast to increase by two to four times by the end of the century according to different studies. Fire frequency is expected to double by the end of the century and triple for large fires.[93]

	SOUTHERN EUROPE	SOUTHERN AUSTRALIA
OVERVIEW	The Mediterranean region accounts for around 85 percent of burned area in Europe due to severe fire weather in combination with problems of land abandonment, flammable tree species, and encroachment of shrubland on peri-urban areas. Annual burned area typically fluctuates between 0.3 and 0.7 mega hectares.	Although wildfire activity is pervasive across the vegetated areas of Australia, risk is most severe in southern areas where extreme fire weather and dry fuels can create catastrophic fires.
CURRENT SITUATION	**EXPOSURE** Europe has high population density, and wildfires are estimated to have killed over 700 people since 2000. Significant WUI exposures are found near the coast and in tourist areas. Economic losses average around €3 billion a year. **FIRE ACTIVITY** With the exception of Portugal, the area burned in Mediterranean countries has been decreasing since the 1980s. However, large megafires have become more common. **EXPENDITURES** Greece, France, Italy, Portugal, and Spain together spend €2.5 billion a year on fire management, with most of the budget consumed by detection and suppression costs.	**EXPOSURE** The state of Victoria accounts for around half of Australian bushfire related economic losses and two-thirds of fatalities. Melbourne's WUI is among the most vulnerable interfaces in the world and continues to encroach into surrounding bushland.[98] Sydney's peripheries also present high exposure to bushfires and continue to sprawl outward. **FIRE ACTIVITY** There has been a significant increase in the number of extreme fire weather days, particularly in Victoria and New South Wales, and a lengthening of the fire season.[99] Bushfire frequencies (for Australia as a whole) have increased by 40 percent in 5 years.[100]
WORST YEAR	**2017** Wildfires in Portugal, Spain, and Italy burned 800,000 hectares, killed 115 people and drove the total cost of European wildfires towards €10 billion.	**2007** The Black Saturday Fires in Victoria burned 450,000 hectares, claimed 173 lives, destroyed over 2,000 homes, and caused A$4.4 billion of economic losses..
OUTLOOK	**EXPOSURE** Southern Europe is expected to have low population growth and urbanization compared to other regions of the world, although notable areas of urban expansion are expected in Portugal, Spain, Italy, and France.[94] In some areas, continued shrubland encroachment may be more of a problem than urban expansion. **FIRE ACTIVITY** Climate change is expected to increase wildfire activity in the Mediterranean region. Models indicate increases in area burned of 100 percent by the end of the century.[95, 96, 97] Modest warming of 1.5˚C, which could be reached sometime after 2030 if temperatures continue on current trends, could lead to a 40 percent increase in area burned.	**EXPOSURE** The population of New South Wales is expected to increase from 7.7 million to 9.9 million over the next 20 years; Victoria's population could grow from 6 million to 10 million by mid-century. Owing to this, bushfire related economic costs in Victoria could more than double, to A$378 million per year.[98] **FIRE ACTIVITY** Southern and eastern Australia could see the number of days of severe fire weather each year increase by 160-190 percent by the end of the century if climate change remains unchecked.[99] Fire danger, measured in terms of the McArthur Forest Fire Danger Index (FFDI) is forecast to increase significantly. Instead of occurring once every few decades, if at all, a 'catastrophic' FFDI score in excess of 100 (it reached 155 on Black Saturday) may occur every few years by the middle of the century.[101]

OUTLOOK: WATCH

SOUTHEASTERN US

Approximately 400,000 hectares are burned each year in the southeastern US. The risk of catastrophic fire is lower than in western US, however, disasters do happen. In 2016, 14 people were killed in an outbreak of fires throughout Tennessee, Georgia, and North Carolina. In 1998, fires in Florida burned 200,000 hectares, forced evacuations in a number of counties and caused at least $600 million of damages.

