California Megafires:

Approaches for Risk Compensation and Financial Resiliency Against Extreme Events

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I. Executive Summary

The increasing frequency and severity of wildfires in California is focusing attention on how to prepare for and allocate unexpected and extreme financial burdens on utility customers and shareholders. In 2017, massive wildfires throughout the state resulted in record levels of property destruction and economic damage. The 2018 wildfire season, still underway as of the issuance of this report, has already resulted in the largest fire in the state's recorded history.

This paper evaluates the magnitude of risks from potential liability for the damages these megafires can cause. This is a one-sided, asymmetric risk, involving only downside potential for uncompensated losses—a possibility which significantly erodes investors' expected returns and could impede a California investor-owned utility from pursuing its normal operations effectively. We explain why such risks are not fully measured or quantified in ordinary estimates of the cost of capital but need compensation, and how the cost of equity could be adjusted in order to restore the opportunity to earn a fair return on its utility investments. Specifically, we show that a premium of 500 basis points added to Pacific Gas and Electric Company's ("PG&E") allowed return on equity ("ROE"), equivalent to about $1 billion per year of net income, would be commensurate with the apparent size of the fire problem as it has been manifest over the past few years.

The paper is organized as follows:

First, after an overview (Section II), we describe the growing scale and frequency of wildfires and megafires in California and the damages and costs associated with these fires (Sections III.A and III.B).

Second, we describe California's no-fault inverse condemnation doctrine, and explain how that doctrine is in conflict with the California Public Utilities Commission's ("CPUC") prudency standard (Section III.C).

Third, we explain how the increase in wildfires and megafires, given the disconnect between no-fault inverse condemnation and the CPUC standards, has had significant adverse impacts on the financial risks faced by California's investor-owned utilities, including PG&E (Section III.D).

Fourth, we explain the concept of asymmetric risks for utilities (in Section IV.A, treated in further detail Appendix A) as to how they arise and why they are not adequately measured in the conventional cost of capital. We provide an illustration of how this risk can be addressed through a supplemental premium to an investor-owned utility's ROE (Section IV.B). More specifically, to quantify the ROE supplement PG&E would need for these risks, we use information from its recent Risk Assessment and Mitigation Phase ("RAMP") proceeding at the CPUC, as well as information on fire size, costs and frequency from the insurance industry. These reveal that loss exposure to PG&E of a billion or more dollars per year from fire damages is likely. As a second basis for quantifying the exposure, we use data from catastrophe bonds recently issued by Cal Phoenix Re, a Bermuda exempted company not affiliated with PG&E, to estimate PG&E's cost to insure against large wildfire damage losses. This shows that broadly insuring against this problem (if that were possible) also has a likely annual cost of around $1 billion or more

These complementary approaches to quantification lead us to the conclusion that PG&E's ROE would need to be increased by approximately 500 basis points to offset the significant problems and risks created by wildfires and megafires in California and the conflict between the application of the no-fault inverse condemnation standard with the CPUC's prudent manager standard.

Finally, we explain some of the limitations of using an ROE supplemental allowance to address this risk, and we suggest that other more sustainable solutions may be available.

II. Overview

California's existing precedent for utility liability and cost recovery in connection with wildfires is complex. California legal precedent, under the concept of "inverse condemnation," presumes a no-fault framework whereby such costs are shared by all customers through utility rates. However, the CPUC process of reasonableness review is not a no-fault framework. Instead, the process can result in disallowing some costs from recovery in rates, creating material potential financial exposure for the affected utilities, without clear guidelines or standards for when and to what extent such liability can occur.

Third-party estimates of PG&E's gross liabilities for the 2017 megafires are on the order of $10 billion or more. In the context of potential claims, and recognizing an almost 10-year long proceeding ending with the CPUC's decision adverse to San Diego Gas & Electric Company ("SDG&E") on its 2007 fire liabilities, PG&E's stock price dropped and its bond ratings were downgraded. Recent legislation enacted in California, Senate Bill 901, attempts to address some of the wildfire-related cost and risk issues for electric utilities. However, the bill does not attempt to change inverse condemnation law or resolve the significant regulatory uncertainty related to wildfire risk. While it remains to be seen how or whether regulators will improve policies for this risk in the long run, the state's currently unresolved approach leaves a very large and poorly defined risk on utility shareholders.

Utilities undoubtedly have an important role to play in fire-risk mitigation and recovery. But this role needs to be carefully cast in terms of clearly defined *a priori* responsibilities. The utilities' role must also be defined by compliance incentives and penalties that target a socially desirable and cost-effective level of prevention and insurance. PG&E has initiated such a risk assessment program—which it presented in its November 2017 RAMP filing with the CPUC—based on statistical and economic principles. We understand that PG&E is continuously refining its risk assessment program to address the intrinsic risk of wildfires in California. However, even with very sophisticated and perfectly applied risk planning and management, wildfires are simply too difficult to prevent, predict, or control.

The regulatory and financial environment in which utilities must now prepare for the potentially extreme costs of megafires is neither sustainable nor efficient. One improvement to the status quo would be to compensate utilities for the risks from potentially disallowed recovery costs, which now falls on shareholders without compensation. This need for a new form of compensation arises because some fire damage risks are wholly different from normal utility business risks and are largely not reflected in the cost of capital nor fully covered in any other kind of anticipatory funding mechanism remotely commensurate with the scale of recent megafire disasters. Fire damage risks are an acute example of "asymmetric risk"—that is, risks of the utility facing potential obligations to pay for extreme losses in the event of adverse circumstances, but with no offsetting opportunity for gains in times when such risks do not materialize. If such risks are not either compensated or offset with other mitigation, they are a *per se* impairment of the utility's ability to recover its costs and to expect to earn a fair return on its invested capital.

One way to immediately address this asymmetric risk would be by increasing the conventionally derived regulated ROE by an amount that reflects the increased costs and risks. The ROE method is not ideal for the long-run, and other ways to address this risk allocation problem may ultimately be reached by future legislation. But, at present an ROE premium allowance may be the best available means of preserving the financial health of the company and of giving it an improved chance of earning its cost of capital. We show herein, based on our compilation of realized costs of several recent megafires and on evidence from the costs of catastrophe bonds, that the annualized cost to PG&E from this problem is on the order of $1 billion or more. The $1 billion figure is equivalent to about 500 basis points as an increment to PG&E's cost of equity applied to its total equity rate base. We caution that there are multiple challenges to applying this ROE approach, not least that there are considerable estimation difficulties of the appropriate amount (given the recent growth in frequency and severity of fires) which make it possible that even a large premium only partly addresses the problem. At the same time, an allowance may create the incorrect impression in the eyes of the public and regulators that the utilities have been fully compensated for this risk, and that they are consequently fully insulated them pass-through of damage costs from all potential megafire catastrophes. Ultimately, megafire risk needs a comprehensive and sustainable solution that is broader than the current inverse condemnation framework supports.

The purpose of this paper is to highlight issues regarding the current regulatory and legal framework for assigning large financial liabilities from megafires to California's regulated investor-owned utilities.[1] We discuss and demonstrate how the prevailing framework that blends inverse condemnation with regulatory approvals and disallowances could be financially (and hence operationally) crippling for the state's investor-owned utilities and, ultimately, counterproductive to the state's ability to recover from destructive and extreme wildfires. We discuss the order of magnitude of the incremental return on equity that would be needed to offset the possible magnitudes of risk. The dramatic scale of those amounts calls for consideration of alternative approaches and mechanisms for financial preparedness and planning for extreme events, drawing from lessons learned and insights from California's past megafires, the insurance industry, and elsewhere in the U.S. electricity industry. However, specific solutions are beyond the scope of this paper.

We use the term "financial resiliency" to refer to the state's ability to recover quickly and sustainably from extreme events costing potentially billions of dollars. Financial resiliency depends on several factors, including how the state allocates those costs to different parties (e.g., individuals versus private companies versus socialized throughout the public), whether costs are incurred in a preventative (*ex ante*, such as through mitigation, purchased insurance, or pre-funding) or reactive (*ex post*, after the actual event costs are known) fashion, how costs must be paid over time (importantly, how broadly they are smoothed over time), and what mechanisms

1 These utilities include PG&E, SDG&E, and Southern California Edison Company ("SCE").

We define **"financial resiliency"** as ability to quickly and sustainably recover from extreme events costing on the order of billions of dollars.

are used to recover any costs that are socialized (e.g., regulated utility rates, amortization of securitized financing, special state agency fees, taxes). The goal of financial resiliency is to support the financial health of the state's utility customers, taxpayers, *and* the regulated utilities that are responsible for maintaining and investing in critical public energy infrastructure.

It is important to note that the risk of extreme resiliency events cannot be eliminated. In fact, there is good reason to believe that risks of megafires are *increasing*, due to both extreme weather-driven events and a growing population. Even with costly, and in some cases long-term, mitigation measures, it is impossible to completely eliminate the risks of fire inherent in providing power to the public.

This paper is intended for high-level discussion about effective means of risk-bearing for extreme events. It is not a rigorous assessment of the likelihood or cost of extreme event risks faced by the utilities, their customers, or other parties in the state. The perceived likelihood or potential consequences of extreme fire risk and decisions about how to best manage that risk depend on judgments about an unknown future, and on subjective risk preferences and tolerances of the affected parties about how to prioritize those risks compared to others.

III. The Growing Need for Financial Resiliency Against Extreme Events

Recent "megafires" striking California have an unprecedented financial scale that is not amenable to status quo procedures for legal liability assignment or regulatory cost recovery.

While the rest of the nation has faced the harsh realities of hurricanes, storms, flooding, and other natural disasters, Californians and others in the West have faced their own version of growing natural disasters: megafires. We characterize megafires based on geographic scope (*e.g.*, acreage affected), direct financial impacts to local residents (*e.g.*, property damage and firefighting effort), and other human and economic costs (*e.g.*, lives lost, injuries, business impacts). California has had several such megafires in recent history—including the 2017 fires covering hundreds of thousands of acres just north of San Francisco and just north of Los Angeles, resulting in at least $11 billion in recorded insured losses alone.[2] Shortly thereafter in

[2] Aon Benfield, "Weather, Climate & Catastrophe Insight: 2017 Annual Report," January 24, 2018, page 6, accessed April 2018, http://thoughtleadership.aonbenfield.com/Documents/20180124-ab-if-annual-report-weather-climate-2017.pdf.

2018, the Carr and Mendocino Complex fires further north in California have been among the most destructive in the state's history.

> **Megafires**
>
> Wildfires above and beyond the "normal" wildfire season, in terms of geographic scope, property damage and firefighting effort, and other human and economic losses

Compared to other types of natural disasters, megafires put California's electric utilities in a particularly precarious financial position. Under "inverse condemnation principles," public utilities are subject to "no fault" cost responsibility based on the theory that costs will be fully socialized throughout the community. The CPUC, on the other hand, applies a prudency standard to the actions of the utilities, which considers fault in evaluating whether the utility acted reasonably. Under this standard, the CPUC may prevent utilities from recovering all liability costs from their customers. Thus, a utility may be held liable in court under inverse condemnation because its facilities were involved in a fire, regardless of fault and even if the utility was fully compliant with all applicable rules and regulations. This simply facilitates applying the revenue collection mechanisms of the utility to cover the harm, without implying any guilt or culpability. In contrast, the CPUC could preclude the utility from recovering these court-assigned liability costs from customers, if the CPUC were to find that the utility was not prudent, even if the source of the alleged imprudent conduct may not directly be the cause of the fire. While inverse condemnation does not consider fault, because the doctrine assumes costs will be socialized by utilities that can automatically pass on costs to customers, the CPUC may prevent that socialization for PG&E and other regulated utilities the prudency standard. The difference between these two standards creates uncertainty and potentially extreme asymmetric risk for utility investors and managers. This issue is addressed in more detail below in Section III.C.

A. Growing Scale of Natural Disasters

Natural disasters, including wildfires, are resulting in increasing catastrophic physical and financial damage, as they grow in scale and frequency in the U.S. and around the world.

There is much evidence that both the frequency and severity of weather and climate-related natural disasters is growing on both a national and global scale.[3] The U.S. Global Change

[3] See, for example, Intergovernmental Panel on Climate Change, "Climate Change 2014: Synthesis Report," Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 2014, accessed April 2018, https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf, and the World Bank Group's "Turn Down the Heat" Series, accessed April 2018, http://www.worldbank.org/en/topic/climatechange/publication/turn-down-the-heat.

