Image Retrieved from Montana Natural History Center

REDUCING THE IMPACT OF AMERICAN WILDFIRES

Alex Knutson

University of Virginia

05/03/2018

REDUCING THE IMPACT OF AMERICAN WILDFIRES

Alex Knutson

May 2018

The Frank Batten School of Leadership and Public Policy

Prepared for the United States Forest Service

Disclaimer:

The author conducted this study as part of the program of professional education at the Frank Batten School of Leadership and Public Policy, University of Virginia. This paper is submitted in partial fulfillment of the course requirements for the Master of Public Policy degree. The judgments and conclusions are solely those of the author, and are not necessarily endorsed by the Batten School, by the University of Virginia, or by any other entity

Acknowledgement:

I would like to briefly thank all of those who assisted with this project. Thank you to my advisor, Prof. Ray Scheppach, for all of your guidance, insight, and assistance. Thank you, Prof. Bill Shobe, for your help in finding a client. Thank you to my contacts with the USFS, Dave Calkin and Matt Thompson, for our initial conversations on the issues pertaining to wildfire. Thank you to all of my Batten peers for their support, review, and camaraderie throughout the process. Finally, thank you to all of numerous Batten professors and faculty who helped us reach this point. You each have my sincerest gratitude.

Honor Pledge:

On my honor as a student, I have neither given nor received aid on this assignment.

-Alex Knutson

Contents

Executive Summary:

Wildfires take too many lives, destroy too many homes, and burn too many acres. Wildfires are a uniquely destructive natural phenomenon that impose costs on the health, land use, property, and environment of Americans. Currently, the United States Forest Service (USFS) struggles to efficiently and effectively mitigate the damage that wildfires impose. This problem has been exacerbated by macrolevel changes such as climate change, human migration to fire prone regions, and past wildfire management difficulties.

This paper aims to discuss a number of critical areas relevant to the issue of wildfire policy. For instance, it investigates current policies, the appropriations history of the USFS, and the USFS's management structure. It discusses anticipated technological change and how future assumptions factor into this analysis. It investigates the tradeoff between suppression vs. prevention efforts, costing based on risk, contract theory and the peaking problem, and public vs. private investment. These aspects, combined with research into best practices, serves as the intellectual basis for crafting a variety of policy options.

In order to reduce the impact of American wildfires, this paper considered several vastly different options. These alternatives approached the wildfire problem from a variety of avenues, attempting to find a number of creative solutions to this persistent problem. The first option would continue the status quo. The second option would be to change the appropriations classifications for forest fire suppression so that large forest fire suppression costs are funded like other natural disasters. The third option would be to create a federal risk tax for individuals living within six miles of the Wildland Urban Interface (WUI). The fourth option would allow wildfires that do not threaten the WUI to burn naturally. The fifth and final option would be to invest in expanding aerial firefighting resources and explore greater equipment sharing with state fire agencies.

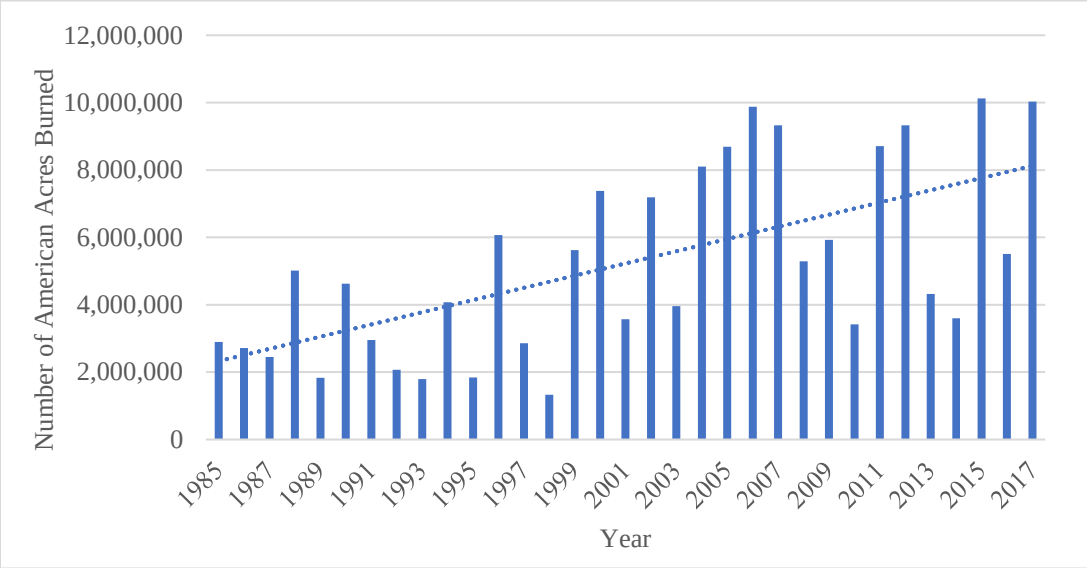
Each of these options were assessed by five, weighted evaluative criteria. These include determining each option's cost effectiveness, political feasibility, implementability, equity, and sustainability. After calculating and considering each aspect, this paper recommends option 3, to create a federal risk tax for individuals living within six miles of the WUI. This option had a cost effectiveness of 218,596 dollars per unit of increased effectiveness, scored medium on political feasibility and implementability, and scored high on equity and sustainability. While each option had its own noteworthy features, option 3 appears as the most balanced and reasonable option at this time. This paper then discusses an implementation strategy designed to increase the probability of adoption, while also ensuring the policy has the greatest opportunity to function as intended and avoid unconsidered errors.

Problem Statement and Introduction:

In 2017, American wildfires claimed over 40 lives, destroyed thousands of homes, and burned over 10 million acres of American land (Federal Firefighting Costs, 2017). In response, the United States Forest Service (USFS) spent nearly 2.4 billion dollars on wildfire suppression (Budget, 2017). The USFS now spends 52 percent of their overall budget on putting out wildfires and this is expected to rise as risks for more frequent and larger wildfires continue to grow

(Rising Cost, 2015). Current, American wildfires take too many lives, destroy too many homes, and burn too many acres. The proceeding sections will attempt to outline the impact of the high cost of fighting forest fires, as well as examine the relevant issues into best practices and potential solutions.

Figure 1: Total Number of American Acres Burned Over Time



Source: National Interagency Fire Center Data, 2017

Current Costs to Society:

American citizens face a number of repercussions for the high number of dangerous and costly wildfires. These costs can be broken down into five main areas: costs to human health and life, costs to the destruction of property, costs to the environment, and costs to government expenditures.

Costs to Human Health and Life: Wildfires can be life threatening and extremely damaging to a community. Since 1910, over 1,114 individuals have died as a direct result of wildfires (Wildland Fire Fatalities, 2017). A series of wildfires in northern California in 2017 alone killed 44 people (Disis, 2017). Forest fires can also contribute to respiratory infections, immune health problems, and can exacerbate mental health concerns (True Cost of Wildfire, 2010).

*Costs on Land Us*e: Forest fire also cause damage to the productivity of the land they burn. Forests and grasslands offer a number of direct and indirect benefits. Land can be used productively for farming, timber harvesting, or use in other human endeavors. Wildfires destroy structures and temporarily remove the natural stock of the land (Stein et al., 2013). Additionally, wildfires can damage areas such as National Parks, wildlife refuges, and historic sites that have indirect value such as recreation (such as hunting and fishing), relaxation, or cultural knowledge.

Costs on Property: Just as wildfires have the capacity to destroy large swaths of land, they also can destroy human structures and property. Most notably, wildfires have the capacity to indiscriminately destroy homes. A series of northern California Wildfires in 2017 destroyed

around 14,000 homes (Grad, 2017). A loss of a home imposes a high cost on families, insurers, and the overall community.

Costs to the Environment: Forest and grasslands serve as effective natural carbon storage mechanisms (Post and Kwon, 2000). When wildfires burn forests and grasslands, there is a large emission of CO_2 into the atmosphere, and a time-lag before that space can be used to store carbon. This is a known contributor to climate change, and one report detailed how California wildfires totaled between 5 and 7 percent of emissions from all sectors between 2001 and 2010 (Gonzalez et al., 2011).

Costs to Taxpayers: Another cost is simply the financial cost imposed on citizens. In order to spend 2.4 billion dollars on fighting wildfires, the government must raise the necessary revenue from taxes, fees, or deficit spending (Federal Firefighting Costs, 2017). Each category carries its own additional economic impacts such as the deadweight loss produced by taxes, reductions in consumer surplus from fees, or the additional interest payments on deficit spending. While 2.4 billion dollars in wildfire suppression is ultimately a small proportion of the 4 trillion-dollar federal budget, it is worthy of greater scrutiny as costs are projected to continue to grow.