The southeast has some of the largest WUI areas in the US, with high populations and many homes located in the WUI. Growth in WUI extent, population, and housing is high compared to other regions.[102]

Climate change is forecast to increase fire risk. The potential for very large fires (greater than 5,000 ha) may increase by 300-400 percent by mid-century.[103]

Increasing area burned due to climate change may be offset by continued urban expansion leading to deforestation and the creation of fuel breaks. Future risk will therefore be shaped by complex patterns of land-use change and urban expansion, resulting in uncertain impacts on fire activity that are likely to vary significantly by state. Forecasts include significant increases in area burned for Florida (16 percent) and Louisiana (30 percent) by mid-century, and reductions for Arkansas, Kentucky, and Tennessee.[104]

A key uncertainty is the extent of future forest cover. Current projections of burned area are lower because they assume that urban sprawl reduces forest cover. But should climate change imperatives limit deforestation in the region, or even promote reforestation (the southeastern US has high reforestation potential, see Exhibit 12) then fire risk could turn out to be much higher.

NORTHEASTERN US

The New Jersey pinelands cover almost 500,000 hectares in flammable pine and are home to half a million people. A recent state risk assessment compared the pinelands to “an inch of gasoline covering all of south and central New Jersey”. Another expert compared it to “the biotic equivalent of a munitions depot”.

Fires break out regularly in the region, but all recent events have been contained. In 1963, fires broke out between Long Beach and Atlantic City, killing seven people and destroying 400 buildings. Since then, fuel loads have increased and the population has more than tripled.[105] According to Stephen Pyne, professor of fire ecology at Arizona State University, “Sooner or later, southern New Jersey will know the fire equivalent of Hurricane Sandy. The cost could be in the billions. The loss of life could be unthinkable.”[106]

Climate change is expected to increase the risk of wildfire in New Jersey, with the potential for very large fires increasing by 300-400 percent by mid-century.[103]

WESTERN SOUTH AMERICA

Recent events in Chile raise serious concerns about the outlook for wildfire risk in the region. A prolonged drought and devastating wildfires in 2014 and 2017 highlighted the vulnerability of the country’s extensive eucalyptus and pine forests to severe fire (see Box 3).

Climate change is expected to result in higher temperatures and reduced rainfall in the region, resulting in hotter, dryer conditions that are more conducive to fire. Wildfire models predict a marked increase in fire probability along the western coast within the next two decades. (see Exhibit 12).

EASTERN EUROPE

Models predict that Eastern Europe may emerge as a new center of wildfire activity, with significant increases in burned area.[107]

CENTRAL ASIA

Models expect climate change to result in a pronounced increase in fire activity in the central Asian steppes.[108]
These areas have low population exposure. However, urban expansion is expected in regions of Kyrgyzstan, Tajikistan, and Uzbekistan (Seto et al. 2012).