Research Program predicts increased incidence rates and intensity of extreme temperatures, heavy precipitation events, extreme storms, heat waves, and large forest fires in the west and Alaska.[4] Both the U.S. Department of Energy and the Department of Homeland Security have acknowledged additional risks and vulnerabilities to the power sector and to the economy in general as a result of these changing trends.[5,6]

The reinsurance industry, which insures private insurance companies against very large claims, catalogues trends in natural disasters and other extreme events over a broad geography and over many years. Reinsurance industry reports have documented an increase in both (a) the number and cost of loss events and (b) the volatility of losses.[7,8,9] Global economic losses from natural disasters increased 4% and 5.9% annually above the average rate of inflation from 1980–1999 and 2000–2017, respectively, with 2017 recording the highest losses from weather-related events.[10]

Figure 1 shows the increase in the number of loss events in the U.S. that cost at least $1 billion, primarily due to meteorological events, such as hurricanes, and hydrological events, such as

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4 U.S. Global Change Research Program, "Climate Science Special Report: Fourth National Climate Assessment, Volume I," 2017, pages 21–22, accessed April 2018, https://science2017.globalchange.gov/downloads/CSSR2017_FullReport.pdf.

5 U.S. Department of Energy, "U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather," July 2013, accessed April 2018, https://www.energy.gov/sites/prod/files/2013/07/f2/20130716-Energy%20Sector%20Vulnerabilities%20Report.pdf.

6 U.S. Department of Homeland Security, "DHS Climate Action Plan," September 2013, accessed April 2018, https://www.dhs.gov/sites/default/files/publications/DHS%20Climate%20Action%20Plan.pdf.

7 Munich Re, "Natural Catastrophes 2017: Analyses, Assessments, Positions," March 2018, pages 23, 42, 46, 53, accessed April 2018, https://www.munichre.com/site/touch-publications/get/documents_E711248208/mr/assetpool.shared/Documents/5_Touch/_Publications/TOPICS_GEO_2017-en.pdf.

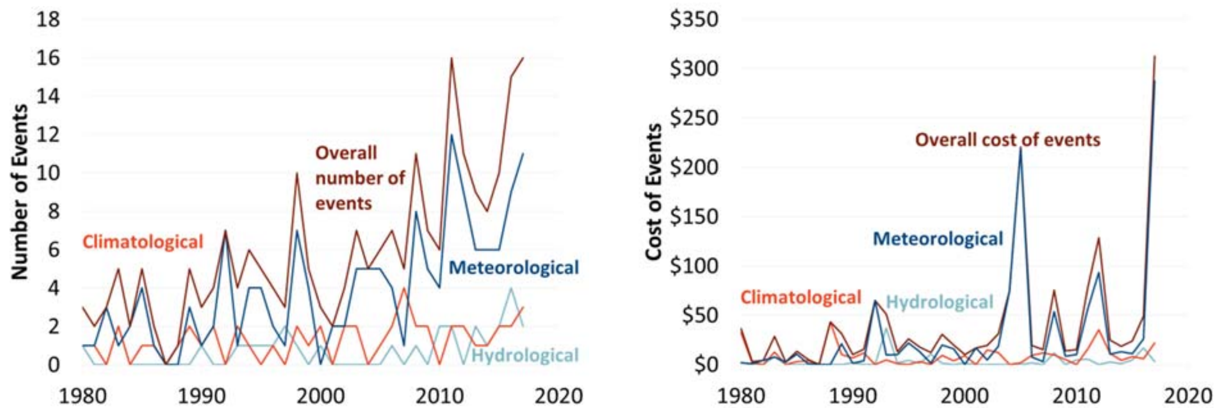
8 JLT Re, "Reinsurance Market Perspective 2018," January 2018, page 18, accessed April 2018, https://www.jltre.com/our-insights/publications/reinsurance-market-prospective-2018.

9 Aon Benfield, "Weather, Climate, & Catastrophe Insight: 2017 Annual Report," January 24, 2018, pages 19, 24, 32, accessed April 2018, http://thoughtleadership.aonbenfield.com/Documents/20180124-ab-if-annual-report-weather-climate-2017.pdf.

10 *Id.*, pages 1 and 3.

flooding.[11] Climatological events, including wildfires, are also increasing in number. In general, the scale and volatility of catastrophic event costs are growing.

Figure 1: Billion-Dollar Weather and Climate Disasters in the U.S.
1980–2017



Source and Notes: NOAA National Centers for Environmental Information (NCEI), "U.S. Billion-Dollar Weather and Climate Disasters 1980–2018," accessed September 2018, https://www.ncdc.noaa.gov/billions/events/US/1980-2018.

B. MEGAFIRES IN CALIFORNIA: SCALE OF DAMAGE AND COSTS

California megafires cause billions of dollars of damage and potential liabilities for the state's utilities, rivaling other natural disasters across the country.

Wildfires in California are commonplace, and there is a "normal" or "expected" amount of damages from wildfires every year. The California Department of Forestry and Fire Protection ("CAL FIRE") responds to over 5,400 wildfires annually.[12,13] However, there are occasional but increasingly more frequent and much larger wildfires in the western U.S.—burning longer and burning more land. An analysis performed by Climate Central using U.S. Forest Service Records from 1970 to 2015 found that the average number of fires larger than 1,000 acres in the 2010s

11 Meteorological events include tropical cyclone, extratropical storm, convective storm, and local storm. Hydrological events include floods and mass movement (such as landslides, avalanches, rock falls). Climatological events include extreme temperatures, droughts, and wildfires.

12 California Department of Forestry & Fire Protection, "CAL FIRE at a Glance," August 2018. http://www.calfire.ca.gov/communications/downloads/fact_sheets/Glance.pdf

13 California Department of Forestry & Fire Protection, "2012 Strategic Plan," June 2012, page 1, accessed April 2018,

http://calfire.ca.gov/about/downloads/Strategic_Plan/StrategicPlan_SinglePages.pdf.

was more than 3 times that in 1970s. The study also found that the average area burned was more than 6 times as many acres, and that the fire season was 105 days longer across the same periods.[14] A recent report published during California's Fourth Climate Change Assessment points out that by end of the century, "if greenhouse gas emissions continue to rise, the frequency of extreme wildfires burning over approximately 25,000 acres would increase by nearly 50 percent, and that average area burned statewide would increase by 77 percent by the end of the century. In the areas that have the highest fire risk, wildfire insurance is estimated to see costs rise by 18 percent by 2055 and the fraction of property insured would decrease."[15] In California, bark beetles and drought have contributed to record numbers of dead trees that fuel and amplify megafires.[16] Firefighting and property damage costs in California also tend to be particularly high compared to the rest of the West, due to factors such as relatively high population and density of human structures.[17,18] The state also has many residents living in relatively high wildfire risk areas. A wildfire risk analysis by Verisk Analytics found that 15% of households in California were at high or extreme risk from wildfires, with Los Angeles, San Diego, San Bernardino, Ventura, and Alameda counties having the largest number of housing units falling into this category.[19]

The graphic in Figure 2 shows the cost of California megafires in the context of other wildfires in the West, and compared to other U.S. natural disasters. As the figure shows, the extent of financial damage from California megafires tends to be much larger than other wildfires in the country, such as the 2011 Las Conchas fire in New Mexico, the 2011 Bastrop County Complex fire in Texas, or the 2012 Waldo Canyon fire in Colorado. Compared to hurricanes, the financial

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14 Alyson Kenward, Todd Sanford, & James Bronzan, "Western Wildfires: A Fiery Future," *Climate Central*, June 2016, page 1, available at: http://assets.climatecentral.org/pdfs/westernwildfires2016vfinal.pdf.

15 Statewide Summary Report, California's Fourth Climate Change Assessment, page 9, August 27, 2018, accessed September 2018, http://www.climateassessment.ca.gov/state/docs/20180827-StatewideSummary.pdf.

16 California Department of Forestry and Fire Protection, "Record 129 Million Dead Trees in California," news release, December 11, 2017, accessed April 2018, http://calfire.ca.gov/communications/downloads/newsreleases/2017/CAL%20FIREandU.S%20ForestAnnouce129MillionDeadTrees.pdf.

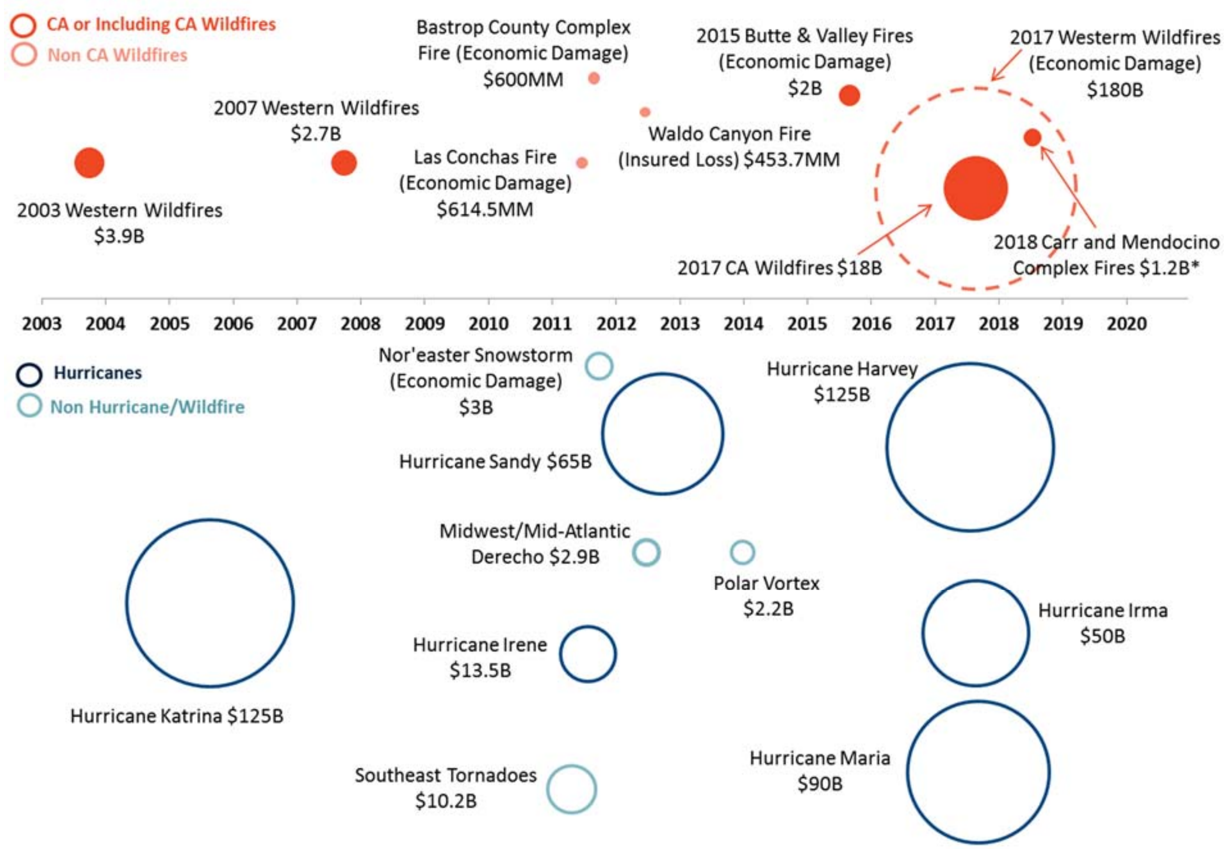
17 Barron, Laignee, "California's Wildfires Have Become Bigger, Deadlier, and More Costly. Here's Why," *Time*, October 17, 2017, accessed April 2018, http://time.com/4985252/california-wildfires-fires-climate-change/.

18 Gregory Scruggs, "Rampant land development will worsen U.S. wildfires – experts," *Reuters*, October 19, 2017, accessed April 2018, https://www.reuters.com/article/us-usa-fires-development/rampant-land-development-will-worsen-u-s-wildfires-experts-idUSKBN1CO2LR.

19 Verisk Analytics, "2017 FireLine State Risk Report – California," accessed April 2018, https://www.verisk.com/insurance/campaigns/location-fireline-state-risk-report/.

impact of California megafires appears relatively small, although it is important to note that hurricanes often damage multiple states at a time. However, megafire costs can be on the order of billions of dollars, and they can reach hurricane-like magnitudes. In 2017, an AccuWeather estimate of the economic damage of wildfires in California—shown by the dotted circle—amounted to about as much as Hurricane Harvey and Hurricane Irma combined.[20]

Figure 2: California Megafires in the Context of Other U.S. Natural Disasters
2003–2018



Notes: Dollars represent nominal total direct financial losses, unless noted otherwise.