Current Federal Policies and Appropriations History:

The USFS is an executive agency within the United States Department of Agriculture. The modern USFS was established by the Transfer Act of 1905. The current general mission of the USFS is to manage 193 million acres of national forest and grasslands, as well as cooperate with state and local entities to manage 500 million acres of non-federal forests (Overview, 2009). This mission makes them the premier wildfire suppression experts in the country. Given its role as a federal agency, the USFS is responsive to both internal rule changes, as well as compliant with federal laws.

There are two critical changes to federal wildfire management policy made in the past 15 years. The first is the 2001 Federal Wildland Fire Management Policy, which was an internal rule change to for the USFS. The 2001 Federal Wildland Fire Management Policy rules were an updated version of policies established in 1995. The Management Policy rules establish that wildfire suppression should be accomplished at "minimum cost, considering firefighter and public safety, benefits, and values to be protected, consistent with resource objectives" (Council, 2009, pg. 13). Additionally, the rules note the necessity for preventative activities, standardization of processes, and interagency cooperation (Council, 2009).

The second is an Act of Congress called the 2009 Federal Land Assistance, Management, and Enhancement Act (FLAME Act). The FLAME Act was meant to authorize funding for emergency wildfire suppression activities undertaken by both the USFS and the Department of Interior (Federal Land Assistance, 2009). It also established seven standards for more cost-effective fire suppression:

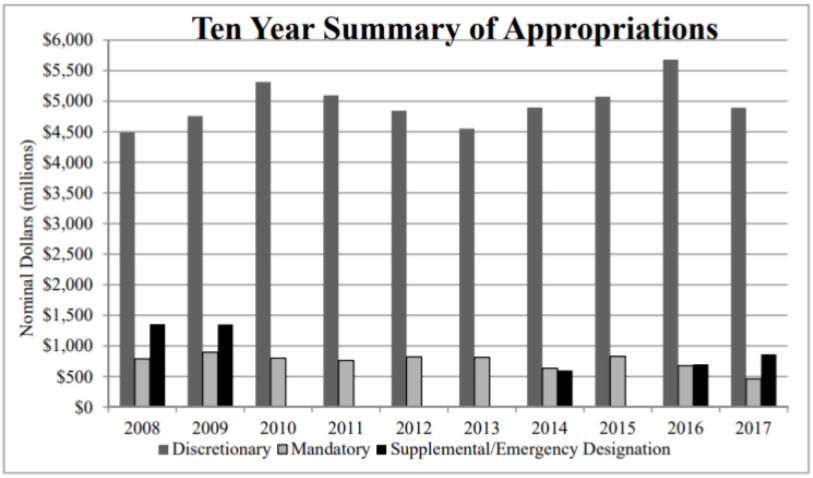
1. Most Cost-effective Means for Allocating Budget Resources
2. Reinvest in Non-Fire Programs
3. Assessing Risk to Communities

4. Employ Appropriate Management Response
5. Allocation of Hazardous Fuel Reduction Funding Based on Priority Projects
6. Assessing the Impacts of Climate Change on the Frequency and Severity of Wildfire
7. Study the Effects of Invasive Species on Wildfire Risk

Despite these changes in federal policy, the USFS continues to experience high costs for fighting wildfires and has difficulty simultaneously funding its multiple priorities (Rising Cost, 2015). This mismatch in the timing of appropriations and the increasing uncertainty of wildfires can frequently require supplemental and emergency appropriations (Gorte, 2013). One notable amendment to the FLAME Act that was proposed in 2015 was S.508. This bill would mandate fuel reduction and timber sales in proportion to suppression budget increases. However, a report by Lueck and Yoder (2016) expressed skepticism that, even if the bill were to pass, it would provide the necessary funding to counter the continually rising costs of forest suppression.

A ten-year summary of appropriations (as demonstrated by Figure 2) notes that the USFS's discretionary and mandatory funding has remained relatively consistent. While numerous emergency/supplemental appropriations have been made, they have not kept pace with the rising cost of fire suppression efforts and also are not issued on a consistent basis. As such, the USFS now spends 52 percent of their overall budget on putting out wildfires. This is expected to rise to 67 percent by the fiscal year (FY) 2025 as risks for more frequent and larger wildfires continue to grow (Rising Cost, 2015).

Figure 2: Yearly USFS Appropriations by Appropriations Type



Source: Graph obtained from USFS FY 2018 Budget Overview

Wildfire Management Matrix:

The USFS is an established bureaucracy with a series of checks and balances intended to keep its wildfire costs contained while effectively addressing wildfires. The agency is led by the US Forest Service Chief. The Chief, "provides broad policy and direction for the agency, works with the President's Administration to develop a budget to submit to Congress, provides information

to Congress on accomplishments, and monitors activities of the agency" (Agency Organization, 2018). From the Chief and his staff, budget authority is further delegated to the nine major USFS regions and their managers.

Deciding how and when to fund wildfire suppression efforts is determined by a complex model of risk management protocols, critical implementation strategies, and decision support tools. These are meant to prioritize "firefighter and public safety and determine the most effective response" (Budget Justification, 2018, pg. 149). Ultimately, this still conveys a large degree of autonomy to regional managers to conduct suppression and prevention efforts as they are deemed necessary by incident commanders. Because of the funding structure of the USFS, these decisions to fund suppression costs at or above their initial budgeted levels is based on case specific need throughout a wildfire season. This leads to frequent fluctuations of the overall amount being spent on wildfire suppression efforts (Hoover, 2016). The decision on how to reallocate funds from the USFS's discretionary budget appears to be made by regional managers working in tangent with the USFS's national headquarters. Together, they determine how to meet the necessary needs during suppression efforts while operating under their budgetary constraints (Budget Justification, 2018).

State and Local Policies:

While states are generally responsible for forest fires on nonfederal lands, forest fires cannot be contained by jurisdictional boundaries (Cook and Becker, 2017). Thus, forest fires that begin on federal lands can quickly spread to state or private lands, and vice versa. This highlights the importance of how the USFS is expected to cooperate with state and local entities to manage approximately 500 million acres of non-Federal forests (Overview, 2009). While state suppression entities will have drastically different policies from region to region, they frequently emulate the leadership and best practices demonstrated by the USFS. Additionally, state policy differences can serve as a laboratory for testing the impacts of different wildfire management practices. For instance, a peer-reviewed longitudinal study by Cook and Becker (2017) examined the best practices from different states when for funding their forest fire suppression efforts.

Even though states generally will be responsible for fighting nonfederal forest fires, local communities can also make policy decisions that have a drastic impact on the cost of wildfire suppression. Local ordinance on zoning can determine where homes and businesses can be built. This can be critical as one of the attributed reasons for rising wildfire suppression costs is the expansion of urban areas into fire prone regions (Gorte, 2013). Another way in which communities can impact wildfire suppression policy is via agreements with their states, such as for a pooled fire insurance policy, or by undertaking their own local fire prevention efforts (Winterton, 2016).

Anticipated Technological Changes:

Technology also presents an evolving area that could drastically alter the effectiveness of fighting wildfires. For instance, the USFS is currently investigating the potential of substantially altering its aerial firefighting fleet to incorporate low cost drone technology (Unmanned Aircraft, 2017). Unmanned aerial vehicles (UAVs) have demonstrated their value as monitoring and

reconnaissance aircraft when working to suppress forest fires, and a simulation paper written by Phan and Liu (2008) speaks highly of integrating using UAVs and unmanned ground vehicles (UGVs) to fight future wildfires.

Additionally, new efforts to monitor and predict weather that can better target wildfire efforts are plausible given the increasing rate of miniaturization of satellites. Currently, the Canadian government is using 178 "microsatellites" to observe and collect data on weather patterns and wildfires (Molenti, 2017). The additional data collection combined with increased computing power and more accurate prediction algorithms could allow for to more successful weather prediction, and better target wildfire suppression efforts (Molenti, 2017). While these technological improvements might significantly impact the way that the USFS approaches fire suppression, the timeline for the potential implementation of this technology is outside the scope of this report. This report will opt to interpret current policy changes assuming no monumental technological change in the near future.