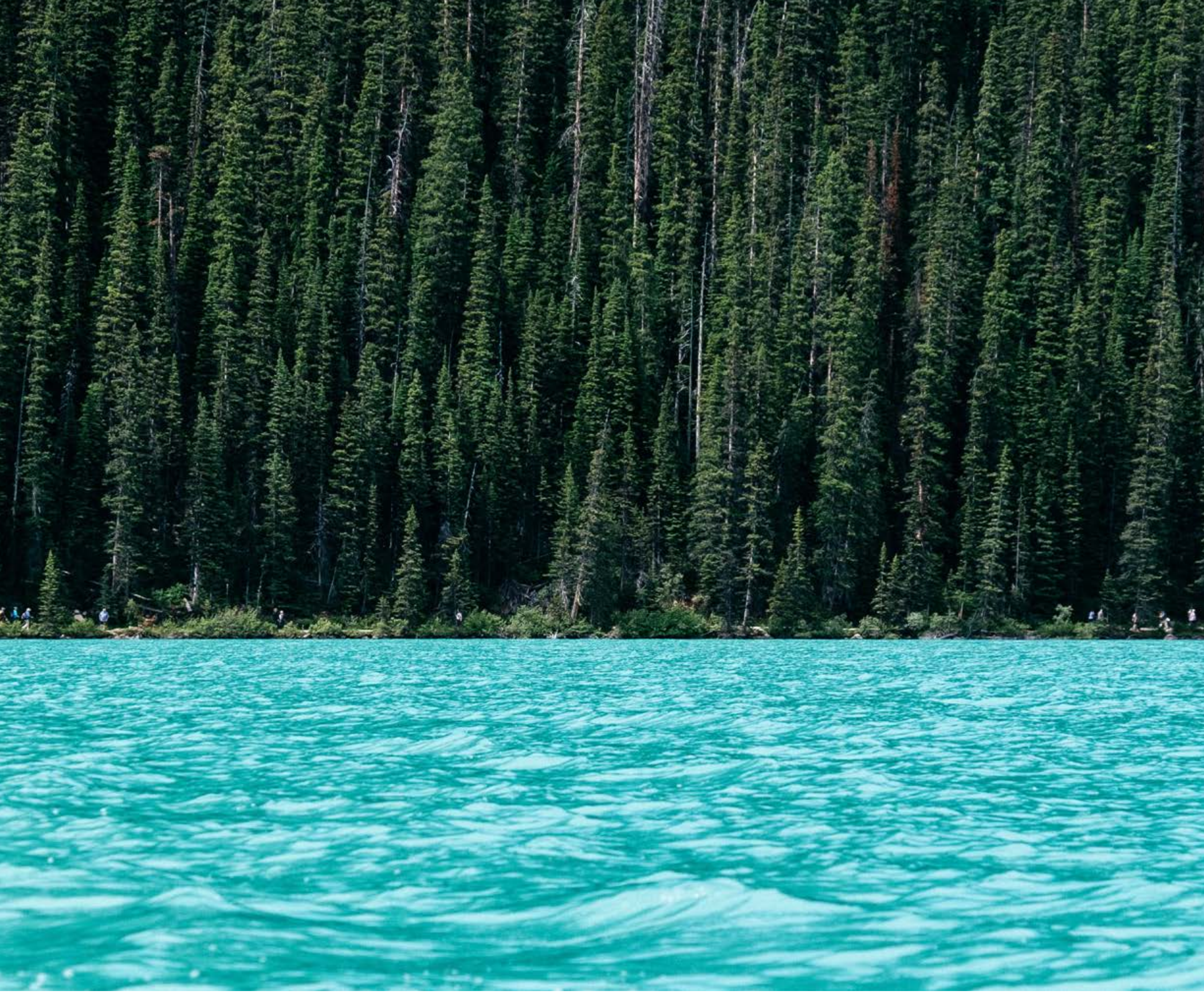
CHINA

China's most severe wildfires tend to occur in the mountainous northeast and southwest regions. In 2019, a wildfire in a remote area of Sichuan province killed 31 firefighters, for example. In 1987, China experienced the largest wildfire ever recorded. The Black Dragon Forest Fire burned through over 7 mega hectares of forest into Russia.

In a country as large as China, climate change's impact on fire regimes is likely to vary by region. Some models predict an increase in fire probability in the west (see Exhibit 13), while another analysis predicts increases in burned area in the south after allowing for the influence of urbanization on patterns of fire activity.[106]

China's future fire risk will depend upon the extent to which large fires remain remote, or start to collide with human populations as a result of urban sprawl or possibly reforestation efforts. The country is expected to see some of the largest areas of urban expansion in the world in the coming decades, particularly in the east.[109]

China is currently pursuing the most aggressive afforestation program in the world. Between 1990 and 2015, more than 35 billion trees were planted as part of a scheme to combat desertification. It now has almost 80 mega hectares of planted forest. However, this is based on monoculture plantations—many of which are reported to be flammable eucalyptus, pine, and bamboo—raising concerns about the resilience of new forests to wildfire under climate change.