*2018 cost estimates are incomplete and still being assessed.

Sources: Brattle research on public data sources. Please see Appendix B for complete citations.

Figure 3, below, provides more detail on the extent of actual and potential gross utility losses from California's megafires in 2003, 2007, 2015, 2017, and 2018. Gross losses—before any cost

[20] "AccuWeather predicts 2017 California wildfire season cost to rise to $180 billion," AccuWeather, accessed April 2018, https://www.accuweather.com/en/weather-news/accuweather-predicts-2017-california-wildfire-season-cost-to-rise-to-180-billion/70003495

recovery and also regardless of insurance coverage—range widely, from $71 million due to the 2003 southern California wildfires, to potentially $17.3 billion due to the October 2017 wildfires. These include the cost of recovery efforts, infrastructure damage, and potential liabilities transferred to the utilities through litigation.

Figure 3: Summary of California Megafires
2003–2018

Year	Name	Utility Area	Gross Utility Loss	Acreage
2018	Carr Fire	PG&E	TBD	229,651
	Mendocino Complex Fire	PG&E	TBD	459,123
2017	October Northern CA Wildfires	PG&E	$10B–$17.3B est.	181,000 *(Nuns, Tubbs, Atlas, and Redwood Valley fires only)*
	December Southern CA Wildfires	SCE	$4B est.	281,893 *(Thomas fire only)*
2015	Butte Fire	PG&E	$1.1B+ est.	70,868
	Valley Fire	PG&E	TBD	76,067
2007	Southern CA Wildfires	SDG&E	$2.4B	516,465
2003	Southern CA Wildfires	SDG&E	$71M	750,043 *(Led by Cedar fire)*

Sources: Brattle research on public data sources. Please see Appendix B for complete citations.

SDG&E recorded total gross costs of $71 million due to its 2003 megafires.[21] The utility recovered about $8 million under FERC-regulated transmission service rates, and $22 million under CPUC-regulated gas and electric service rates already in place.[22] The remaining net cost of $41 million was recovered from SDG&E customers under a Catastrophic Event Memorandum Account ("CEMA") with CPUC approval.[23]

21 California Public Utilities Commission, "Opinion on the Reasonableness of San Diego Gas and Electric Company's Response to the 2003 Wildfires," Application No. 04-06-035 (Filed June 28, 2004), Decision 05-08-037, page 3, August 25, 2005.

22 *Id.,* page 4.

23 The account was used for, "[r]ecording and recovering the costs incurred by SDG&E to restore utility service to customers, repair, replace or restore damaged facilities." *Id.*, page 36.

Several years later, SDG&E incurred $2.4 billion in gross costs and legal fees associated with the 2007 southern California wildfires.[24] A large share was recovered through liability insurance ($1.1 billion in coverage) and $0.8 billion in settlements with Cox Communications and three contractors. Some was recovered through FERC-regulated rates, and SDG&E proposed to voluntarily contribute $42 million.[25] A net cost of $379 million was recorded in SDG&E's Wildfire Expense Memorandum Account ("WEMA").[26] According to the CPUC, utility equipment was identified as the cause of three of more than a dozen fires.[27] At the end of 2017, the CPUC denied SDG&E's request to recover the $379 million from customers, and so these costs were ultimately borne by shareholders under a legal and regulatory framework we discuss in the next sections. This amount represented 6.7% of SDG&E's electric book value of equity that was in place at the beginning of 2017.[28]

Utility shares of total costs from the 2015, 2017, and 2018 megafires are yet to be determined. The order of magnitude of these costs will likely depend on whether utility equipment was involved. As of early 2018, PG&E estimated a potential gross loss to the utility of $1.1 billion for the Butte wildfires in northern California in 2015.[29] At the time they occurred, the late 2017 megafires in both northern and southern California were reportedly the most destructive in recent history.[30,31] By the beginning of 2018, the northern California fires in October 2017, including most significantly the Tubbs fire, had resulted in insurance claims of about $10

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24 California Public Utilities Commission, "Decision Denying Application," Application No. 15-09-010 (Filed September 25, 2015), Decision 17-11-033, page 3, November 30, 2017.

25 *Id.,* page 3.

26 *Id.*, pages 2–3.

27 *Id.,* page 2.

28 San Diego Gas & Electric Company, "Form 10-K for the Fiscal Year Ended December 31, 2017," F-17, accessed May 2018, http://files.shareholder.com/downloads/SRE/6253627488x0xS86521-18-19/86521/filing.pdf.

29 "[PG&E] currently believes that it is probable that it will incur a loss of at least $1.1 billion, increased from the $750 million previously estimated as of December 31, 2016, in connection with the Butte fire." Pacific Gas and Electric Company, "Form 10-K for the Fiscal Year Ended December 31, 2017," pages 29 and 138, accessed April 2018, http://investor.pgecorp.com/financials/sec-filings/default.aspx.

30 Munich Re, "Natural Catastrophes 2017: Analyses, Assessments, Positions," March 2018, page 45, accessed April 2018, https://www.munichre.com/site/touch-publications/get/documents_E380900654/mr/assetpool.shared/Documents/5_Touch/_Publications/302-09092_en.pdf.

31 California Department of Insurance, "California statewide wildfire insurance claims nearly $12 billion," press release, January 31, 2018, accessed April 2018, http://www.insurance.ca.gov/0400-news/0100-press-releases/2018/release013-18.cfm.

billion.[32,33] A February 2018 Fitch Ratings assessment assumes that PG&E could be liable for costs of $15 billion or more.[34] Also, in June 2018, J.P. Morgan estimated that PG&E's liabilities from the 2017 could range from $13.5 billion to $17.3 billion.[35] For reference, PG&E has about $13 billion of book equity in its CPUC-regulated utility (gas distribution, electricity distribution, and electricity generation), plus about $5.5 billion of book equity in its FERC-regulated utility (electricity transmission and natural gas transmission and storage).[36] Further, SCE could owe up to $4 billion for a December 2017 fire.[37] In 2018, two more megafires have already struck California. The Carr fire in July 2018 was the eighth most destructive fire in California's history, and the Mendocino Complex shortly thereafter is the largest wildfire ever to burn in the state.[38,39]

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32 *Id.* About $2 billion in claims were for the southern California fires in December 2017.

33 "If the Utility were to be found liable for certain or all of such other costs and expenses, the amount of PG&E Corporation's and the Utility's liability could be higher than the approximately $10 billion estimated in respect of the wildfires that occurred in October 2017, depending on the extent of the damage in connection with such fire or fires." Pacific Gas and Electric Company, "Form 10-K for the Fiscal Year Ended December 31, 2017," page 28, accessed April 2018, http://investor.pgecorp.com/financials/sec-filings/default.aspx.

34 Fitch Ratings, "Fitch Downgrades PG&E Corp. to 'BBB+'; Places on Rating Watch Negative," February 26, 2018, accessed September 2018, https://www.fitchratings.com/site/pr/10021816.

35 J.P. Morgan, "PG&E Corp. Company Liability Estimates Tell Us Little at This Stage," page 2, June 21, 2018, accessed September 2018.

36 Equals rate base times PG&E's 52% equity ratio. In addition to the CPUC General Rate Case ("GRC") rate base ($25.6 billion updated for tax reform), PG&E has a Gas Transmission and Storage ("GT&S") rate base of $3.7 billion and a Transmission Owner ("TO") rate base of about $6.9 billion, both under FERC jurisdiction. *See* Pacific Gas and Electric Company, Form 10-K for the Fiscal Year Ended December 31, 2017, pages 12, 69, 71, 72 accessed April 2018, http://investor.pgecorp.com/financials/sec-filings/default.aspx. *See also* Pacific Gas and Electric Company, "Attachment B to Petition for Modification of Decision 16-06-056 of Pacific Gas and Electric Company to Reflect Tax Changes, filed March 30, 2018, page 5 (Table 2), http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M212/K646/212646816.PDF.

37 Fitch Ratings, "Fitch Maintains Southern California Edison & Edison International on Rating Watch Negative," August 23, 2018, accessed September 2018, https://www.fitchratings.com/site/pr/10042429.

38 Vox, "Why the Carr Fire in Northern California is so severe," August 14, 2018, accessed September 2018, https://www.vox.com/energy-and-environment/2018/8/1/17637026/carr-fire-california-heat-wildfire-deaths.

39 The Sacramento Bee, "Mendocino Complex approaching full containment as massive wildfire hits 1-month mark," August 28, 2018, accessed September 2018, https://www.sacbee.com/news/state/california/fires/article217439080.html.

C. PRECEDENTS FOR UTILITY LIABILITIES IN CALIFORNIA

California legal precedent has assigned property damage responsibility to utilities on a no-fault basis when their equipment is involved, presuming the utilities' ability to socialize the costs among customers. However, there is a high degree of regulatory uncertainty on whether no-fault full cost recovery will be allowed or would be even feasible for some megafires.

Precedent for cost recovery in connection with wildfires in California is complex. Where a utility's equipment is shown to be the cause of a fire, courts have held that the legal doctrine of "inverse condemnation" applies. Inverse condemnation imposes strict liability on the utility regardless of any finding of negligence or mismanagement, based on the presumption that a utility has the ability and is an appropriate agency to recover such costs from customers.

Unlike public utilities, investor-owned utilities like PG&E must have their costs approved by the CPUC in order to recover them. However, the no-fault doctrine of inverse condemnation is in conflict with the presently more subjective standard used by the CPUC to evaluate whether to allow investor-owned utilities to pass on costs. This creates a highly uncertain situation for investors and utility planners. In the context of mounting exposure to potentially huge financial costs from wildfires, this disconnection underscores an acute need to rationalize catastrophic risk allocation rules. As a result of this disconnect, PG&E has challenged the applicability of inverse condemnation to investor-owned utilities.

Inverse Condemnation. The Fifth Amendment of the U.S. Constitution specifies one condition for the exercise of eminent domain: that the government must fairly compensate owners when their property is taken for public purposes. The corresponding provision under California law—Article I, §19 of the California Constitution—extends this concept to include compensation for property *damage* caused by public enterprises, allowing property owners in such circumstances to take legal action against government entities under the doctrine of "inverse condemnation." In the 1960s, courts in California started to interpret inverse condemnation as imposing strict liability on government agencies, regardless of any finding of negligence.[40] This has been based on the reasoning that damages caused by public infrastructure should be borne by the full community of users, along with the presumption that public entities have the ability to spread the costs through taxation:

> "[T]he cost of such damage can better be absorbed, and with infinitely less hardship, by the taxpayers as a whole than by the owners of the individual parcels damaged."[41]

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40 *Albers v. County of Los Angeles* (1965) 62 Cal.2d 250 is frequently cited as a seminal ruling on inverse condemnation. Significantly, the plaintiff's own negligence was not necessarily a bar to a finding of strict liability (see *Blau v. City of Los Angeles* (1973) 32 Cal.App.3d 77).

41 Blau, 32 Cal.App.3d at 84-85.

Beginning with the *Barham decision* adverse to SCE in 1999, courts extended inverse condemnation to apply to investor-owned utilities as well as government agencies.[42] In subsequent inverse condemnation rulings relating to California utilities, the premise of regulatory cost recovery has, until recently, remained as an explicit part of the rationale. For example, in a decision adverse to SCE in 2012, the court noted that "Edison has not pointed to any evidence to support its implication that the Commission would not allow Edison adjustments to pass on damages liability during its periodic reviews."[43]

Thus, to be sustainable in practice, inverse condemnation would seem to require strict flow-through of property damages back to utility customers regardless of "blame."[44] Such an approach may have been tractable when the damages were relatively small and/or significantly offset by insurance or public funds. Now, however, with the far greater magnitude of damages incurred by recent wildfires, inverse condemnation is coming under renewed scrutiny.