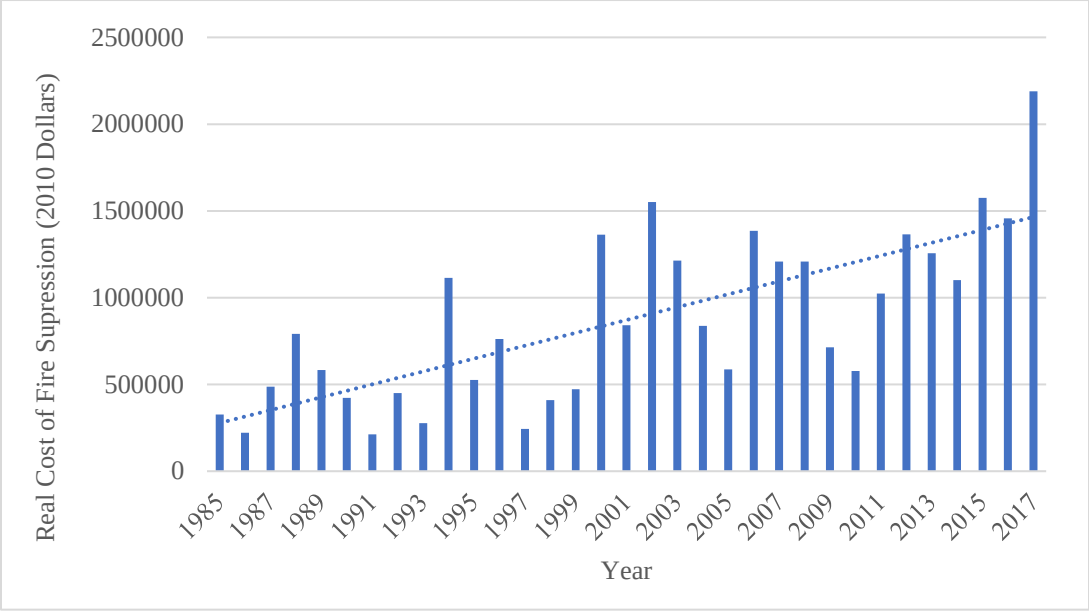
Key Decision Issues:

The proceeding section will provide a detailed investigation into the relevant issues using high quality data and literature published by subject matter experts. These issues will serve as the intellectual basis to investigate new policy solutions, and as the foundation for structuring policy options.

The Costs of Suppression vs. Prevention:

Fighting increasingly costly forest fires has an opportunity cost to the USFS. In order to accommodate the necessary spending on a shrinking budget, the agency has had to shift financial resources and greatly reduce other programs. This includes a 68 percent reduction in facility maintenance and capital investments for the USFS, a 46 percent reduction in the maintenance of the rural transportation network, and a 24 percent reduction in vegetation and watershed maintenance (Rising Cost, 2015). As a report by the USFS notes, operating within a constrained budget that sacrifices current to fund fires suppression efforts can actually increase the risk of future wildfires: "as more and more of the agency's resources are spent each year to provide the firefighters, aircraft, and other assets necessary to protect lives, property, and natural resources from catastrophic wildfires, fewer and fewer funds and resources are available to support other agency work—including the very programs and restoration projects that reduce the fire threat" (Rising Cost, 2015, pg. 2). This contributes to a negative self-replicating cycle in which fighting current forest fires simply shifts the resources away from preventing and avoiding future forest fires.

Figure 3: Yearly USFS Fire Suppression Expenditures Over Time



Source: National Interagency Fire Center Data, 2017

Another concern with expensive wildfire suppression is the lack of positive outcomes. A study by Katuwal, Calkin, and Hand (2014) demonstrates how traditional and expensive suppression efforts employed by the USFS are inefficient and do little to control forest fires. Katuwal, Calkin, and Hand seem sympathetic to the view that "large fires are sensitive only to weather and landscape characteristics and do not respond to active wildfire management" (2014, pg. 235). This would mean current fire suppression efforts fail to efficiently resolve the severe economic, social, and environmental costs of wildfires. While the authors do caution that their study should be interpreted against the practical implication of fire suppression, it may be necessary to both investigate methods that are more affordable and more effective at resolving the growing threat of wildfires.

In the ongoing debate regarding the best practices for reducing the impact of wildfires, experts tend to agree that the current high costs of suppression can be tracked back to decades of poor wildfire policy. As discussed in a policy review by Busenburg, wildfire policy "persistently focused attention on wildfire suppression rather than on wildland fuel reduction" (2004, pg. 153). This meant that as federal and state governments focused on ensuring that fires did not start, they failed to reduce or remove the unhealthy and unnatural build of smaller trees, fallen wood, and other fuel. This build up meant that when wildfires occurred, they tended to be larger and costlier (Gorte, 2013). While the impacts from fuel build up are well accepted, the most cost-efficient method for reducing the fuel buildup is an issue of contention between experts. The three most commonly accepted methodologies are for widespread fuel reduction, targeted fuel reduction, and the use of naturally occurring or controlled fires to reduce the overall fuel load in a given forest.

An article by Stephens et al. (2012) described the importance of addressing underlying fuel build up in a greater region might be the most cost effective long-term solution. The authors explain that currently, only 2 percent of forests experience any form of preventative management, including fuel reduction. Additionally, the authors note that, "designing more fire-resistant stands and landscapes will likely create forests that are more resistant and resilient to the changes imposed on them by climate change" (Stephens et al., 2012, pg. 558). While the authors note more experiments are necessary to repeat their findings, their research seemed to be supported in other studies such as a forest management review conducted by Mitchell, Harmon, and O'Connell (2007). Ultimately, these papers fail to quantify the specific cost of wide spread fuel treatment and forest design, and leave serious questions about their immediate viability.

Another proposition from the research is for more targeted and specific preventative efforts that could reduce the cost of forest fire suppression. These efforts would mostly consist of fuel treatment and preventative design in the wildland-urban interface (WUI). The WUI is where urban areas, such as residential and business communities, borders either private or public wildlands (Theobald and Romme, 2007). Given that fire agencies such as the USFS have mandates to prioritize the protection of human life and developed property, expansions in the WUI are logically linked to higher costs of fire suppression. In a peer-reviewed national analysis by Theobald and Romme found that national WUI spaces have expanded by 52 percent since the 1970's. A study conducted into forest management practices by Winter, Vogt, and Fried (2002) appeared to suggest targeting fuel reduction in the WUI through a variety of methods is beneficial. An additional controlled study by Ager, Vaillant, and Finney (2010) found that preventative practices in the WUI resulted in "higher expected loss of large trees, but relatively lower burn probability and flame length within structure buffers" (pg. 1556) indicating potential mixed results.

The final major field of practice tends to assert that fuel reduction and preventions cost effectiveness is overexaggerated, and that the most efficient means of reducing fuel build up is to actually allow fires to burn and naturally reduce fuel loads. A provocative paper by Houtman et al. (2013) simulated the impacts of allowing fire to burn on the anticipated effects of vegetation, suppression effectiveness, and suppression costs. They found that, while further research is necessary, "the potential cost savings may be substantial" (Houtman et al., 2013, pg. 871) as opposed to either widespread or targeted fuel treatment. Additionally, an analysis by O'Toole argues that fuel treatment is only an appropriate prescription for approximately 15 percent of national forests, with the needs of the remaining 85 percent forests being much more diverse than just fuel treatment. However, both of these studies fail to articulate how one should prevent small, manageable fires from morphing into much larger and dangerous fires that threaten the health and safety of the forests and those who live near them.

One concern throughout the literature is that many of these studies are conducted in ways that limit their external validity. These studies also tend to suggest that methods should differ greatly depending on the specific region, forest, and fire type. However, allowing for fires to naturally reduce fuel when possible and allowing for fuel and adaptive treatment around WUI when

necessary might be the best way to mix the necessity of prevention and suppression in a more cost-effective way.

Costing Based on Risk:

As discussed earlier, it has become a widely stated position that developing houses near fire prone areas have contributed to the rising cost of fighting forest fires, have led to more deaths, and have led to more homes destroyed (Gorte, 2013). A quantitative report by Gude et al. (2013) found that there exists a positive linear relationship between the cost of fire suppression efforts and the number of houses within six miles of an active fire. While this report was focused specifically on data from California, it continues to support the position that increased urbanization around woodland areas is a dramatic influencer in the overall cost of wildfire suppression.

Given this, a logical conclusion influenced by basic economic theory suggests that taxing homes based on the risk of exposure to fire suppression may reduce the number of homes built in dangerous areas, encourage migration out of fire prone regions, as well as generate an additional funding stream for the USFS. This idea is supported by some research into taxation's effects on behavior, for example a study by Manning et al. (1989) that observed that increases on taxes on cigarettes reduced the number of smokers. While smoking risk is not equivalent to fire risk, the underlying concept of pricing based on risk is helpful and indicates an arena that could benefit from additional investigation.

Currently, fire suppression efforts are paid for through general tax revenue (Lueck and Yoder, 2016). As a result, two studies by Kousky and Olmstead (2014) and Yoder (2012) found that private land owners near forests have weak incentives to either reduce the risk of fire or relocate based on the risk of fire. This presents a basic moral hazard problem in which homeowners are both contributing to a rise in the cost of wildfire, but bare little to no direct incentive to reduce the overall cost of wildfire suppression or prevention efforts.