MANAGING WILDFIRE RISK

Wildfire risk is set to increase in many regions of the world, as populations continue to spread into wildland areas—increasing both exposure and ignitions—and as climate change increases fire activity. Risk management will need to be tailored to the landscape and type of fuels and the prevailing climatological characteristics. However, the experiences of countries already dealing with serious wildfires offer some valuable lessons.

TAKE A RISK-BASED APPROACH TO MANAGING WILDFIRES

Wildfires may be an inescapable feature of certain landscapes. Nevertheless, these landscapes can still be managed to reduce the risks to people and property, and mitigate the risk of the most destructive megafires.

REDUCED SUPPRESSION AND MORE PRESCRIBED BURNING

Aggressive suppression of wildfires in landscapes where they are a natural feature can lead to the accumulation of fuel and greater risk of megafires. In regions where climate change increases the likelihood of large, intense fires, suppression may become increasingly uneconomic and ineffective. Prescribed burning allows fire that is ultimately unavoidable to occur under controlled conditions in favorable weather. Although it is not risk free, prescribed burning has been used effectively in a range of regions and fuel types, in southeast US, Europe, and Australia for example.

Authorities should also consider a more opportunistic approach to wildfires, using naturally occurring fires as a means to reduce fuel loads, thereby reducing suppression costs and the need for prescribed burns. The deteriorating economics of suppression may eventually leave governments with little choice in any case, but money and lives can be saved by an early escape from the 'firefighting trap'.

New technologies should improve the efficacy and reduce the risk of prescribed and opportunistic burns in the future. Advanced modeling and remote sensing technologies are already being used to help fire services identify the optimal conditions for prescribed burns and anticipate how fires are likely to spread.[110] These capabilities can also help identify fires that can be left to run their course, and those that may develop to pose a risk to people and property.

FORESTRY

The area devoted to forests will need to increase in the future if climate objectives are to be met. Large scale afforestation and reforestation are needed for carbon sequestration purposes. At the same time, demand for forest products may increase significantly – for example, if wood comes to be widely used as a substitute for high carbon construction materials such as steel and concrete. But in a warmer future with more fire weather, care must be taken to not repeat the mistakes of the past.

Monoculture plantations of fast-growing trees such as pine and eucalyptus may provide the greatest yields, but they are highly flammable and are unlikely to be resilient to fire in a future of higher temperatures, increased drought risk and more severe fire weather. In many contexts, it may be most advisable to restore original forests, which are naturally resilient to local fire regimes.

In a future of greater wildfire risk, forestry practices will need to place greater emphasis on developing and maintaining fire resilient forest structures.[111] Where harvesting is necessary, this should build or maintain resilience to fire – for example, by removing dangerous fuel loads while retaining more resilient, older trees.

BREAK OUT OF THE FIREFIGHTING TRAP

In certain regions, the twin trends of climate change and expansion of the WUI create the prospect of a budgetary death spiral for governments caught in the trap of escalating suppression costs and declining investment in fire prevention. The warning signs in countries such as the US, Canada, and Portugal are already apparent. Breaking out of the 'firefighting trap' requires governments to find an accommodation with wildfire in which more fires are allowed to run their course (see section on REDUCED SUPPRESSION AND MORE PRESCRIBED BURNING); it will also require sufficient, ring-fenced funds for mitigation activities such as prescribed burns and community resilience measures.

NEW REVENUES FOR MITIGATION

Governments should explore new revenue opportunities to finance mitigation. Options can include:

- A charge or fee for homeowners in high-risk areas. Until recently, California charged property owners $152.33 a year per habitable property in areas where the state is responsible for wildfire prevention and suppression. A more equitable and risk-based approach would vary the charge according to a map of fire risk and property value.
- Budgetary contributions from companies operating in high-risk areas that receive an implicit subsidy from publicly funded mitigation. These might include utilities, forestry companies, and extractive companies. In Canada, British Columbia's 2004 Wildfire Act introduced a cost-sharing program that saw commercial 'clients' of the state's fire mitigation activities contribute almost a quarter of the fire budget.