CPUC's November 2017 Ruling for SDG&E. Despite its long history, the presumption of cost recovery from customers under inverse condemnation has not been accommodated by the CPUC. Notably, regarding the damages arising from the 2007 southern California megafires affecting SDG&E, the CPUC ruled in late 2017 that the utility's actions prior to the event were not reasonable and SDG&E was therefore liable for damages of $379 million.[45] The CPUC found SDG&E's actions had not properly invoked inverse condemnation, noting that "[w]e are not aware of any Superior Court determination that SDG&E was in fact strictly liable for the costs requested in its application."[46] As a result of this decision grounded in more traditional utility cost recovery standards (prudence, causality), there is now uncertainty surrounding how the pending costs of more recent (much larger) fires will be allocated.[47]

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42 *Barham v. So. Cal. Edison Co.* (1999) 74 Cal.App.4th 744.

43 *Pac. Bell v. So. Cal. Edison Co.* (2012) 208 Cal.App.4th 1400. The Pacific Bell decision was echoed in a more recent Superior Court ruling finding that PG&E is liable for inverse condemnation in connection with the Butte fire (Ruling on Submitted Matter: Inverse Condemnation Motions, Butte Fire Cases, Case No: JCCP 4853, Superior Court of California for the County of Sacramento, June 22, 2017).

44 It is less clear as to whether this would apply to all such costs, or to just the net costs after other private or other-agency mechanisms for compensation and recovery have been applied.

45 California Public Utilities Commission, "Decision Denying Application," Application No. 15-09-010 (Filed September 25, 2015), Decision 17-11-033, pages 11, 14, 29, 36–37, November 30, 2017.

46 *Id.*, page 65.

47 The CPUC denied SDG&E's subsequent request for rehearing in July 2018. California Public Utilities Commission, "Order Denying Rehearing of Decision (D.) 17-11-033," Application No. 15-09-010 (Filed September 25, 2015), Decision 18-07-025, July 12, 2018.

California Senate Bill 901. At the end of August 2018, California passed a bill that takes some steps towards addressing the cost allocation problem for the 2017 megafires.[48] Senate Bill 901 expands various fire prevention and mitigation efforts by several state agencies, and it clarifies the CPUC's reasonableness review of utility activities and costs regarding fire mitigation. The bill also creates a framework for possibly socializing wildfire-related costs in 2017 and in future years through a securitized utility financing mechanism called a recovery bond.

For 2017 specifically, the bill mandates that the CPUC take into account "the electrical corporation's financial status" by determining "the maximum amount the corporation can pay without harming ratepayers or materially impacting its ability to provide adequate and safe service."[49] The bill thus establishes a mechanism for PG&E to recover costs for 2017 wildfires that would otherwise be disallowed, at least beyond the point to where the disallowance would threaten the utility's financial viability or its ability to provide utility service. However, the bill does not resolve regulatory uncertainty on even the order of magnitude of a possible disallowance amount and thus it still leaves the utility financially exposed, with consequences discussed below.

D. Recent Implications for PG&E

The prospect of an SDG&E-like outcome for decisions about fires that have not yet been reviewed in regulatory proceedings creates a large financial risk for utility investors with strong implications for PG&E's financial health, as already evidenced in PG&E's stock performance and creditor reactions.

The reactions of credit rating agencies and utility investors to the SDG&E 2007 wildfire decision discussed above highlight the serious implications of the regulatory uncertainty of the utilities' ability to recover the costs of megafires on utilities' financial stability. Leading up to the November 2017 decision, for example, Moody's stated that, "a less credit supportive regulatory environment will likely result in worse financial metrics and weakened credit quality for California IOUs."[50] In early December 2017, Moody's Investors Service commented that the outcome "may make it difficult for utilities to meet the CPUC's prudency standards in the future."[51]

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48 California Senate Bill No. 901 (Wildfires), Legislative Counsel's Digest, published September 8, 2018, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB901.

49 Section 27 of Senate Bill 901.

50 Moody's Investors Service, "California wildfires could create material contingent liabilities and credit challenges," Sector Comment, December 20, 2017.

51 Moody's Investors Service, "San Diego Gas & Electric Company: Regulator denies San Diego Gas & Electric's recovery of wildfire costs, a credit negative for all California utilities," Issuer Comment, December 4, 2017.

On December 20, 2017, PG&E's Board of Directors announced suspension of common stock dividend payments, beginning with the fourth quarter of 2017, and suspended dividends on preferred stock, beginning with the three-month period ending January 31, 2018.[52] This dividend suspension has had an immediate function to conserve cash and increase liquidity in the face of uncertainties, but it also had detrimental effects from the perspective of rating agencies and equity investors.

Moody's viewed the dividend suspensions as a credit negative "because it signals how management views the company's potential exposure to the Northern California wildfires."[53] They also noted that the dividend cuts suggest that the uncertain liabilities associated with wildfire damages "may exceed liquidity reserves as well as impact the company's ability to access the capital markets, and potentially the solvency of the utility."[54] Standard & Poor's reacted similarly and downgraded PG&E's preferred stock from BBB to BB.[55] In February and March 2018, Fitch, Moody's, and Standard & Poor's each downgraded the company.[56] Moody's noted, for example, that "the uncertainty associated with the wildfire-related damages, especially those related to the application of inverse condemnation, has increased PCG and PG&E's risk profile."[57] The credit ratings agencies have maintained a negative outlook on PG&E, warning investors of the potential for further downgrades going forward.

Equity investors have responded correspondingly: PG&E Corporation's stock price dropped dramatically from approximately $70 per share in September and early October 2017 before the fires began, to about $57 per share in mid-October 2017 just after the fires started, to about $45 per share from the day after the dividend suspension was announced on December 20th 2017,

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52 Pacific Gas and Electric Company, Form 8-K, December 20, 2017, accessed April 2018, http://investor.pgecorp.com/financials/sec-filings/default.aspx.

53 Moody's Investor Service, "Moody's Places PG&E Corporation and Pacific Gas & Electric Company's Ratings on Review for Downgrade," December 21, 2017.

54 *Id.*

55 S&P Global Ratings, "PG&E Corp. and Subsidiary Placed on CreditWatch Negative on Suspended Dividends Due to Liability Exposure," Press Release, December 22, 2017.

56 Fitch Ratings Inc., "Fitch Downgrades PG&E Corp. and Sub to 'BBB+'; Places on Rating Watch Negative," press release, February 26, 2018.

Moody's Investors Service, "Ratings Action: Moody's Downgrades PG&E to A3 and PG&E Corp to Baa1, Outlooks are Negative," March 19, 2018.

S&P Global Ratings, "PG&E Corp. and Subsidiary Downgraded to 'BBB+' on Contingent Liabilities; Still CreditWatch Negative," Research Update, February 22, 2018.

57 Moody's Investors Service, "Ratings Action: Moody's Downgrades PG&E to A3 and PG&E Corp to Baa1, Outlooks are Negative," March 19, 2018.

through the time of this report in mid-September 2018.[58] Most of this decline occurred in the months of October and November 2017—immediately before and just after the SDG&E decision. This deterioration in investor confidence is counter-productive to the state's broader efforts to manage the costs of an extreme event because it is occurring precisely at the time when an ongoing commitment of capital from investors is most needed to improve fire mitigation as well as to improve the system for other service amenities. Loss of investor confidence hampers the company's financial flexibility and ability to raise additional equity capital. It is difficult to conceive of how putting the regulated utilities in this financial position, due to regulatory uncertainty, is helpful for the state's ability to manage the underlying risks of megafires.

Senate Bill 901 has to date only partly assuaged investor concerns, and many of its features remain to be determined. On September 6, 2018, after the Legislature passed the bill, Moody's responded by further downgrading PG&E's senior unsecured ratings from A3 to Baa1, and the parent company PG&E Corporation from Baa1 to Baa2.[59] Moody's explained that "SB901 failed to address the most important risk factor, inverse condemnation, and the benefits it provides are dependent on implementation by state regulators."[60] Fitch followed suit with a downgrade to BBB on September 13, 2018, stating that, "S.B. 901 grants wide latitude to the [CPUC] to authorize recovery of third party liabilities associated with catastrophic wildfires."[61] Furthermore, the bill does not address fires in 2018, nor does it define a sustainable post-2017 risk or cost allocation framework. Overall, the bill does set up a mechanism for cost socialization through recovery bonds in certain circumstances, but there are still many regulatory uncertainties on when and to what extent those bonds will be used.

IV. Compensating Utility Risk Under the Status Quo

Regulated utilities can be risk-intermediaries for megafire mitigation and recovery, but that requires clear guidelines for how to pursue risk management, plus a reliable mechanism for cost recovery, much like financial hedging needs this clarity.

Regulated investor-owned utilities are powerful agencies for financing, investing in, and maintaining public infrastructure. Utilities can also be effective intermediaries for cost socialization relating to public goods and public costs, planned or otherwise (though at some

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58 *Yahoo! Finance*, PG&E Corporation (PCG) Historical Stock Prices, accessed September 2018, https://finance.yahoo.com/quote/PCG/history?p=PCG.

59 Moody's Investor Service, "Rating Action: Moody's Downgrades Pacific Gas & Electric Company to Baa1 from A3 and PG&E corporation to Baa2 from Baa1; Rating Outlooks Remain Negative," September 6, 2018.

60 *Id.*

61 Fitch Ratings Inc., "Fitch Downgrades Pacific Gas & Electric and PG&E Corp IDRs to 'BBB'; Outlook Negative," press release, September 13, 2018.

point that can distort the price signaling about the value of its core services). It thus makes sense for a regulated utility to provide some degree of financial resiliency after major crises, by smoothing extreme spikes in costs to make them more bearable for utility customers, and by holding and managing the financial tools to do so.

However, regulated utilities cannot be used for systematically and one-sidedly transferring risks inherent to a public good or geography *away* from customers or taxpayers and *to* the utility investors, without violating the public/private bargain implicit in the regulatory compact. Under this arrangement, investors in a private company agree to finance and maintain public infrastructure and act as risk intermediaries, in exchange for a regulated profit (rate of return). Indeed, no risk intermediary in any industry can be viable for long if it is expected to provide a financial safety value and absorb the costs when adverse outcomes occur. At best, it can be compensated to make arrangements to pre-fund portions of those potential costs and then to smoothly and equitably distribute any residual costs after an event takes place. In the immediate context, largely unpredictable wildfires near high-value property are a fact of life in California, and no utility can eliminate that as a cost of living in that region. Failing to appreciate this can have catastrophic financial implications for the utility, which, in turn, would hinder its ability to serve as a public vessel and ultimately harms customers.

The 2000–2001 California Power Crisis is a striking example of a break in the regulatory compact. The investor-owned utilities were expected to purchase power for customers at exceedingly high unhedged wholesale prices in what became a dysfunctional market, but they were not allowed to pass those costs on to customers in a financially viable manner due to retail rate freezes designed to protect customers. The utilities were forced to procure an enormous amount of debt to finance their shortfalls, and their financial health was seriously harmed. In particular, PG&E filed for bankruptcy after it was estimated that it had incurred $9 billion in unrecovered power costs.[62]

A. The General Problem of Asymmetric Risk for Regulated Companies

Regulated utilities face a "heads I break even, tails I lose" risk exposure which has become critically acute for California utilities due to megafires.

Every regulated utility faces some amount of asymmetric risk. Investors must accept the real, but usually slim, possibility that they will take a financial hit from disallowances or losses after an unforeseen negative event, and that the chances for offsetting financial boosts of the same magnitude are even more remote. Ratemaking generally is based on normalized recent past or coming-year projected operations, with rates set to cover those costs at the expected volume of

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62 U.S. Energy Information Administration, "Subsequent Events California's Energy Crisis," n.d., accessed April 2018, https://www.eia.gov/electricity/policies/legislation/california/subsequentevents.html.

sales, with no material contingencies built into the allowed costs or returns.[63] If they sometimes lose when worse conditions occur but cannot make an excess return if those conditions do not arise, utilities will face a "heads I break even, tails I lose" risk exposure under regulated operations. Ideally that asymmetric risk is rather slight in likelihood or consequences; however, the extreme scale of potential wildfires makes such asymmetries dramatic and untenable.[64]

It is perhaps not obvious that such asymmetries are not a normal type of risk for utilities that is already implicitly compensated in their allowed cost of capital. After all, those allowances are derived from financial models that assume markets are efficient and reflect available information, so surely investors have foreseen this problem and priced it into their required returns.

Asymmetric risks of megafires to a utility arise from uncompensated cost exposure that is effectively unbounded, even after net insurance proceeds and stipulated recovery from customers.