While pricing based on risk may not be present at the federal level, a study by Cook and Becker (2017) has found that some states have employed landowner assessments on risky land to great effect. The report notes the necessity of these funds as having helped both Oregon and Washington fund their forest fire suppression efforts (Cook and Becker, 2017). A report by Haas, Calkin, and Thompson (2013) notes that modeling fire simulations has the potential to be both a better information tool on disclosing risk, but could also be used as a tool to price more dangerous regions. Finally, a peer-reviewed survey report compiled by Fried, Winter, and Gilless (1999) found homeowning respondents had a strong willingness to pay for incremental risk reductions in losing their homes to forest fires, even with insurance against such outcomes.

The literature, while incomplete on the question of costing based on risk, tends to support the conclusion that incremental increases on taxing homes in fire prone regions could both reduce the number of homes built in these regions, thus reducing the cost, and create additional funding. Both a series of theoretical papers as well as best practices emerging from states such as Oregon and Washington note these possibilities. While further research appears necessary into the specifics, these factors may be influential in designing future policy.

The USFS and Cost Control:

While costs of wildfires due to trends in prevention vs. suppressions and increases in housing risk are uncontrollable, some literature has become critical of the USFS at controlling its own costs. An analysis by Lueck and Yoder claims that "current policy reforms indicate they would do little to change the underlying incentives" (2016, pg. 34) of suppression organizations, allowing for continued mismanagement and rises in costs. Indeed, a USFS report notes that "part of the cost escalation may be due to a lack of discipline in cost containment and adequate cost benchmarking of incidents" (Overview, 2009, pg. 27). Additionally, an analysis by Calkin, Thompson, and Finney notes that "existing management incentive structures result in policy implementation that is straining the resilience of fire adapted ecosystems and the communities that reside in and adjacent to them" (2013, pg. 1) Combined, it seems important to investigate questions of the efficiency of the USFS and the potential theories on moving responsibilities and resources away from the agency. This conversation will focus most notably on the expensive use of aerial firefighting resources.

The Peaking Problem and Long-term Contracting:

One of the essential questions in contracting aerial firefighting resources is the efficiency of longer-term contracts when operating under uncertainty and during peak pricing periods. Exclusive use (EU) contracts are longer-term contracts that retain a certain firm's goods or services for a fixed period of time. In the case of aerial firefighting resources, this typically entails retaining a private company and their aircrafts, and maintenance expertise. Pilots are typically provided by the forest service (Lavender, 2013). Call-when-needed contracts tend to be added on when unexpected shocks, such as greater than anticipated fire intensity/number, arise and additional resources are deemed necessary. Additionally, these contracts often occur during the summer and experience "peak pricing", also known as charging higher prices during high use periods (Wenders, 1976). This peak pricing can also be a contributor to the raised price of private contracting as these ad hoc needs are expressed more in the form of urgency than established and continuing need that can be employed during nonpeak periods (Gabbett, 2018).

When considering the origin of EU contracts, they are most frequently observed in "a tool for managing the intellectual property of firms in `high technology' industries" (Anad and Khanna, 2000, pg. 103). While aerial firefighting is a high-tech industry in the sense that it uses advanced machinery and tactics, the competition between companies is frequently for government contracts. This implies the crux of EU contracts are less concerned with limiting information exchange, and more concerned with retaining controlling a quality resource in a monopsony environment, given that EU "prices favoring buyers" (Armstrong and Wright, 2007, pg. 379). When considering the academic consensus that climate change will lead to greater wildfire intensity and frequency, this means the concerns with contracts shift to concerns with managing uncertainty and variability of wildfires from year to year (Millar, Stephenson, and Stephens, 2007).

The literature clearly conveys that contracting under uncertain conditions and during peak periods is difficult and potentially costly. An influential social psychology randomized control trial (RCT) by Tversky and Kahneman (1974) explored the heuristic and biases individuals face

when making decisions under uncertainty. Tversky and Kahneman conclude that, "heuristics are highly economical and usually effective, but they lead to systematic and predictable errors" (1974, pg. 1124). When combined with an analysis by Fischhoff (1975) on hindsight bias, it is clear how EU contracts can systematically error due to the human natures preference for recent and observable trends over actual statistical prediction (Larrick, 2004). These systematic errors suggest that uncertainty will consistently result in an improper combination of EU contracting, and as a result, lead to either more or less CWN contracting to correct for these errors. In addition to the human error in contracting on variable information, there are also academic concerns with the government contracting in specific.

The literature is fairly consistent that government contracting, independent of the question of public vs. private ownership, is only efficient under particular circumstances. For instance, an analysis by Prager (1994) found that government contracts are at their most efficient when they capitalize on the scope, scale, or organization of the contracted company. Additionally, a developmental paper by Schooner (2002) outlines the key aspects necessary to make an efficient and effective government contract: "(1) competition; (2) integrity; (3) transparency; (4) efficiency; (5) customer satisfaction; (6) best value; (7) wealth distribution; (8) risk avoidance; and (9) uniformity" (pg. 103). In an academic book by Lavery (1999), government contracting should only occur when "the service is tangible, monitoring costs are not excessive, and a competitive market exists for services" (pg. 11) These academic articles begin to establish the necessary criteria for when an effective contract can be established.

Private vs. Public Investment:

Outside of the considerations on proper government contracting, there is also the larger question of private vs. public partnership on aerial firefighting resources. While there has been limited research into this specific question, there are broader studies that can be examined questioning the degree of state ownership. While contracting is often seen as a more cost effective and efficient form of providing goods and services, common academic criticisms are frequently leveled at the actual cost savings private companies deliver, the perceived gap in poorer services, a lower threshold for proper management, and the consistent potential for corruption (Larvey 1999).

A frequent economic argument for private contracting in place of public investment is the perception of greater technical expertise and innovation in private markets over public agencies. Private enterprise only serves as a viable alternative when "incentives to innovate and to contain costs {are} strong" (Shleifer, 1998, pg. 25). However, an empirical analysis by Mowery (1983) demonstrated that private investment for research or innovation does not serve as an equivalent substitute to the services provided by public entities. While these incentives typically exist in a monopsony, there are situations where private markets will outpace the ability of private enterprise to innovate and reduce cost.

As demonstrated, the frequent conversation in the scope of government comes down to a question of cost and expertise. In a quantitative economic research paper that used prisons as their case study, Hart, Shleifer, and Vishny (2017) found that a combination of public-private partnership can result in the best balance between costs and efficacy. For instance, simple

services such as garbage collection, and complex services such as weapons production are best left to private entities given their ability to innovate and particular expertise. However, when providing for large and complex policy apparatuses, frequently public institutions are more effective at service delivery (Hart, Shleifer, and Vishny, 2017). However, the authors also note that many "arrangements is a great deal more complicated and requires a much more detailed model of competition, contracts, and regulation" (Hart et al., 2017, pg. 1159).

There are two critical reports that offer this form of specific analysis towards the current fleet design of United States Forest Service. One report published by a Joint Legislative Audit and Review Committee of Washington State found that "maintenance and operation costs for its own fleet of helicopters was less expensive than exclusive use contracts" (Bowden, 2011, pg. 23). This conclusion was made under the additional condition that more investigation was necessary to investigate the specific cost pattern and deployment requirements. Additionally, a RAND study into the fleet effectiveness for the USFS also seemed to suggest that their firefighting capabilities could be better optimized through greater ownership of particular aircraft (Keating et al., 2012). However, this study also called for greater research into this specific question before definitive conclusions could be reached.

International and Domestic Best Practices:

While each of the key issue discussed above are important, local and international governments have begun to experiment with different policy solutions that reduce the frequency and impact of wildfires. For instance, a variety of European countries have implemented controlled burning a greater number of programs to mitigate the risk of large and costly wildfires (Montiel and Kraus, 2013). Part of this can be attributed to a cultural history of controlled burns throughout several European countries. Countries like France, Portugal, and Spain are leading the way in innovative prescribed burning practices. For instance, the literature suggests these countries now follow practices that target burning against homogenous fuel types, prescribed burning programs for understory burning, and using controlled burns to preemptively slow down and inhibit the spread of larger fires (Montiel and Kraus, 2013). However, European fire agencies still acknowledge the need for further study of prescribed burning practices before they are universally integrated into fire management practices (Valkó, Török, Deák, and Tóthmérész, 2014). This concern is mostly centered on the grassland regions in Estonia, Germany, the Netherlands, Sweden, and Switzerland (Valkó et al., 2014).

While incorporating prescribed burning has been the primary policy initiative in Europe, other countries continue to experiment with ways to better monitor and analyze wildfires and their costs. A report in Canada has recommended a series of policies that are designed to contain the projected costs of wildfire, including "reducing the size of fire exclusion zones, responding to fewer fires, monitoring rather than aggressively attacking more fires, or re-evaluating suppression options after attacked fires have escaped initial attack" (Hope et al., 2016, pg. 17). Additionally, the Canadian government has also begun to invest more in managing and sharing data surrounding the size, scope, and costs of wildfires in an effort to better analyze trends and improve policy options (Hope et al., 2016).