COST SMOOTHING

Governments can also explore solutions to smooth fire suppression costs, making suppression spending more predictable thus making it easier to manage budgets so as to plan mitigation spending. For example, a government could self-insure by establishing a fund to cover (a portion of) suppression costs. Contributions to the fund could come from the government or from a broader base of 'clients' such as corporates and homeowners in high-risk areas.

Alternatively, governments can use insurance as an alternative tool to smooth the costs of fire suppression (see section on LEVERAGE RISK TRANSFER).

INNOVATIVE FINANCING

Investment in wildfire mitigation could potentially be financed using debt, either on a pay-for-performance basis or possibly using a resilience financing structure in which financing costs are paid through a reduction in insurance premiums.

There is already an example of a pay-for-performance approach in the western US, where the Forest Resilience Bond has mobilized public and private investment in forest restoration activities. It includes a component in which private beneficiaries—in the first case, a water company—repay capital based on predefined performance indicators (such as increased water volumes). Such an approach could be scaled to mobilize funding for wildfire-mitigating forest restoration from a range of beneficiaries including local communities, forestry companies, and electricity utilities.

A resilience financing structure would work on a similar basis. Assuming the wildfire risk reduction associated with a mitigation investment can be quantified, it can be linked to a reduction in insurance premium which repays the initial investment. Investments might include forest restoration projects, prescribed burns, the introduction of fuel breaks,[112] and community projects such as home retrofits, or all of the above. The first step is to develop robust models that are able to quantify wildfire risk reduction arising from different mitigation investments.

DEVELOP A RISK REDUCTION STRATEGY

Models to quantify the costs and benefits of different mitigation actions are needed more generally, to evaluate different investment cases and ultimately build the case for allocating more resources to mitigation. This should help inform a strategy for where and how mitigation investments can most efficiently reduce risk. Governments should undertake regular reviews of wildfire risk, identify how key drivers are evolving and where risks are increasing. These studies should inform the development of risk mitigation strategies that target investments to build resilience in vulnerable areas and tackle risk drivers.

BUILD RESILIENT COMMUNITIES

The WUI is increasing across the world. And as such, urban development in fire-prone areas must follow simple rules to reduce vulnerability to fire.

BUILDING CODES

A building's susceptibility to fire depends to a large extent on its materials. Flammable roofing and wall-sidings, such as those made from wood shingles, can quickly catch fire when they come into contact with burning embers. In fire-prone areas, building codes should stipulate the use of fire-resistant materials.

Governments could undertake inspections in high-risk areas and offer low-interest loans to support homeowners with necessary retrofits.

HOMEOWNER RESPONSIBILITIES

It is not only the materials from which a home is built that determine its vulnerability to fire. Maintenance of the property and immediate surroundings is also critical. Roofs, decks, and gutters need to be kept clear of flammable leaves and pine needles; yards and gardens should not contain flammable vegetation too close to houses, creating a defensible space around the structure.

Education programs can help homeowners maintain safe properties, but information and awareness do not always lead to risk reducing behaviors, and in densely populated areas the failure of one homeowner to take proper precautions may put the entire community at risk. Education programs may therefore be best combined with behavioral nudges which encourage homeowners to act on the information they receive. Examples include writing to homeowners to provide them with details of their neighbors' efforts at mitigation, or information on the resilience of their property compared to those in the vicinity.