Surprisingly this is not the case: These asymmetric exposures are basically like insurance risks and not ordinary business risks. Insurance risks involve loss, unless you are paid to cover those risks (which utilities are not). Insurance risks reduce the expected cash flows from an asset, but they are not accompanied by any prospect of compensatory upside returns such as might be expected from a private sector business investment that can be electively pursued only if/when conditions are favorable. For instance, if your house is newly discovered to be in a flood or earthquake zone, it will lose value, and thereafter it will not appreciate back to some level that compensates you for that loss. You cannot expect future home buyers to somehow undo that inconvenient discovery. Likewise, when a utility stock faces an asymmetric risk such as the increasing exposure to wildfire liability in California, its stock price will fall (as happened to PG&E). But, that stock will not be expected

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63 Under the CPUC, PG&E's ratemaking is based on a future test year. Under FERC, PG&E's ratemaking has historically been based on a future year. However, PG&E is requesting a new method of "formula rates" under FERC, which is used by other utilities across the country to address uncertainties in both costs and volumetric customer sales. Formula rates would be based on the prior year's costs, plus adjustments for expected future cost changes, plus a true-up mechanism to align revenues with actual incurred costs. But it should be noted that the true-up mechanism is not a guarantee of cost recovery, particularly if costs are sudden and dramatic, beyond the order of magnitude of expected norms.

64 Some risks utilities face are fairly symmetric, such as the possibility that loads will be a bit below or a bit above the forecast (though demand-side resources are eroding that confidence). But some risks are more likely to be lopsided such as a plant development exceeding its budgeted costs with a cap on the allowed value if the plant is expensive, but marking it to actual cost for ratemaking if it should come in below budget. Here, the risks of having fire damages imposed that were not in allowed rates in the first instance, and for which there is no extra, reward money when fires do not occur, is clearly asymmetric.

thereafter to appreciate more than similar utilities that do not have that problem, and so shareholders will not have the opportunity to cover the unexpected loss. Correspondingly, the market-required return estimated by applying quantitative models (such as the Capital Asset Pricing Model ("CAPM") and the Discounted Cash Flow ("DCF") model) to a proxy group of other utilities does not capture a premium for all asymmetric risk. So when that measured rate of return is allowed against the equity in rate base, shareholders are not compensated for such exposures. With time and after extreme risk exposures become realized costs, some amount of additional risk may be internalized in markets and in the financial data supplying these models. But it is not likely for asymmetric risk to be estimated and calibrated accurately by CAPM or DCF to offset the potential cost of megafires. Appendix A provides a more detailed discussion of how capital market models generally fail to price asymmetric risk.

Failing to recognize this gap caused by asymmetric risk has several adverse consequences. First, it means the utility does not have a fair expectation of achieving its allowed cost of capital, violating principles of regulatory design. This can lead to impaired financial health or more limited access to capital, ultimately interfering with the quality, cost, or pace of introduction of other utility services. In addition, the lopsided exposure to any specific type of asymmetric risk can make the utility managers and investors unduly sensitive to this type of risk compared to all others. They may choose to mitigate it in a way that is not efficient in relation to other risks or other services of importance. Thus, there is "no free lunch"– customers cannot win, in the long run, from penalizing a utility in bad outcomes and not giving it an offsetting opportunity for gain if and when adverse conditions do not occur. There are many possible means of providing this opportunity, or for altering the risk-sharing arrangement so that it does not have unintended, adverse side-effects on the rest of utility operations. These are discussed in the final section of this paper.

If the investor-owned utilities are expected to bear additional asymmetric risk, one helpful mechanism for reducing the adverse effects would involve compensating investors with an increased allowed ROE, well above the market cost of equity. The required increase would reflect the annualized risk, to the extent known, of the share of expected property damage risks from fires that a utility might be asked to bear without socialization in rates. The required increase could be larger than that expected amount, to the extent the utility is seeking (and regulators and customers want) a high probability of financial resilience for the utility, should a larger than typical fire occur sooner than expected.[65]

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[65] Villadsen, Bente, Michael J. Vilbert, Dan Harris, and A. Lawrence Kolbe, *Risk and Return for Regulated Industries* (London: Academic Press, 2017), Chapter 10.

B. ILLUSTRATIVE RISK COMPENSATION VIA RETURN ON EQUITY

An incremental adjustment to ROE would address asymmetric risk, but it would be hard to estimate and might not be fully protective.

A regulated utility's allowed return on equity is typically a point of considerable debate in ratemaking proceedings. The ROE essentially determines how much the utility earns for investing in assets necessary to provide service to customers. Over the past two and a half decades, the CPUC, for example, has granted PG&E ROEs ranging from today's 10.25% to 11.9% in the 1990s—declining over time in conjunction with declining interest rates.[66] The largest change in PG&E's approved ROE during that time was from 11.35% to 10.40%, a reduction of 0.95% (95 basis points). Great care is devoted to quantifying the fair rate of return, sometimes with heated disputes over 25-50 basis points. In contrast, the megafire-related financial risks faced by the California utilities would require incremental ROE adjustments potentially <u>an order of magnitude higher</u> than 1%, as we demonstrate in this section.

PG&E's total equity rate base under both CPUC and FERC jurisdictions is about $18.8 billion.[67] Therefore as a rule of thumb, 100 basis points of an ROE spread across the total rate base equates to about $200 million. This makes it immediately apparent that the potential billions of dollars of exposure that PG&E shareholders may face in the future for each extreme event could have very dramatic implications if translated into an asymmetric risk adjustment under this traditional ROE paradigm.

1. The Range of Potential ROE Increases

Depending on PG&E's executive managers' and investors' perception of financial risks, an appropriate incremental risk adjustment to ROE could be substantial.

Figure 4 demonstrates the magnitude and range of the required ROE increase, depending on the anticipated scale of annual megafire events (in steps of billions of dollars) and the anticipated likelihood of their annual occurrence (in %) that it would cover. The illustrated range of event

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66 "Rate Case History", S&P Global Market Intelligence, April 19, 2018.

67 Equals $36.2 billion total rate base times PG&E's 52% equity ratio. In addition to the CPUC General Rate Case ("GRC") rate base ($25.6 billion updated for tax reform), PG&E has a Gas Transmission and Storage ("GT&S") rate base of $3.7 billion and a Transmission Owner ("TO") rate base of about $6.9 billion, both under FERC jurisdiction. *See* Pacific Gas and Electric Company, Form 10-K for the Fiscal Year Ended December 31, 2017, pages 12, 69, 71, 72 accessed April 2018, http://investor.pgecorp.com/financials/sec-filings/default.aspx. *See also* Pacific Gas and Electric Company, "Attachment B to Petition for Modification of Decision 16-06-056 of Pacific Gas and Electric Company to Reflect Tax Changes, filed March 30, 2018, page 5 (Table 2), http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M212/K646/212646816.PDF.

costs span a 2015 Butte-megafires-type event ($1.1 billion gross cost to PG&E) to a 2017 megafires-type event (for which PG&E could be exposed to liabilities of $10 billion or more). The table entries within the matrix represent the PG&E ROE increase needed to insure that size and likelihood of annual events. The ROE increases are calculated based on PG&E's total equity rate base of $18.8 billion.

Figure 4: ROE Increase Depending on Anticipated Financial Burden
Calculated based on PG&E's total equity rate base of $18.8 billion

Anticipated Net Cost of Event to Utility ($B)	Probability of Event per Year		
	10%	20%	50%
$1	0.5%	1.1%	2.7%
$2	1.1%	2.1%	**5.3%**
$3	1.6%	3.2%	8.0%
$4	2.1%	4.3%	10.6%
$5	2.7%	**5.3%**	13.3%
$6	3.2%	6.4%	15.9%
$7	3.7%	7.4%	18.6%
$8	4.3%	8.5%	21.3%
$9	4.8%	9.6%	23.9%
$10	**5.3%**	10.6%	26.6%

Note: Net cost represents costs to utility shareholders, that is, net of insurance payouts and cost recovery, if any, from customers.

As Figure 4 shows, the basic parameters for characterizing the potential financial burden and corresponding ROE increase yield a very large range of results of 1–27%. A given sized increase could be sufficient to cover several different combinations of events and likelihoods. For instance, a 5% increase is enough for a $10 billion risk with a 10% chance, or a $2 billion event with about a 50% chance. In monetary terms, a 5% increase would be about $1 billion per year, so not enough to fully cover either of these events unless they occurred a few years after the ROE allowance had been in effect. Below, we describe some rough estimates of the apparent fire risk and its net cost along with the ROE increases they imply.

RAMP-estimated risk value for a "normal" year benchmark. PG&E's 2017 Risk Assessment and Mitigation Phase analysis is informative for exploring the scenario where the utility must plan on covering a "normal" or "expected" amount of wildfire damage each year. Before discussing ROE increases of extreme events and megafires, the "normal" is a useful benchmark for comparison purposes. The 2017 RAMP analysis estimates $84 million in financial costs and $23 million in environmental costs for a "normal" amount of wildfires every year.[68] If PG&E needed to self-insure against this sum of $107 million in a normal year, it would need to collect an incremental **0.57%** on ROE (or 57 basis points) more than its recently allowed cost of equity.[69]

The RAMP model also considers other important reliability, safety, and customer satisfaction impacts. These are not explicitly monetized in the model's input parameters, but they are, in some sense, implicitly monetized in RAMP's concluding mitigation plan. The proposed mitigation plan for wildfires averages about $249 million per year in capital costs.[70] This amount of mitigation is expected to avoid $20 million in financial and environmental costs per year, and to reduce other non-monetized impacts by 14–19%.[71] This plan has not yet been approved, and we do not know whether it will be deemed "cost-effective" or how it will be compared with risk reduction benefit-cost ratios for other risks in RAMP. To our knowledge, none of the risk measurement or prevention proposals in RAMP have yet been approved. Nonetheless, we presume for illustrative purposes that the willingness to consider a $249 million annual plan indicates a comparable order of magnitude for the problems the mitigation plan is designed to fix.[72] Thus we have taken the $249 million as a conservative proxy for total potential risk PG&E may face in a normal wildfire year. If PG&E needed to self-insure against costs on the order of $249 million in a normal year, it would need to collect and set aside the equivalent of a **1.32%** ROE increase.[73]

Insurance for extreme events beyond RAMP. We understand that RAMP is not yet calibrated for megafires comparable to what has been observed a few times in the past decade, because the realized cost of any of those amortized over 10 years is far larger than the RAMP financial exposure estimates. But a policy to compensate PG&E for bearing wildfire damage costs must consider the burden of such extreme events. For instance, if PG&E anticipated liabilities similar to the 2015 Butte megafires ($1.1 billion) could arise once in every 5 years, it would need to

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68 2017 RAMP model, annual baseline consequences in 2022 (the last year of the modeled mitigation period).

69 $107 million / $18.8 billion total equity rate base.

70 Pacific Gas and Electric Company, "2017 Risk Assessment and Mitigation Phase," Chapter 11 (Wildfire), Figure 11-3. The figure shows $746,457,000 in capital costs for the proposed mitigation plan, over three future years (2020, 2021, and 2022).

71 2017 RAMP model, the expected annual baseline minus the expected mitigated consequences in 2022. Because of the cumulative nature of mitigation programs, the last year of a given mitigation program usually shows the strongest cumulative mitigation effect.

72 That is, we are implicitly assuming the benefit-cost ratio on the plan is at least 1-1, even though details supporting that conclusion are lacking in the RAMP model. Cost-effectiveness, in the conventional sense, cannot be a bright-line test if some benefits (such as safety) are explicitly recognized but not monetized.

73 $249 million / $18.8 billion total equity rate base.

collect an additional $220 million annually, which is equivalent to a **1.17%** ROE increase.[74,75] This ROE increase would be needed above and beyond any "normal" year costs, such as the 1.32% discussed above, for **a total of 2.49%** above the ordinary cost of equity.

However, this is likely not a sufficient scenario for risk planning. Under the framework of any officially approved ROE increase sized to match PG&E's own risk assessments, it becomes much more likely that PG&E would face a higher degree of financial exposure for cost recovery than the ROE was designed to cover, because of the presumption that the allowed ROE increase was designed to shift the burden fully to the utility (and that if it naively asked for too little, that is the utility's problem, not the customers).