There are emerging best practices from Australia that encourage limiting construction in the WUI, considered to be more sustainable land use planning (Syphard, Massada, Butsic, and Keeley, 2013). Using econometric modeling, Syphard et al. (2013) anticipate that better land management practices that shift human housing and developments away for the WUI are expected to significantly reduce fire risk even as threats from forest fires grow due to macrolevel shifts. The authors note that "land use planning for wildfire has yet to gain traction in practice, particularly in the United States" (Syphard et al., 2013, pg. 3). While they have not gain widespread traction, some states have begun using taxes, fees, and greater restrictions of WUI construction. For instance, states such as Washington and Oregon have additional fees they levy on households built within the WUI (Cook and Becker, 2017). While these fees are unsubstantial (around 200 dollars a year), these fees might be considered well within the willingness-to-pay arena, and thus are not high enough to act as a behavioral altering tax.

States have also been helpful in exploring a variety of methods for limiting the damage of wildfire and continue to serve as policy laboratories. While it is difficult to assess all states independently, many states have found successful in trying to create a better relationship with industrial land users and private land owners (Cristan et al., 2015). A comprehensive literature review by Cristan, Aust, Bolding, Barrett, Munsell, and Schilling (2015) found that states are often best prepared to treat the specific ecosystems and forests, and that these differences can make it difficult to prescribe nationwide best practices. However, these state practices often suggest a well-rounded approach, where preventative efforts such as mechanical fuel processing are paired with culture change, effective communication, and increasing fire knowledge to at risk populations (Fire Science, 2018).

Even though states generally will be responsible for fighting nonfederal forest fires, local communities can also make policy decisions that have a drastic impact on the cost of wildfire suppression. Local ordinance on zoning can determine where homes and businesses can be built. This can be critical as one of the attributed reasons for rising wildfire suppression costs is the expansion of urban areas into fire prone regions, a new best practice research suggests stricter building requirements, zoning laws, and land maintenance might limit the impact of wildfires on human communities (Gorte, 2013). Another way in which communities have had a successful impact on wildfire suppression policy is via agreements with their states, such as for a pooled fire insurance policy, or by undertaking their own local fire prevention efforts (Winterton, 2016).

Policy Options:

Option 1 - Continue with the Status Quo:

The status quo continues to present the most realistic and most risk averse present course of action, with the least potential for unintended consequences and costly interruption. Continuing the status quo allows for research to continue into best practices for reducing the impact of wildfires at the lowest cost. This option also requires a number of assumptions. Two future trends that assign a degree of uncertainty to the status quo are potential changes in the USFS's funding stream, as well as potential changes in technology. However, this report assumes that Congress will not appropriate additional budgetary resources, and that no significant technological improvements will occur in the next ten years.

Option 2 - Change Appropriations Classifications So That Large Forest Fire Suppression Costs Are Funded Like Natural Disasters:

This option would change the funding stream for the USFS so that catastrophic forest fires are funded more like other natural disasters (such as hurricanes and earthquake) and don't reduce funds from preventative programs. This option would strongly mimic the key elements proposed under the Wildfire Disaster Funding Act. Under this option, the Disaster Funding Section 251(b)(2)(D) of the Balanced Budget and Emergency Deficit Control Act of 1985 would be changed so that fire suppression was funded separately from the USFS's discretionary budget. This would create a separate funding structure for the USFS, one specifically for its suppression efforts, and one for all other non-suppression related USFS activities. Thus, the activities for non-suppression related activities could remain consistently funded at roughly 3.1 billion per year (Budget Justification, 2018). Meanwhile, the suppression efforts for each given year could be funded based on ten-year averages with additional revenue as needed. For FY 2018, this would be 1.46 billion in new budget authority (S.1842, 2017-2018). Both budgets for the USFS would be funded from the general revenue of the United States.

The concepts outlined in the bill are very popular and have attracted a number of bipartisan cosponsors. This policy option would make it easier for the USFS to receive funding to suppress the most costly and catastrophic fires while safeguarding the resources that are intended to be reserved for prevention. While this in the long run would be designed to reduce costs by reducing the overall risk of fires, there are concerns that this policy would simply shift the internal burden of funding within the government. As such, this seems to keep the current structure for fighting large and costly fires, with the hope that preventive actions reduce the long run cost through reducing frequency and severity of naturally occurring wildfires. This could also shift the burden of long term funding for fire suppression away from being logistically managed by the USFS and require greater Congressional action to ensure the long-term sustainability of wildfire suppression costs.

Option 3 - Impose Federal Risk Tax for Individuals Living Within Six Miles of the WUI:

Homeowners that live near or in the WUI of federal forests currently bare no additional cost for living in a fire prone region. However, when a fire threatens their property and safety, the USFS

is forced to engage in dangerous and costly fire suppression at no additional cost to the homeowner. Given that the current pricing structure does not reflect the increases in risk, this option would have owners who live within six miles of a federal WUI face a new, tiered federal risk tax. The pricing of this risk tax would be designed to incentivize constructing homes and living in less fire prone regions, while also creating additional revenue to assist the USFS. The property tax schedule would operate on the following tiered model:

- Homes within 0-2 mile of federal WUI (Highest Risk Homes): **0.8%** annual federal property tax rate
- Homes within 2-4 miles of federal WUI (Medium Risk Homes): **0.4%** annual federal property tax rate
- Homes within 4-6 miles of federal WUI (Lower Risk Homes): **0.2%** annual federal property tax rate

This tax is designed to incentivize behavior change. After looking at the studies on the willingness to pay for fire suppression related services, these taxes are anticipated to be above the willingness to pay for many homeowners and would thus begin to incentivize behavioral change (Kaval, Loomis, and Seidi, 2007). The tax revenue would contribute towards a newly created "Wildfire Trust" that would be used to fund catastrophic forest fire suppression efforts and allow other budgeted priorities, such as preventative efforts, to continue without impact. Thus, even if this risk tax would serve primarily as a behavioral change tool, any additional revenue generation would be able to be contributed toward fire suppression efforts.

Option 4 - Allow Wildfires That Do Not Threaten the WUI To Burn:

There is currently a body of research that suggests one of the most cost-effective method for reducing long term fire suppression costs is to permit wildfires to burn themselves out. Specifically, these fires would be ones that don't immediately threaten the WUI and would be expected to be contained by natural or manmade boundaries. By allowing smaller and less concerning fires to burn unabated, the USFS could invest more of its resources in preventative efforts and selectively fight higher risk fires that threaten the WUI. This option would be structured similarly to successful policies in Canada and Europe that utilize a combination of targeted preemptive burns to reduce fuel loads, and changes in fire monitoring to allow reasonable fires to naturally reduce the long run threat of fires.

However, controlled burns are often seen as a contentious policy shift. Some bodies of research assert the specific opportunities for controlled burns are too forest specific to generalize into a single policy (Calkin and Gebert, 2006). By acknowledging the inherent nuances in specific fires, this would seemingly shift more responsibility of basic wildfire suppression to state and local entities, as federal forests would now be more prone to sustained and potentially problematic fires. While this is perhaps a riskier option, it presents an opportunity to redefine modern wildfire suppression, while also granting the USFS's more flexibility in how it fights wildifres. This would require greater cooperation and monitoring efforts between the USFS and state fire agencies.

Option 5 - Invest in Expanding Aerial Firefighting Resources and Equipment Sharing:

It seems that both contracting theory and theories on public vs. private ownership suggest that it might be more efficient for the government to outright own a greater number of aerial firefighting resources, rather than continue to pay for expensive private contracts (Hart, Shleifer, and Vishny, 2017). Under this option, the USFS would make a 65-million-dollar investment in updating its aerial fleet and explore methods to better partner with state and local firefighting aerial fleets for equipment sharing. The partnership model could follow a model similar to how the National Guard shares training responsibilities and equipment. The projected cost savings would most likely not result for several years after the investments, until the new additions and logistical sharing can be fully integrated. Additional potential benefits of this option would be an increase in the quality of aerial firefighting (as anecdotes are that contractors are frequently less efficient) and well as the ability to more adequately respond to macrotrends in wildfire suppression (such as fighting larger fires over a greater fire season and in multiple jurisdictions). However, the immediate challenges in acquiring the resources and reshaping aerial cooperation might present serious hurdles.