ZONING AND BUILDING RESTRICTIONS

The simplest and most effective way to avoid wildfires is to avoid building in high-risk areas in the first place. Increasingly sophisticated risk maps of fire-prone regions make it possible for developers to avoid the most hazardous areas. Yet, all too often development takes place regardless, and sometimes even on recently burned land. Reconstruction of the town of Paradise, razed to the ground by the Camp Fire in 2018, began within a few months of the last embers dying. Incredibly, most Californian burn sites contain more buildings five years after fire than they did before.[113]

The short-term political and economic pressures to rebuild quickly after a catastrophic fire are understandable. However, local authorities have a duty of care and responsibility towards the communities they govern, which is hard to reconcile with issuing construction permits in places likely to catch fire. If authorities are unwilling to refuse development in high-risk areas, then they should mandate the purchase of market-priced insurance that fully reflects risk (see section on LEVERAGE RISK TRANSFER).

URBAN PLANNING

If development is to occur in high-risk areas, then thought should be given to the layout of buildings, roads, and other infrastructure, ensuring appropriate spacing between buildings and the creation of nearby fuel breaks. Moreover, there should be sufficient road access to ensure fast and safe evacuation of communities. This is a particular concern in areas of the US WUI, where the road network has not expanded at the same rate as housing density.

GET THE INCENTIVES RIGHT

A range of different government interventions may cloud homeowners' judgment about fire risks, subvert risk reducing behaviors, and discourage the purchase of insurance. For example:

- People living in fire-prone areas may benefit from a sizable subsidy in the form of publicly funded fire prevention and suppression activities to protect their properties. And while it is undoubtedly a part of the government's role to protect its population from harm, the net result may be to encourage development in fire-prone areas by shielding homeowners from the true cost of fire protection.
- Governments may provide subsidized insurance in high-risk areas or intervene to suppress market premiums. This creates moral hazard as homeowners are not incentivized to reduce risk on their properties and can access insurance that does not reflect the risks of building in a high-risk area.

These two examples illustrate how well-meaning government interventions can lead to perverse incentives that increase risks. Ultimately, market-based insurance that reflects the risk of fire and rewards risk reducing behaviors on the part of the homeowner and the wider community will create the correct incentives.[114] Government interventions that crowd out private insurers or limit their ability to charge the full cost of risk are likely to promote further expansion at the WUI and undermine efforts to build resilience among the communities already there.

LEVERAGE RISK TRANSFER

In a future of increasing wildfire risk, governments and businesses may need to use a range of risk transfer solutions to manage different layers of risk.

CONVENTIONAL INSURANCE

The case for increased penetration of private insurance among homeowners in the WUI is made in the earlier section on incentives (Get the incentives right). Insurance can also be used by governments to smooth suppression costs. For example, the state of Oregon in the US takes out insurance which pays out above a certain level of emergency fire costs.

Power utilities operating in fire-prone areas can use insurance to reduce the liability risks they face (see Box 1). For example, Sp Ausnet used liability insurance to recoup costs after settling with victims of the Black Saturday Fires, as did the Californian utility SDG&E when agreeing a $2.4 billion liability settlement after wildfires in 2007.[115]

The cost of insurance will, however, increase where wildfires become more frequent and destructive and/or where urban sprawl increases exposure in fire-prone areas. The cost of Oregon's insurance increased significantly after large payouts in 2013 and 2014, and Californian utilities struggled to purchase liability cover in the wake of the 2018 wildfires.

CAT BONDS

Diversified global capital markets are better placed than governments to carry the risks of location-specific natural catastrophes. In 2018, the US Federal Emergency Management Agency (FEMA) issued a $500 million CAT bond to transfer risk from the National Flood Insurance Program, followed by a second $300 million transfer in 2019.[116] CAT bonds can also be used to transfer wildfire risk (wildfire specific CAT bonds have been issued by the Californian utilities PG&E and SDG&E) and can be issued by sub-national governments as well as national governments. The possibility therefore exists for governments carrying significant wildfire risk to use CAT bonds to transfer a portion to the capital markets, although investor interest in Californian wildfire risk is currently low following the fires of 2018.

PARAMETRIC INSURANCE

Parametric insurance products—where the payout is triggered based on a pre-defined parameter being met or exceeded—have become increasingly common as a way to transfer risks arising from natural hazards such as floods, earthquake, storms, and droughts. Their principal advantage is flexibility: because there is no need for loss adjustment, payout is rapid, and the funds can be put to whatever use the policyholder sees fit.