The second reason the 1.17% ROE increase above is probably not sufficient is that recent history has shown the frequency and severity of megafires is higher than what is assumed in this example. One indicator of that fact is that private insurance companies in California are reportedly asking for commercial insurance rates that seek 40 cents on the dollar of insured property, essentially implying a major fire is likely to occur once every three years.[76] Further, the 2017 megafires could prove to be another order of magnitude more costly than the Butte megafires, while occurring only two years later. As an example of a perhaps more realistic calculation, suppose that PG&E faces a Butte-like event once every three years instead of once every five years. In addition, suppose PG&E faces a 2017-like event once in every ten years, with similar potential liabilities, say $10 billion. Then PG&E would need to collect and set aside $1.367 *billion* annually just for this insurance, which is equivalent to a **7.26%** ROE increase.[77]

Going beyond the expected-cost approach. We have referred to the above as an "expected cost approach" in that these estimates are a (very approximate) attempt to characterize just the likely cost per year of certain kinds of potential fire damage to properties. The expected cost amount is sufficient for insurance companies (ignoring additional charges for their own costs and profits, and if they would in fact extend such coverage) to the extent they are highly diversified across many other settings, clients, and types of risks, so that they are only partially exposed to any big catastrophes and can expect to survive them long enough to have the premiums cover the claims. However, for a utility that is self-insuring in a completely undiversified manner, the expected

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74 Pacific Gas and Electric Company, Form 10-K for the Fiscal Year Ended December 31, 2017, page 138, accessed April 2018, http://investor.pgecorp.com/financials/sec-filings/default.aspx. "The Utility currently believes that it is probable that it will incur a loss of at least $1.1 billion, increased from the $750 million previously estimated as of December 31, 2016 in connection with the Butte fire."

75 $220 million / $18.8 billion total equity rate base.

76 Letter from Russell G. Worden to Timothy J. Sullivan, "Letter of notification establishing a Z-Factor for costs associated with incremental wildfire-related liability insurance," December 29, 2017, pages 2–3. The letter describes a $120.9 million premium for an incremental $300 million in coverage.

77 $1.367 billion / $18.8 billion total equity rate base. The annualized $1.367 billion is equal to $0.367 billion ($1.1 billion every 3 years) plus $1 billion ($10 billion every 10 years).

amounts are only sufficient if a megafire never is larger than was foreseen in setting the amount, and if it only occurs at the end of the time frame of expected frequency of occurrence (so that prior increases can cover most of its total costs). In terms of financial preparedness of extreme events, the cost of being "wrong" can be disastrous. For instance, planning for a $3 billion event once every five years but experiencing a $10 billion event after only two years would be financially ruinous.

In general, when an entity must self-insure, it is necessary to be more conservative than the annualized risk would require. This is easily seen by looking at personally funded retirement planning: Suppose you plan your annual savings based on a statistically-expected average lifespan of 80 years, but you live to be 100 years old. That outcome, while perhaps attractive for non-financial reasons, would likely be a tragic failure in terms of financial planning. You must prepare for a "worse" (longer life) case than is typical, so that you can deal comfortably with that eventuality. A diversified insurance company (*e.g.*, selling annuities) does not need to over-insure, because with a large pool of customers, some will die before 80 and their assets will fund the ones who live beyond 80.

Along those same lines, an ROE increase based on annualized risk in this manner may not provide the type of financial resiliency the utility and its customers need. Exactly how to treat the contingency of events occurring sooner or with more severity than expected is a very difficult problem, both analytically and in terms of appropriate policy. For instance, if after-the-fact socialization of extreme costs is possible, it may be more equitable to not quickly cover a worst case outcome, but to wait and see if it actually happens.

Nonetheless, we know with certainty what direction of adjustment self-insuring requires, which is a larger premium. If we were to follow suit with private insurance companies, and collect enough for high probability of surviving the "worst case" outcome within two or three years, the ROE increases would be extremely high. The increases would also be volatile in a way that goes beyond current conventions. On average such an increase would over-collect the need, but you would not know that for quite a while. At some point, if no extreme events have occurred, the ROE increases would need to be adjusted downward, and you would need a mechanism for re-investing or managing the cash.

Insurance industry benchmarks. The private insurance industry is organized and experienced to price the risk of natural disasters, so the cost and nature of their services in the California setting provides useful context for the costs of self-insuring as discussed above. A key challenge, of course, is that the industry has not actually priced exposures of the dollar magnitude implied by recent megafire experience. Still, extrapolation from visible data points on insuring parts of more "ordinary" disasters suggests annual costs of $1 billion or more for fires.

Recent data specific to PG&E is available for this purpose. In particular, PG&E increased its coverage for third-party property damage due to wildfires through the reinsurance market, where a $200 million catastrophe bond issued by Cal Phoenix Re was used to fund the insurance (the "CAT Bond").[78] . The CAT Bond was offered to Cal Phoenix Re investors with a fixed spread to LIBOR of 7.5%, effectively representing the insurance premium.[79] We understand that this was the first CAT bond of its kind, *i.e.* the first written for company-specific wildfire damages in the context of inverse condemnation liability exposure in California. More commonly, catastrophe bonds have been issued for relatively more diversified insurance company exposure to hurricanes, earthquakes, and other more familiar and widely occurring large disasters than the California megafires.

Based on information from the Offering Circular, the CAT Bond was structured to cover approximately 40% of a band of residual risk after the first $1.25 billion of realized loss up to $1.75 billion, and they were specifically targeted to third-party property damage. This $500 million loss "layer," in which the CAT Bond investors participate up to $200 million, covers events with a statistically expected loss rate of approximately 1%. The expected loss rate was derived via a detailed model of California wildfire risk potentially affecting PG&E's service territory prepared by AIR Worldwide Corporation ("AIR").[80] This model was prepared by AIR for Cal Phoenix Re in connection with the CAT Bond.

As was shown above, the total exposure from megafires could reach several billion dollars, which is greater than the amount raised by Cal Phoenix Re through the CAT Bond. One method of extrapolating the cost of the CAT Bond to the full extent of potential wildfire exposures is to combine the following:

1) *Total exposure* to third-party property damage beyond the $500 million layer covered by the CAT Bond and the corresponding expected loss (based on the AIR model);

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78 Cal Phoenix Re Ltd. Confidential Offering Circular Supplement No. 1, July 30, 2018 ("Offering Circular").

79 Bloomberg. Catastrophe bonds have developed in recent years as a mechanism for insurance companies to access deeper pools of capital and diversify exposure. They consist of securities issued to pre-fund the costs of specifically identified risks (such as wildfires affecting PG&E). If the specified events occur, the funds are used to pay associated costs, but are otherwise repaid to the investors (with interest), like conventional bonds. Interest payments on catastrophe bonds in excess of risk-free rates can be likened to insurance premiums on the specified catastrophe risks, since they form the bulk of compensation to investors for bearing them.

80 Per the bond documentation, "AIR, established in 1987, is independent software and consulting firm that develops catastrophe risk assessment and management methodologies and techniques." Cal Phoenix Re Ltd. Confidential Offering Circular Supplement No. 1, July 30, 2018.

2) An appropriate *premium,* based on publicly available data for a broader universe of catastrophe bonds at varying levels of expected loss, with an adjustment for the newness and thinness of wildfire coverage of this magnitude and basis for liability exposure;[81]

3) An additional scaling of the loss exposure beyond property damages to cover certain additional types of risks not included in the AIR data.

This model indicates an annual cost for insurance approximating $1 billion, consisting of $22.8 billion in total modeled exposure plus an insurance premium of approximately 4.6% of that maximum outcome. Key features of the data and corresponding adjustments are described further below.

1) *Wildfire risk-of-loss distribution based on AIR data and models*—AIR modeled wildfire risk in PG&E's territory based on insurance industry and other databases. AIR reviewed the history of wildfires in California from 1992 to 2015 and developed a sample of over 7,000 fires from which it modeled a probability distribution of potential costs from property and other losses (including an adjustment for the probability that a fire would be caused by PG&E's electrical transmission equipment based on proximity to such equipment and historical findings). The modeling consisted of running a Monte Carlo-like simulation against this distribution of past events for 10,000 trials ranging from damages of zero to a worst-case level of $15.7 billion, each with a probability of 1/10,000 (or 0.01%). For any given level of damages, the statistically expected loss was equal to the number of trials in which losses were allocated to investors (when over $1.25 billion in total losses) weighted by investor losses in each trial (up to $500 million), divided by 10,000. As noted above, this resulted in approximately a 1% expected loss corresponding to the exposure borne by the CAT Bond.

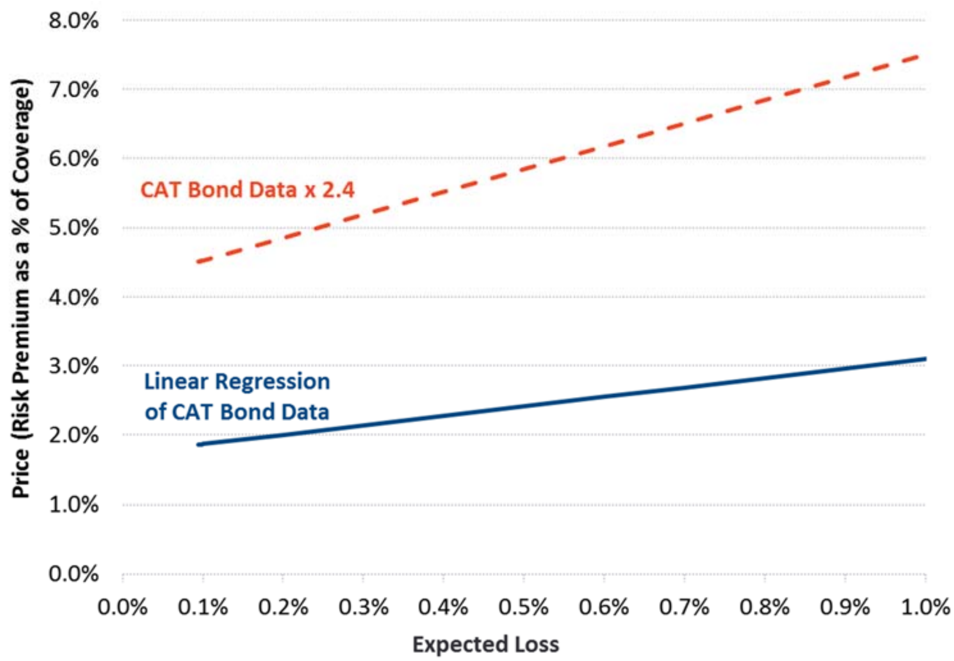
   This AIR model used for the CAT Bond can also be used to approximate the expected loss corresponding to total potential damages, essentially lifting the cap used for the CAT Bond on the insured range up to a modeled worst case scenario of $15.7 billion. Per the loss model developed by AIR, and assuming property damage coverage of $1.2 billion as estimated by PG&E, this would come to a 0.14% expected loss against the maximum amount (ultimately, applied to the scaled up $22.8 billion as described below).

   Importantly, this expected loss level is likely to be conservative because the AIR model does not reflect 1) wildfires ignited by distribution (as opposed to transmission) lines, or 2) the increased severity of wildfires after 2015.

81 Based on transaction data compiled by Artemis (http://www.artemis.bm/).

2) *Catastrophe Bond Market Data*—A ready guide to adjusting the CAT Bond premium for this larger but less likely type of loss is to review market data for pricing of catastrophe bonds generally in relation to expected loss rates. Recent compilations of catastrophe bond price and expected loss data on 39 catastrophe bonds issued in 2018 provided by Artemis indicate that investors have recently required risk premia between 2.25% and 4.25% on bonds with an expected loss at or close to 1%.[82] A linear regression of the catastrophe bond data is shown by the solid blue line in Figure 5 below, with a premium of 3.1% corresponding to an expected loss of 1%.

Figure 5: CAT Bond Premium per Dollar of Covered Loss



Source: Artemis Catastrophe Bond & Insurance-Linked Securities Deal Directory, accessed August 2018, http://www.artemis.bm/deal_directory/.

Importantly, however, the universe of catastrophe bonds covered by Artemis does not reflect California wildfire risk under inverse condemnation, because as noted above, this is a new application of catastrophe bond financing. Notably, the 7.5% spread on the CAT Bond falls well outside the range for non-wildfire catastrophe bonds at the same level of expected loss. This may be attributable to the relative novelty of California wildfire bonds, with correspondingly thin market capacity to absorb this kind of risk. It may also be because, for any given level of expected loss, investors are unfamiliar with the potential distribution of outcomes and concentration of losses in the case of wildfires.