Evaluative Criteria:

When considering the variety of option, this paper intends to analyze the effectiveness of each proposed policy along five criteria that vary in weighted importance:

1. Cost Effectiveness (65 percent weight)
2. Political Feasibility (15 percent weight)
3. Implementability (10 percent weight)
4. Equity (5 percent weight)
5. Sustainability (5 percent weight)

Cost Effectiveness:

Cost effectiveness is the most critical criteria considered in this analysis. The ideal outcome for any policy change should be measured against the USFS's ability to effectively meet their fire suppression guidelines at the lowest cost. These guidelines, as prescribed by the *Guidance for Implementation of Federal Wildland Fire Management Policy* (2009), emphasize "wildland fires are suppressed at minimum cost, considering firefighter and public safety, benefits, and values to be protected, consistent with resource objectives" (pg. 14). In its most basic terms, this means that the ideal unit of measurement of effectiveness is a measurement of the safety for individuals, risk reduction in future fires, and protection of manmade and natural resources. Safety is both the immediate risk to the lives of the fire fighters and citizens threatened. Risk appears to convey the impact that the fire will have not only in the short turn, but also the potential benefits the fire may have in the long run health and stability of the forest ecosystem. Finally, resources that need to be protected are often are associated with manmade resources, such as homes, business, and personal property. Combined, managing safety, risk, and resources is the crux of the USFS's mission when engaging in wildfire suppression activities, and the ultimate measure of effectiveness.

While these elements make logical sense, it is important to determine a quantifiable criterion that can be ascertained from these more abstract ideas (such as safety, risk, and resources). The criteria for safety can be loosely be considered lives lost to individual firefighters and citizens due to wildfires. To try and quantify the elements of resource damage, it seems as though this could be realistically and reasonably accomplished through observing the total number of acres burned. The WUI has often been used as a means to best understand the risk to communities and as a way to measure the potential damage that wildfires have on homes (Martinuzzi et al., 2010, pg. 10). Even though these tools may not perfectly align with the complex and ideal wildfire suppression criteria, we hope to be able to serve as an effective unit of measurement to evaluate the impact of forest fires in a quantifiable way.

In order to provide a standardized set of assumptions, it is important to create an index for applying the different aspects of effectiveness. A policy can be determined to be "effective" if it is able to reduce the number of lives lost, number of homes destroyed, and/or the total number of acres burned. While each of these are critical, they must be weighted in a reasonable way. According to the Department of Transportation (DOT), the value of a statistical life in 2016 was 9.6 million dollars (DOT, 2016). According to the National Association of Realtors, the median value of an American home in 2017 was 227,300 dollars (Existing Homes, 2018). Finally, a value of an acre of forest (including the natural resources, recreational use, and environmental contributions) is equivalent to roughly 2,000 dollars according to a report by Penn State (Jacobson, 2017). Using these dollar values assumptions, we can create an index of a single unit of effectiveness.

One unit of effectiveness is equivalent to one of the following:

- A single life saved
- 42 homes saved
- 4,800 acres saved

Meanwhile, cost will be considered the expected direct and indirect costs of enacting each policy. These costs include the material costs, managerial costs, and labor costs required to enact the policy, and ensure its effectiveness and continuation. Additionally, the incorporated projected spillover costs, externalities, and opportunity costs on society. These will attempt to be measured in dollars and use comparable projects and projections whenever available to justify the expected financial cost. Whichever policy can result in the lowest cost over the greatest value of effectiveness will receive a higher rating (cost-effectiveness ratio = total cost/units of effectiveness). As such, this criterion is intended to be weighted at 65 percent of the overall importance in this evaluation.

Political Feasibility:

Political feasibility is the next most important concern when evaluating potential policy options. Any proposed policy should be able to be passed by the relevant authority in order to be seriously considered. As such, when interpreting political feasibility, it is important to consider whether the policy will need to be enacted internally or externally of the USFS. Different policy options will require different bodies of support in order to be enacted. This can be separated into

either Congressional support, or interagency support with contingent approval from the Office of Management and Budget (OMB).

For instance, a policy creating a new national tax or changing the funding structure of the USFS will require Congressional action in order to be codified into law. In order to determine the political feasibility when a law is the responsibility of Congress, it is important to understand the relevant committees and subcommittees the law would be referred too, the relative ideology of the issue, the different avenues of support, and the overall complexity of the regulation. On average, we could anticipate a friendlier committee, a less ideologically contentious policy, and a more streamlined policy would be more politically feasible then the opposite.

Meanwhile, an adjustment to the USFS's guidelines for permitting wildfires to be burn longer or changing the composition and sharing of wildfire suppression resources would require a change within the USFS hierarchy with approval and consultation with the OMB. In order to determine the political feasibility when a change is the responsibility of the USFS, it is important to understand how the rules change would impact managers, the relative evidence and support for the issue, key proponents and opponents, and the overall complexity of the regulation. On average, we could anticipate that a policy that had a limited impact on manager discretion, with a wide variety of support in best practices and in data, and a policy with strong internal proponents would be more politically feasible then the opposite.

While political feasibility is critical, this report ultimately aims to focus first on the most cost-effective policy, and then on the policy that can best be enacted. Thus, this criterion is intended to be weighted at 15 percent of the overall importance in this evaluation. It will be scored on a spectrum from low political feasibility, to high political feasibility.

Implementability:

The third most important concern when evaluating potential policy options is its implementability. The USFS's wildfire suppression efforts are critical to the safety of thousands of Americans and the protection of hundreds of millions of acres of forests. As such, any policy must be able to be implemented in a reasonable, unobtrusive, and seamless way in order to avoid disrupting the incredibly important mission of the USFS. When evaluating along this criterion, it is important to consider the number of external stakeholders that would be involved in passing a policy, as more stakeholders generally suggest a more difficult experience having a policy implemented. Next, it is important to see how the additional requirements would align with the USFS's existing priorities and infrastructure, as a completely new policy would be more difficult to implement then a policy that complements existing functions. Finally, to understand implementability, it is important consider the possible timeline for adopting the new policy, evaluating its effectiveness, and allowing it to reach full maturity. More complex policies would expect a longer timeline and thus, be harder to implement. This criterion is intended to be weighted at 10 percent of the overall importance in this evaluation. It will be scored on a spectrum from low implementability (indicating greater difficulty when attempting to implement the policy), to high implementability (indicating lesser difficulty when attempting to implement the policy).

Equity:

This criterion will focus on balancing the benefits of policy change for general citizens at the expense of property owners in fire prone regions. Equity is critical as the costs of the policy option should, in general, be targeted towards those receiving the most benefits. Currently, homeowners and residents living in more fire prone regions receive a disproportionate amount of benefits when compared to residents that do not reside in fire prone regions. As such, the ultimate costs of the policy change should mostly impact the individuals whom are most responsible for the high cost of fire suppression. Evidence suggests that property owners and residents in riskier locations are a root cause of the rise in fires suppression costs, and thus should bear the greater burden on any policy changes. Meanwhile, general taxpayers who do not benefit as much from fire suppression efforts would be expected to bare less of the policy's costs.

Equity will be measured by looking at the shift of the direct and indirect costs of policy change between these two groups. A positive change in equity would see homeowners in fire prone regions experience additional costs to support policy change. A negative change in equity would see general citizens experience additional costs to support policy change. While a more equitable policy is preferable, there are a number of policies that could substantially reduce the costs of fire suppression while also not targeting the beneficiaries as the primarily responsible party. As such, this criterion is intended to be weighted at 5 percent of the overall importance in this evaluation. It will be scored on a spectrum from low equity, to high equity.

Sustainability:

Finally, sustainability is critical as the policies should be able to be continued across a broad time horizon and continue to deliver benefits beyond the immediate future. In order to consider this criterion, sustainability seems to be a factor of measuring the method of being enacted, the projected long-term support for a policy, and the timeline for expected returns. A policy that is codified into law would be expected to be a more sustainable policy on average when compared to an internal agency rule change. Meanwhile, policies that appear less contentious and have long-term allies (such as powerful internal and external stakeholders) seem more likely to retain support even after a policy is introduced. Finally, policies that are expected to return benefits over a longer period of time as opposed to immediately return benefits would be considered more sustainable. This criterion is intended to be weighted at 5 percent of the overall importance in this evaluation. It will be scored on a spectrum from low sustainability, to high sustainability.

Cost Effectiveness Calculations:

As established in the evaluative criteria section of this appear, it is important to create an index for applying the different aspects of effectiveness. A policy can be determined to be "effective" if it is able to reduce the number of lives lost, number of homes destroyed, and/or the total number of acres burned. One unit of effectiveness is equivalent to each of the following and a justification can be found in the evaluative criteria section:

- A single life saved
- 42 homes saved
- 4,800 acres saved

In order to anticipate the relative changes in effectiveness, it is important to establish the expected baseline for each of these three effectiveness measures. Then, research into best practices, programs that resemble this analysis's policy options, and relevant literature can offer an estimation of the increase in effectiveness each program would be expected to offer.

Meanwhile, cost will be considered the expected direct and indirect costs of enacting each policy. These costs include the material costs, managerial costs, and labor costs required to enact the policy, and ensure its effectiveness and continuation. Additionally, the incorporated projected spillover costs, externalities, and opportunity costs on society. These will attempt to be measured in dollars and use comparable projects and projections whenever available to justify the expected financial cost. Similar to making judgments on effectiveness, any cost will be seen as a change from the projected baseline. Any additional cost savings that result from a program will only be measured as the difference from the baseline projected cost.