The drawback of parametric insurance is basis risk. Any parameter is likely to be an imperfect proxy for actual loss, so there may be occasions when losses occur without payout because the parametric trigger is not activated. In the past, parametric insurance has been used to cover wildfire risk in the forestry sector, where (timber) losses correspond closely to area burned (the parameter), thus minimizing basis risk.

Recently, however, parametric solutions[117] based on indices of burned area have been extended to a wider set of stakeholders, including local governments, local businesses, and communities. For local governments, where fire suppression costs are probably closely correlated with area burned near population centers, a parametric product can provide early financing for firefighting and recovery efforts. For local businesses, parametric insurance could cover damages to property and costs of business interruption; and for communities, it could provide upfront funding for the costs of evacuation and temporary relocation.

RISK POOLS

Risk pools allow participants to share risks. Insurers have established risk pools in situations where a particular risk is too great for any one underwriter to bear – for example, pooling resources (and exposures) to provide flood insurance for households in areas of high flood risk, as is the case with the UK's Flood Re. Businesses may choose to create a risk pool if insurance is expensive or unavailable. Governments may form risk pools—such as the Caribbean Catastrophe Risk Insurance Facility—to provide collective cover for catastrophic risks, diversifying their risks in the process.

Applying these examples to the case of wildfire suggests the following opportunities:

- Establishing insurance pools to provide cover to households in areas of high wildfire risk. Where climate change increases the area at risk of wildfires, homes and properties that were once considered low-risk will become increasingly hard to insure. Wildfire insurance pools could act as an insurer of last resort for homeowners in these areas and provide information and guidance to help communities reduce risk. California's Fair Access to Insurance Requirements (FAIR) Plan provides an example of such a scheme. It has seen a steady increase in policies for homeowners in risky areas as insurance becomes harder to find.[118, 119] To avoid encouraging development in high-risk areas, cover could be restricted to properties built before a specified date.
- Establishing electrical utility pools in locations of high liability risks. In instances where utilities face significant liability risks that they are unable to transfer to the insurance or capital markets, it may be appropriate to establish a risk pool. The economics of this may be challenging if the participants are co-located, as this is likely to reduce any diversification benefit – a severe fire season in California could have implications for all Californian utilities simultaneously, for example. However, an argument can be made for a quantum of public subsidy on the grounds that a viable economic model for utility companies is essential to ensuring access to electricity among the population. More equitably, payments into the pool could be augmented by additional levies on the electricity rates of households in areas of very high fire risk.
- Establishing inter-government wildfire risk pools. As Exhibit 8 demonstrates, wildfire suppression costs among western US states show a considerable degree of independence, indicating that pooling risks could provide a significant diversification benefit. Western US state governments could establish a pool to provide cover for suppression costs during extreme wildfire years, and possibly transfer risk from the pool to the reinsurance or capital markets. Potentially greater diversification benefits could be achieved by extending participation to southeastern states. A similar model could be explored among Mediterranean countries in Europe, or southern states in Australia.

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ACKNOWLEDGEMENTS

AUTHORS

Rob Bailey
Director, Marsh & McLennan Insights
Rob.Bailey@mmc.com

Jaclyn Yeo
Research Manager, Marsh & McLennan Insights
Jaclyn.Yeo@mmc.com

CONTRIBUTORS

Marsh & McLennan Companies:
Alex Wittenberg, Lucy Nottingham, Wolfram Hedrich,
Erick Gustafson, Jennifer McPhillips, Sydney Hedberg, Clair Olson

Marsh:
Ron Santaniello

Guy Carpenter:
Manuel Chirouze, Mark Hope, Kimberly Roberts, Julian Alovisi

Oliver Wyman:
Jose Lopez, Jared Westheim

NERA:
Lawrence Wu

Mercer:
Alex Bernhardt

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