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82 Artemis is a news, analysis and data media service focused on catastrophe bonds and insurance linked securities.

To estimate a wildfire insurance premium for the entire range up to $15.7 billion, it is reasonable to apply the same "gross up" between the 7.5% risk premium that was the actual cost quoted for the CAT Bond and the premium of 3.1% for similarly risky non-fire CAT bonds, a factor of 2.4 times. Applying this factor across all levels of expected loss, the implied premium for wildfire CAT bonds with an expected loss of 0.14% would be 4.6%, as observed at the left side of the red line above.

Again, this level of premium applied to much larger wildfire coverage amounts reaching into billions of dollars of rare but possible exposure is likely conservative. If such extreme coverage were available at all, it is likely that a larger premium would be required in current markets, simply from a supply and demand perspective.

3) *Risks beyond 3rd Party Property Damage*—The AIR model estimates property damage due to wildfires ignited by the utility's equipment, which does not include other costs such as personal injury liability, fire suppression costs, and legal and other costs that a utility could well face in an adverse liability decision. Based on its experience with large wildfires, we understand that PG&E estimates that costs other than third-party property damages could range from 25% to 45% of total liabilities. Taking the midpoint of this range, the total costs for all liabilities would be 1.58 times the property damages. Making that adjustment, the insurance coverage need of $14.5 billion ($15.7 billion minus $1.2 billion) based on the AIR model should be grossed up by 1.58, so the total coverage for all liabilities would be $22.8 billion.

Combining these calculations, the expected cost of insuring this entire exposure with catastrophe bonds would be 4.6% of $22.8 billion, or $1.06 billion per year. Intuitively this also corresponds to covering a 1/10 chance of a $10 billion risk every year, albeit it was derived based on the full range of fire sizes and frequencies with which they have occurred, as well as the assumption of a $1.2 billion initial coverage already being in place to cover damages from less extreme fires before CAT bond coverage would begin.

As noted above the $1 billion cost estimated from the CAT Bond data likely forms the bottom end of the range of ultimate costs. Anecdotally, private insurance companies in California have asked for commercial insurance rates that seek 20-40 cents on the dollar of insured property, whereas here we are indicating that 5 cents is about the required premium. For instance, at the end of 2017, after a record year of wildfires in California, SCE sought $300 million in additional liability and wildfire insurance. The utility found a "diminishing general liability and wildfire insurance market in California for investor-owned utilities, to the extent even available."[83] The

83 Letter from Russell G. Worden to Timothy J. Sullivan, "Letter of notification establishing a Z-Factor for costs associated with incremental wildfire-related liability insurance," December 29, 2017, pages 2–3.

utility found only one insurer willing to provide the additional coverage, at a cost of $120.9 million and a $10 million deductible.[84] That is a 40% premium.

This analysis and our survey of actual fire costs and their estimated or realized property damages over the past few years show that the expected cost as well the insurance cost of covering megafires for PG&E is a multi-billion dollar exposure. This exposure yields a multi-hundred million dollar cost to defray the likely average annual realization of costs or to obtain coverage to offload that responsibility to third parties (assuming that was even feasible). Absent some new, not yet established legislative and regulatory protection from incurring such extreme costs, this loss exposure represents an impairment of the utility's ability to recover its full costs, including a fair return on capital. That is, it is a somewhat unlikely loss potential with no upside, which can only bring expected returns below the intended, required rate of return. As noted above, a 1% increase in allowed ROE against PG&E's rate base is about $200 million of incremental revenues. Thus, a $1 billion offset to this risk would require a 500 basis point increase in the allowed ROE.

2. Limitations of the ROE Approach

Among other concerns, the ROE approach could still leave shareholders with residual risk, while creating the impression that they had been fully covered.

Given the large losses an uncompensated liability for wildfires could impose, an ROE increase for the asymmetric risk of megafires has intuitive appeal. It certainly is important that some offsetting compensation be provided, and an ROE adjustment is one practical way of doing so. However, protecting utility shareholders in this way can be problematic for a few reasons.

First, and most fundamentally, it unlikely that the required ROE increase can be estimated and calibrated accurately to offset the potential cost of megafires. While the above calculations show that protecting against the probabilistic risk of megafires can be very costly, even an ROE increase sized at several hundred basis points could prove be inadequate to protect against the cash flow requirements of some plausible scenarios. Indeed, the suggested 500 basis points should not be construed as the current best estimate of the annualized cost. Instead, it is the amount that would defray an annual expected exposure of about $1 billion of otherwise uncompensated losses. The $1 billion loss potential is certainly supported by recent past evidence, but the risks of megafires appears to be increasing, and the value of the properties that may be exposed is also a moving target depending on how and where the California economy expands.[85]

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84 Letter from Russell G. Worden to Timothy J. Sullivan, "Letter of notification establishing a Z-Factor for costs associated with incremental wildfire-related liability insurance," December 29, 2017, pages 2–3.

85 Importantly, the asymmetric risk at issue cannot be assumed to be static over time, since both climate and regulatory trends indicate a growing problem. If wildfires continue to increase in frequency and

Continued on next page

Second, an ROE increase will still leave a residual risk concentrated on current shareholders under many circumstances if or when any increased ROE allowance, even accumulated over time, does not match the immediate burden of costs from a megafire. In principle, reliably ongoing future allowances in an ROE premium after a large fire could provide expected cash flows sufficient to gradually compensate a large fire and to cover future ones, but investors are likely to have some skepticism about the continuity of such a policy, especially after a large disaster.

Finally, the existence of an ROE increase may create the impression for regulators and the public that the utility and its shareholders have been fully compensated for any and all fire risks (notwithstanding the difficulty in estimating the exposure), with no need for additional protection even though a fire might exceed what was expected in the original design—a "circularity" problem that leaves utilities exposed to the full scale of any unforeseen or mispriced extent of risk.[86]

Thus, while an ROE premium would be helpful and appropriate under current circumstances, it would be more desirable to reach a stronger and more sustainable solution for how to socially plan for and share the costs of fires across as broad a base of customers as possible, as well as for spreading the expected and incurred costs over long time periods. There are many such possibilities which should be considered by legislators and regulators, but their design is beyond the scope of this analysis.

Continued from previous page

severity, and if the apparent inconsistencies between the application of inverse condemnation and the CPUC's prudency standards remain, then it is also fair to imagine a scenario where the insurance industry and utility customers (via the CPUC) continue and possibly accelerate their flight away from the financial burden.

86 Villadsen, Bente, Michael J. Vilbert, Dan Harris, and A. Lawrence Kolbe, *Risk and Return for Regulated Industries* (London: Academic Press, 2017), Chapter 10.

V. Conclusions

The extreme potential costs, and apparently growing risk of megafires in California, plus the state's unsettled legal and regulatory approach to assigning financial responsibilities of those events, highlight the need to create mechanisms for managing the risks and costs of extreme events in the state. The conflict between the application of the no-fault inverse condemnation standard with the CPUC's prudency standard has created a significant uncompensated asymmetric risk for investor-owned utilities. The practice of inverse condemnation in California courts, abutting against the CPUC's application of traditional prudency standards to megafire cost recovery, may result in material disallowances on the cost recovery of fire damages and has created significant uncompensated asymmetric risk for investor-owned utilities. This is not a sustainable financial model for the state or for utilities. If left unaddressed, this asymmetric risk harms the regulated utilities' ability to fund ongoing normal business.

An ROE allowance of around 500 basis points, creating additional income of about $1 billion per year, is consistent with the apparent size of the problem as seen from either recent past fires or from pricing evidence for catastrophe bonds. This is not to suggest that this is precisely the true or full cost of the risk, but to show that a large amount is almost certainly required to be roughly commensurate with the problem. Authorizing such an amount on top of the cost of equity (measured in conventional ways and reflecting risk positioning in the industry) would provide monies that offset the overhanging potential losses from fires. Importantly, such a premium is not needed because it is part of the ordinary cost of capital but rather because it is the amount needed to restore investor expectations of being able to earn the normal cost of capital.

Appendix A: Asymmetric Risk

The asymmetric risk facing an investor in a regulated utility can be analogized to the risk facing an investor in corporate bonds: Although they both have the opportunity to earn a stipulated return (the authorized ROE for a utility and the coupon rate for a bond), there is no guarantee for either and not much upside (though bonds can appreciate if interest rates fall after they are issued), while there is unbounded downside (albeit with low probability). For example, a corporate bond default can wipe out the entire value of the bond. Similarly, a utility investment is exposed to adverse "black swan" events that, while rare by definition, have the potential to severely handicap or even bankrupt the company and similarly wipe out much of its value.

By the nature of the utility business, these adverse events tend to have a strong regulatory flavor, such as:

- The natural gas price deregulation in the 1980s, which pushed two natural gas pipelines into bankruptcy, largely because they held bypassable long-term supply purchase contracts (for resale to distribution customers) that were well above spot market prices (which itself was created by the deregulation).
- The mid-1990s' vertical unbundling and wholesale deregulation of generation in the electric industry, which created significant stranded costs that were not always reliably or fully compensated.
- The California Energy Crisis of 2001, in which anticompetitive behavior in the poorly designed, newly-formed competitive wholesale market, combined with strict constraints on hedging imposed on the utilities, caused runaway spikes in power prices, leading to financial disaster for utilities.

A more recent and less dramatic, but still widespread, example of asymmetric risk is the regulatory disallowances of utility gas hedging costs in forward contracts that were struck when natural gas wellhead prices were high (2007–2009). These positions became rapidly and significantly "out of the money" as gas prices fell dramatically due to technological advances in shale gas development. There was no reward (in most cases) for utilities whose hedges ended up being in the money, but penalties and disallowances for those whose hedges turned out to be above spot prices in the delivery months. Hence, a one-sided, "heads I break even, tails I lose" proposition.

In order for investors to be comfortable with funding an entity facing substantial asymmetric risk, stipulated or "promised" returns must exceed the cost of capital. Again, the example of corporate bonds helps to show why this is the case. The best a bondholder can hope for is that the bond pays off in full and on time at its promised coupon rate of return. However, the bond might instead default, in which case the bondholder will receive something less than the promised coupon return. The expected return, the probability-weighted average of returns in scenarios ranging from the best (*i.e.*, no default) to the worst (*i.e.*, receipt of less than the promised payments) outcomes, will be below the promised return, and equal to the actual cost of capital. This means the yield on a junk bond is not its cost of capital, but the amount it needs to potentially collect to earn its somewhat lower cost of capital. This is illustrated in Figure 6 below.

Figure 6: Illustration of Risk and Return Scenarios

To remedy the possibility of loss relative to the promised payments, investors will bid bond prices down to a level where the yield to maturity compensates for the perceived likelihood of downside outcomes; that is, to where the prevailing yield, times 1 minus the probability of default, equals the true cost of capital. This is why bonds with poorer ratings have progressively higher yields compared to U.S. Treasury bonds of comparable maturity.

Notably, while investment in regulated utilities resembles investment in corporate bonds from the perspective of facing asymmetric risk (in that many investors turn to utilities for relatively steady, likely cash flows), utility investments differ in that it is not clear they are similarly compensated for "default" (asymmetric) type risks in their allowed levels of return. This is because regulators have traditionally adopted the academic definition of cost of capital—on which allowed returns are based—as equal to expected returns. This is a correct understanding of the cost of capital, but if it is awarded as if there is no chance of an asymmetric loss (*i.e.*, as if the factors of future costs and loads used in setting rates are the expected values), the actual expected return for the utility will be below the cost of capital.

Correspondingly, the financial economic models used to estimate the cost of capital reflect the expected outcome, not some analogue to the "promised" outcome. The Capital Asset Pricing Model ("CAPM"), for example, commonly relies on historical data to estimate betas and the market risk premium, and those historical data include bad outcomes as well as good ones. Similarly, the Discounted Cash Flow model ("DCF") uses forecasts of dividend or earnings' growth rates. Properly developed, those forecasts should take the possibility of bad, asymmetric outcomes into account, but so does the stock price against which the Internal Rate of Return ("IRR") of the projected cash flows is determined, so again there is no net revelation of the cost of these downsides. In neither case can we observe what the return would be that is equivalent to a corporate bond's "in full and on time" outcome and then adjust it to being a default-weighted yield. Thus, an allowed rate of return equal to the cost of capital does not provide an adequate rate of return for a regulated company faced with substantial loss from asymmetric risk, even when the cost of capital is estimated perfectly and the market is fully aware of the risks facing the regulated company.[87]

This result might seem paradoxical, because the cost of capital is also deemed by financial economists to be the required return for the underlying risks. Stock prices in an efficient market should rise or fall to a level where the expected return is also the required return. However, not all risks require a return, if they can be diversified away. This is often the case for asymmetric risks, to the extent they arise for idiosyncratic reasons unrelated to financial markets or the economy as a whole but instead are peculiar to the luck and specific circumstances of the company in question. At the extreme, consider a utility whose disallowance risk, or failed cost recovery risk from unforeseen market or regulatory conditions, is equivalent to flipping a coin and getting tails instead of heads. Such random risks have nothing to do with the economy, so they are deemed "nonsystematic" and are generally diversifiable (if held in a portfolio of many other securities in the market, some of which might benefit from the same problem).