Because implementation time for both costs and increases in effectiveness can lag due to the rate of adoption, calculations will be made assuming full project maturity. The adoption rate will then be factored in and the relative costs and benefits will be adjusted to incorporate the perceived adoption timeline. For additional information, please refer to Appendix A.

The projected outcomes will attempt to be calculated for a ten-year period, from 2018 to 2027. This period will allow for the different policy programs to reach maturity, and for the relative costs and benefits to stabilize. Additionally, effectiveness will be determined at a nationwide level, primarily by observing the anticipated reaction of the USFS.

Finally, both costs and benefits will be discounted at a 3 percent rate as is cautioned by the OMB. This allows this paper to take into account the opportunity cost of the both the money spent on the program and the perceived effectiveness in present terms. The PV formula is the summation of cost per year, divided by 1.03 raised to the power of the year minus 1. At the core, whichever policy can result in the lowest cost over the greatest value of effectiveness will receive a higher rating (cost-effectiveness ratio = total present value cost over ten years/ total present value units of effectiveness over ten years). For each program, this paper will establish the basic assumptions for calculations and offer the numerical calculations it concluded.

Baseline/Status Quo:

Table 1: General Assumptions Considering Baseline and Status Quo

General Effectiveness Assumptions		
Assumption:	**Value:**	**Based On:**
Discount rate:	3%	OMB Circular
Analysis Period:	10 Years	Necessary Period to Allow Options to Reach Maturity
One unit of effectiveness in:	-	-
Lives Saved	1 Life	DOT Circular on VSL
Homes Spared	42 Homes	US Census Median Home Value
Acres Preserved	4,800 Acres	Jacobson (2017)
Average Lives Lost Baseline:	18.64 Lives Per Year	Regression of NIFC Data
Average Homes Lost Baseline:	2,189 Homes Per Year	Regression of FAMWEB Data
Average Acres Burned Baseline:	8,973,774 Acres Per Year	Regression of NIFC Data
General Cost Assumptions		
Assumption:	**Value:**	**Based On:**
Average Annual Suppression Costs	2,833,415,000	USFS FY 2019 Justification Data
Total Discounted Suppression Cost Over 10 years	24,894,692,810	NPV Calculations

Using a variety of simple time series linear regressions, this paper was able to generate the anticipated baseline of future trends for the three effectiveness outcomes. On average, this paper would expect roughly 18.64 lives to be lost, 2,189 homes to be destroyed, and 8,973,774 acres to be burned as the result of wildfires each year. Thus, any anticipated decrease in these values as the result of some policy initiative will be seen as effective. Additionally, the total discounted cost of all suppression related activities from wildfires has been measured at 24,894,692,810. Any deviation in cost away from this value will be important to consider when attempting to cost out each of the options.

Cost-Effectiveness of Changing Appropriations Classification:

Table 2: Cost-Effectiveness of Changing Appropriations Classification Assumptions

Effectiveness Assumptions		
Assumption:	**Value:**	**Based On:**
Funding Stream Change	30% Increase in Fuel Treatment Budget	Super (2017)
Total Cost of Controlled Burn Fuel Treatment	60 Dollars Per Acre	Calkin and Gebert (2006)
Total Cost of Mechanical Fuel Treatment	213 Dollars Per Acre	Calkin and Gebert (2006)
Total Cost of Average Fuel Treatment	137.5 Dollars Per Acre	Calkin and Gebert (2006)
Average Fuel Treatment Effectiveness	55%	Vaillant and Reinhardt (2017)
Average Annual Reduction In Acres Burned At Program Maturity	4.90%	Dividing anticipated acres saved from policy change over baseline acres burned
Average Annual Reduction in Lives Lost at Program Maturity	4.90%	Carrying over effectiveness increase in acres saved
Average Annual Reduction in Homes Destroyed at Program Maturity	4.90%	Carrying over effectiveness increase in acres saved
Time to Reach Program Maturity	1 Year	NA
Program Effectiveness During Year 1	50.00%	NA
Cost Assumptions		
Assumption:	**Value:**	**Based On:**
Average Annual Cost at Program Maturity	109,800,000	USFS FY 2019 Justification Data
Time to Reach Program Maturity	1 Year	NA
Program Cost During Year 1	50% of average	NA

By changing how forest fires are funded, Congress would provide more financial resources to confront wildfire suppression, and free up resources to be dedicated to prevention efforts. Using these assumptions outlined in Table 1 and a more detailed analysis displayed in Appendix A, this paper was able to roughly estimate the projected discounted total costs and total increase in units of effectiveness. The total net present value of the program cost over ten years, incorporating staffing costs, staff benefits, material costs, risk, and opportunity costs is 855,841,610 dollars. Meanwhile, the total net present value of programs increases in effectiveness, incorporating lives saved, homes preserved, and acres not burned is 792 units of additional effectiveness. This means that one unit of increased effectiveness is roughly equivalent to **1,080,061** dollars of increased cost.

Cost-Effectiveness of Imposing Federal Homeownership Tax:

Table 3: Cost-Effectiveness of Imposing Federal Homeownership Tax Classification Assumptions

Effectiveness Assumptions		
Assumption:	**Value:**	**Based On:**
Number of Homes In "High Risk" Areas subject to .8% Property Tax	746,916 Homes	Verisk Data (2017)
Number of Homes In "Medium Risk" Areas subject to .4% Property Tax	746,916 Homes	Verisk Data (2017)
Number of Homes In "Lower Risk" Areas subject to .2% Property Tax	746,916 Homes	Verisk Data (2017)
Mitigation Rate Based on Willingness to Pay for "High Risk" Region at Maturity	55%	Kaval, Loomis, and Seidl (2007) and Loomis, and González-Cabán (2009)
Mitigation Rate Based on Willingness to Pay for "Medium Risk" Region at Maturity	40%	Kaval, Loomis, and Seidl (2007) and Loomis, and González-Cabán (2009)
Mitigation Rate Based on Willingness to Pay for "Lower Risk" Region at Maturity	25%	Kaval, Loomis, and Seidl (2007) and Loomis, and González-Cabán (2009)
Total Reduction in Number of Homes Destroyed from Baseline at Project Maturity	30%	Gude and Rasker (2013)
Total Reduction in Number of Lives Lost from Baseline at Project Maturity	30%	Gude and Rasker (2013)
Total Reduction in Number of Acres Burned from Baseline at Project Maturity	0%	Specifications of the Option
Time to Reach Program Maturity	5 Years	Grossman and Chaloupka (1997)
Growth in Effectiveness Maturity Per Year	20%	100% Divided By 5
Taxes Generated from Tax Will Be Considered Transfer Payment Outside of the Scope of This Analysis	NA	NA
Cost Assumptions		
Assumption:	**Value:**	**Based On:**
Costs Will Be Assumed by IRS	NA	NA
Average Annual Cost at Program Maturity	4,634,253	IRS FY 2016 Justification Data
Growth in Cost Maturity Per Year	20%	100% Divided By 5
Taxes Generated from Tax Will Be Considered Transfer Payment Outside of the Scope of This Analysis	NA	NA

By changing the tax code to reflect costing based on risk, Congress would provide an incentive for homeowners to migrate away from more fire prone regions and discourage future construction in the riskiest area. Using the assumptions outlined in Table 3 and a more detailed analysis displayed in Appendix A, this paper was able to roughly estimate the projected discounted total costs and total increase in units of effectiveness. The total net present value of the program cost over ten years to the IRS, incorporating staffing costs, staff benefits, material costs, advertisement costs, and opportunity costs is 31,714,593 dollars. Meanwhile, the total net present value of programs increases in effectiveness, incorporating lives saved and homes preserved (as acres not burned would be minimal) is roughly 145 units of additional effectiveness. This means that one unit of increased effectiveness is roughly equivalent to **218,596** dollars of increased cost.