This is not to say that such risks do not matter to investors or to the management of the affected companies. To the contrary, those asymmetric exposures reduce expected future cash flows and so reduce the value of the stock, but once that is reflected in the price, there is no additional premium for the problem. As an analogy, you could not expect to earn more on a home you bought in a region with hurricane risks than one in a region without that problem. Instead, the home in the hurricane region should sell for less, everything else being equal, and then appreciate comparably to elsewhere. To offset the hurricane risk, you need insurance, not a higher appreciation rate for the house.

Importantly, asymmetric risk cannot be ignored by regulators simply because it is not priced by traditional models, such as the CAPM or DCF models used to estimate the cost of capital. Under long-received and uncontroversial legal decisions and regulatory conventions, utilities must be entitled to a fair (*i.e.*, unbiased) opportunity to earn their cost of capital against their prudently invested capital. This assures they will be cost-based and adequately compensated compared to unregulated investments of similar risk. (Recall that unregulated investors can pick and choose

[87] There is an exception to this general rule, whereby some of the cost of the asymmetric risk may be priced: It is likely that as a political matter, most regulators are more willing and able to extend a cost recovery allowance for unexpected costs if the economy is doing well, while they may be very reluctant to do so if the economy is doing poorly. If so, there will be some portion of asymmetric losses that is more likely to be recoverable in proportion to the state of the economy. This will make them somewhat systematic, and over time that premium should be observed in the CAPM (once the period of history for the sampling includes such events and firms with comparable exposure). However, the state of the economy is certainly not enough to assure recovery in good times and nothing in poor ones, and even if that was the case, there would be net losses. So some, likely most, asymmetric risk is never priced in the measured cost of capital.

their targets to achieve their expected return, while utility managers and their investors cannot.) Thus, if regulatory allowances for revenue requirements and the associated return components are not somehow marked up to offset the black swan possibility of adverse events asymmetrically undermining cost recovery, this goal of risk parity with other financial investments will not be achieved. For utilities, the "promised return" is just the allowed cost of capital, which, unlike the bond yield, does not include a markup for default risk.

It is equally true that asymmetric risk is not compensated in the cost of capital of unregulated firms, yet they seem to get by without any requests or needs for supplemental compensation. Why then do utilities need an allowance? The answer is their obligation to serve. The utilities must invest whenever there is a need and then hope to get back their cost of capital. In contrast, unregulated firms can wait to invest until the need is so strong that they can expect to earn more than their cost of capital if no black-swan types of asymmetric events occur. Unregulated firms can also retain excess profits indefinitely when they are not incurring unlucky outcomes, while utilities are not usually eligible for such success profits.

In principle, you could solve this by assessing the asymmetric downside exposure and adding to the allowed ROE (above the measured cost) to make a utility revenue allowance more like a bond yield, probabilistically scaled up for "default" risk. However, it is generally not appropriate to do this for utilities because by providing compensation for an asymmetric risk that is within the control of the regulator to impose, the regulator may be tempted to later impose the loss on the utility, reasoning that the utility had already received compensation for the expected risk. The latter will necessarily be below the true cost of the risk, once fulfilled, if the ROE risk adjustment gives the regulator license to penalize. Under these moral hazard conditions, adequate compensation for the risk of disallowance would have to be equal to the full amount of the investment that could be disallowed.

Appendix B: Sources to Figure 2 and Figure 3

Sources to Figure 2

Label	Value	Source
2003 Western Wildfires	$3.9B	NOAA National Centers for Environmental Information (NCEI), "U.S. Billion-Dollar Weather and Climate Disasters 1980–2018," accessed September 2018, https://www.ncdc.noaa.gov/billions/events/US/1980-2018. Hereafter referred to as "NOAA Table." Smith, Adam B., Jessica L. Matthews, "Quantifying Uncertainty and Variable Sensitivity within the U.S. Billion-dollar Weather and Climate Disaster Cost Estimates," accessed September 2018, https://www.ncdc.noaa.gov/monitoring-content/billions/docs/smith-and-matthews-2015.pdf.
Hurricane Katrina	$125B	NOAA Table.
2007 Western Wildfires	$2.7B	NOAA Table.
Southeast Tornadoes	$10.2B	NOAA Table, 2011, Southeast/Ohio Valley/Midwest Tornadoes.
Las Conchas Fire	$614.5MM *(economic damage)*	Impact DataSource, "The Full Cost of New Mexico Wildfires," page 4, January 24, 2013, accessed April, 2018, https://pearce.house.gov/sites/pearce.house.gov/files/6%20Full_Cost_of_New_Mexico_Wild_Fires_1-24-13.pdf.
Hurricane Irene	$13.5B	NOAA Table.
Bastrop County Complex Fire	$600MM *(economic damage)*	Aon Benfield, "Costliest U.S. Wildfires: Economic Loss (1950-Present)," accessed April 2018, http://catastropheinsight.aonbenfield.com/Top10/U.S.-Wildfire-Economic-Insured-Loss-Events.pdf.
Nor'easter Snowstorm –	$3B *(economic*	Aon Benfield, "October 2011 Monthly Cat Recap – Impact Forecasting," November 3, 2011, accessed September 2018,

Label	Value	Source
All States	*damage)*	http://thoughtleadership.aonbenfield.com/ThoughtLeadership/Documents/201111_if_monthly_cat_recap_october.pdf.
Midwest/Mid-Atlantic Derecho	$2.9B	NOAA Table, 2012, Plains/East/Northeast Severe Weather.
Waldo Canyon Fire	$453.7MM *(insured loss)*	Rocky Mountain Insurance Information Association, "Wildfire," accessed April 2018, http://www.rmiia.org/catastrophes_and_statistics/Wildfire.asp.
Hurricane Sandy	$65B	NOAA Table.
Polar Vortex	$2.2B	NOAA Table, 2014, Midwest/Southeast/Northeast Winter Storm.
Butte & Valley Fires	$2B *(economic damage)*	Aon Benfield, "California wildfire claims breach $1bn as peak season begins, according to Aon catastrophe report," press release, October 8, 2015, accessed September 2018, http://ir.aon.com/about-aon/investor-relations/investor-news/news-release-details/2015/California-wildfire-claims-breach-1bn-as-peak-season-begins-according-to-Aon-catastrophe-report/default.aspx.
Hurricane Harvey	$125B	NOAA Table.
Hurricane Irma	$50B	NOAA Table.
2017 Western Wildfires	$18B	NOAA Table, 2017, Western Wildfires, California Firestorm.
2017 CA Wildfires	$180B *(economic damage)*	AccuWeather, "AccuWeather predicts 2017 California wildfire season cost to rise to $180 billion," accessed April, 2018, https://www.accuweather.com/en/weather-news/accuweather-predicts-2017-california-wildfire-season-cost-to-rise-to-180-billion/70003495.
Hurricane Maria	$90B	NOAA Table.
2018 Carr	$1.2B	Carr Fire total economic impact ($1B):

Label	Value	Source
and Mendocino Complex Fires	*(damages still being assessed)*	Aon Bonfield, "Global Catastrophe Recap," page 5, July 2018, accessed September, 2018, http://thoughtleadership.aonbenfield.com/Documents/20180809-ab-analytics-if-july-global-recap.pdf. Mendocino Fire insured losses ($56MM) as of September 6, 2018: California Department of Insurance, "The 2018 Mudslide and the 2017 & 2018 Wildfires," accessed September 2018, http://www.insurance.ca.gov/0400-news/0100-press-releases/2018/upload/nr106Insuredlosses090618.pdf. Mendocino Fire suppression costs ($200MM): Geographic Area Coordination Center, "National Large Incident Year-to-Date Report as of 09/07/2018," page 10, accessed September 2018, https://gacc.nifc.gov/sacc/predictive/intelligence/NationalLargeIncidentYTDReport.pdf.

Sources to Figure 3

Label	Value	Source
2018 Carr	$TBD	
	229,651 acres	California Department of Forestry and Fire Protection, "Carr Fire Incident Information," last modified September 4, 2018, accessed September 2018, http://www.fire.ca.gov/current_incidents/incidentdetails/Index/2164.
2018 Mendocino Complex	$TBD	
	459,123 acres	U.S. Department of Agriculture, "Mendocino Complex Information—September 7, 2018," News Release, September 7, 2018, accessed September 2018, https://inciweb.nwcg.gov/photos/CAMNF/2018-08-01-1630-Mendocino-Complex/related_files/pict20180807-105736-0.pdf.
2017 October Northern CA	$10B–$17.3B est.	$10B: Pacific Gas and Electric Company, Form 10-K for the Fiscal Year Ended December 31, 2017, p. 28, accessed April 20, 2018, http://investor.pgecorp.com/financials/sec-filings/default.aspx.

Label	Value	Source
		$15B: Fitch Ratings, "Fitch Downgrades PG&E Corp. to 'BBB+'; Places on Rating Watch Negative," February 26, 2018, Accessed September, 2018, https://www.fitchratings.com/site/pr/10021816. $13.5B–$17.3B: J.P. Morgan, "PG&E Corp. Company Liability Estimates Tell Us Little at This Stage," Page 2, June 21, 2018.
	181,000 acres	(Nuns, Tubbs, Atlas, and Redwood Valley only) California Department of Forestry and Fire Protection, "Top 20 Most Destructive California Wildfires," last modified 8/20/2018, accessed September, 2018, http://www.fire.ca.gov/communications/downloads/fact_sheets/Top20_Destruction.pdf.
2017 December Southern CA	$4B est.	Fitch Ratings, "Fitch Maintains Southern California Edison & Edison International on Rating Watch Negative," August 23, 2018, accessed September 2018, https://www.fitchratings.com/site/pr/10042429.
	281,893 acres	(Thomas Fire only) "Thomas Fire Incident Information," California Department of Forestry and Fire Protection, last modified March 28, 2018, accessed April, 2018, http://cdfdata.fire.ca.gov/incidents/incidents_details_info?incident_id=1922.
2015 Butte	$1.1B+ est.	Pacific Gas and Electric Company, "Form 10-K for the Fiscal Year Ended December 31, 2017," pages 29 and 138, accessed April, 2018, http://investor.pgecorp.com/financials/sec-filings/default.aspx.
	70,868 acres	"Butte Fire Incident Information," California Department of Forestry and Fire Protection, last modified October 15, 2015, accessed April, 2018, http://cdfdata.fire.ca.gov/incidents/incidents_details_info?incident_id=1221.
2015 Valley	$TBD	
	76,067 acres	"Valley Fire Incident Information," California Department of Forestry and Fire Protection, last modified October 15, 2015, accessed April, 2018, http://cdfdata.fire.ca.gov/incidents/incidents_details_info?incident_id=1226.
2007	$2.4B	California Public Utilities Commission, "Decision Denying

Label	Value	Source
Southern CA		Application," Application No. 15-09-010 (Filed September 25, 2015), Decision 17-11-033, page 3, November 30, 2017.
	516,465 acres	California Department of Forestry and Fire Protection, "California Fire Siege 2007: An Overview," page 67, n.d, accessed April, 2018, http://www.fire.ca.gov/fire_protection/downloads/siege/2007/Overview_CompleteFinal.pdf.
2003 Southern CA	$71MM	CPUC, "Opinion on the Reasonableness of San Diego Gas and Electric Company's Response to the 2003 Wildfires," Application No. 04-06-035 (Filed June 28, 2004), Decision 05-08-037, page 3, August 25, 2005.
	750,043 acres	California Department of Forestry and Fire Protection, "California Fire Siege 2003: The Story," n.d, page 4, accessed April, 2018, http://www.fire.ca.gov/downloads/2003FireStoryInternet.pdf.

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