Cost-Effectiveness of Greater Controlled Burns:

Table 4: Cost-Effectiveness of Greater Controlled Burns Assumptions

Benefits Assumptions		
Assumption:	**Value:**	**Based On:**
Ratio of Mechanical Fuel Treatment vs. Controlled Burning Treatment	50% to 50%	Calkin and Gebert (2006)
Total Cost of Controlled Burn Fuel Treatment	60 Dollars Per Acre	Calkin and Gebert (2006)
Total Cost of Mechanical Fuel Treatment	213 Dollars Per Acre	Calkin and Gebert (2006)
Average Fuel Treatment Effectiveness	55%	Vaillant and Reinhardt (2017)
Adjusting Controlled Burn Prevalence to 80%	NA	Option Specification
Average Annual Reduction In Acres Burned At Program Maturity	8.60%	Dividing anticipated acres saved from policy change over baseline acres burned
Average Annual Reduction In Lives Lost At Program Maturity	4.30%	Reisen, Hansen, and Meyer's (2011)
Average Annual Reduction In Homes Destroyed At Program Maturity	4.30%	Reisen, Hansen, and Meyer's (2011)
Time To Reach Program Maturity	2 Year	Rate of Internal Rules Change
Program Effectiveness During First 2 Years	50% Year 1, 75% Year 2	NA
Cost Assumptions		
Assumption:	**Value:**	**Based On:**
Average Annual Cost at Program Maturity	450,000,000	Gude and Rasker (2013)
Time to Reach Program Maturity	2 Year	Rate of Internal Rules Change
Program Effectiveness During First 2 Years	50% Year 1, 75% Year 2	NA

By changing internal USFS fuel management guidelines, the USFS could implement global best practices and treat a greater number of acres. While this would reduce their own internal burden, it would most likely increase the burden of states. Using the assumptions outlined in Table 4 and a more detailed analysis displayed in Appendix A, this paper was able to roughly estimate the projected discounted total costs and total increase in units of effectiveness. The total net present value of the program cost over 10 years to the USFS and States, incorporating staffing costs, staff benefits, material costs, increased state expenditures, and opportunity costs is 3,395,452,564 dollars. Meanwhile, the total net present value of programs increases in effectiveness, incorporating lives saved, homes preserved, and acres not burned is roughly 1,316 units of additional effectiveness. This means that one unit of increased effectiveness is roughly equivalent to **2,580,014** dollars of increased cost.

Cost-Effectiveness of Equipment Purchase and Sharing:

Table 5: Cost-Effectiveness of Equipment Purchase and Sharing

Effectiveness Assumptions		
Assumption:	**Value:**	**Based On:**
Initial Investment Amount	65,000,000	GAO-16-217T
Average Annual Reduction in Acres Burned at Program Maturity	3%	Keating et al. (2012)
Average Annual Reduction in Lives Lost at Program Maturity	3%	Keating et al. (2012)
Average Annual Reduction in Homes Destroyed At Program Maturity	3%	Keating et al. (2012)
Time to Reach Program Maturity	2 Years	Rate of Coordination and Material Acquisition
Program Effectiveness During First 2 Years	0% Year 1, 50% Year 2	NA
Cost Assumptions		
Assumption:	**Value:**	**Based On:**
Current Annual Total Cost Of Aerial Fleet Operations	249,000,000	Keating et al. (2012)
Increase in Annual Total Cost Of Aerial Fleet Operations After 65 Million Dollar Investment	15%	Keating et al. (2012)
Decrease in New Annual Total Cost Of Aerial Fleet Operations After 65 Million Dollar Investment as the Result of Equipment Sharing	25%	GAO/NSIAD-97-206
Total Cost Per Year of Coordinating Cost Sharing Arrangements	1,000,000	GAO/NSIAD-97-206
Period of Total Purchasing For 65 Million Aerial Fleet Upgrade	Year 1	NA
Time to Reach Program Maturity	2 Years	Rate of Internal Rules Change
Program Effectiveness During First 2 Years	0% Year 1, 50% Year 2	NA

By acquiring 65 million dollars' worth of additional aerial firefighting equipment, and implementing an equipment sharing program between the USFS and other state fire agencies, the USFS could meaningfully increase their ability to respond to wildfires, while also mitigating costs. Using the assumptions outlined in Table 5 and a more detailed analysis displayed in Appendix A, this paper was able to roughly estimate the projected discounted total costs and total increase in units of effectiveness. The total net present value of the program cost over ten years to the USFS and states, incorporating upfront acquisition, staffing costs, staff benefits, material costs, maintenance fees, communications and logistical costs, and opportunity costs is 140,579,547 dollars. Meanwhile, the total net present value of programs increases in effectiveness, incorporating lives saved, homes preserved, and acres not burned is roughly 425 units of additional effectiveness. This means that one unit of increased effectiveness is roughly equivalent to **330,802** dollars of increased cost.

Anticipated Outcomes:

Table 6: Outcomes Matrix

	Projected Outcomes				
Options:	**Cost Effectiveness (65%)**	**Political Feasibility (15%)**	**Implementability (10%)**	**Equity (5%)**	**Sustainability (5%)**
1. Status Quo:	NA	Medium High	High	Low	Low
2. Change Appropriations Classifications:	1,080,061	Medium High	Medium High	Low	Medium High
3. Wildfire Risk Tax:	218,596	Medium	Medium	High	High
4. Greater Controlled Burns	2,580,014	Medium Low	Medium Low	Medium	Medium Low
5. Investment in Aerial Fleet and State Partnership:	330,802	Medium	Medium Low	Low	Medium High

Evaluation of Cost Effectiveness (65%):

While the previous section had a much more in-depth discussion of cost effectiveness, based on the analysis of this paper, the wildfire risk tax imposed on homeowners living on or near the WUI would be the most cost-effective solution. We would expect the average cost effectiveness for the ten-year period of this option to be 218,596. This is slightly more favorable than the

option to increase the aerial fleet and state partnership (330,802), and significantly more cost-effective than changing the appropriations classification (1,080,061) or allowing for greater controlled burns and (2,580,014). Because the status quo served as a baseline measurement, it was not possible to establish a cost-effective measurement, given that there were no anticipated changes in projected effectiveness outcomes, or cost, based on previously established expectations.

Evaluation of Political Feasibility (15%):

While politically feasibility was ranked significantly lower in terms of the overall weight of this evaluation, it is still the second most important criteria in this analysis. Politically feasibility refers to two potential paths: either legislative action by Congress, or an internal rule change by the USFS in conjunction to consultation with the OMB. The two highest rated policies for this criterion were the status quo and a change to the appropriations classification. The status quo was ranked medium high given that current political inaction on the issue of wildfire funding and reform seems to continually be put aside to address more serious and politically contentious issues such as healthcare or tax overhauls. Additionally, while elements within the USFS and other state fire agencies have expressed discontent with the current level of wildfire funding and suppression, bureaucratic hurdles and oversight make any substantial change difficult to achieve (Perdue Calls, 2017). This option was not rated higher for political feasibility given there has been some increased pressure and scrutiny to act in recent years, and continual inaction over the next ten-year period could be less politically desirable.

Changing the apportions classification was ranked medium high given recent movement on the issue, its relative bipartisan support, and its opportunity to build on past legislature such as the FLAME Act. For instance, S.1842 has 17 cosponsors from both political parties (2018). Since wildfires affect a variety of states, and in the wake of recent natural disasters such as the series of California wildfires or Hurricanes Harvey, Irma, Maria, this move could be billed as common-sense legislation that prevents future devastation. This option does not receive a higher evaluation because the link between climate change and wildfire has the chance to add additional political charge to the issue, and because of its relative increase in spending after repeated calls from Republicans, Democrats, and President Trump to reduce domestic spending.

A wildfire risk tax receives a medium evaluation because of the political difficulty of achieving tax change with the current Republican control of power in Washington. While Republican leadership and President Trump seem severely against any raise in taxes, especially following their 2018 tax overhaul, this risk tax might be slightly more feasible given its risk costing nature. Currently, homeowners living in the most dangerous areas prone to wildfires pay no additional fees despite being the primary beneficiaries of suppression services (Stein, 2013). Given the tax would essential cost out an externality, would be designed for behavioral change, and would reduce the overall cost of wildfire suppression efforts, its tangible and symbolic benefits could make the tax increases somewhat more tolerable. Additionally, there are some concerns that citizens and interest groups, such as real-estate developers, would be opposed to the decreased demand for homes in these riskier regions, it seems logical to expect that these groups will be relatively dispersed across the nation and will have difficulty organizing.

Investment in expanding the aerial fleet and expanding state equipment partnerships was ranked as medium. There are numerous political avenues that complicate this policy politically, such as the need for additional appropriations, the interagency and state changes that would be necessary, and the willingness of the USFS to give up some of its aerial fleet autonomy. While this would be a relatively insignificant increase in funding necessary, current Congressional inaction would creates grave uncertainty if and when the USFS would receive the necessary resources to implement these changes. Additionally, the lack of a permanent Forest Service Chief could also complicate the integration and interagency cooperation that would make this plan politically feasible.

Finally, greater controlled burns and shift greater responsibility to the states scored a medium low on political feasibility. Internally, a rule change moving towards greater use of controlled burns seem difficult and unpopular. USFS experts and researchers routinely call into question the practices overall effectiveness, and a reduction in the autonomy of decision making for fire chief would be unpopular (Calkin and Gebert, 2006). Additionally, states would likely push back against the greater responsibility they would have over fire suppression efforts and would lament the effects on state budgets calling for an average increase of 7.5 million dollars per year (Gude and Rasker, 2013).

Evaluation of Implementability (10%):

The status quo was ranked as high given that current practices are implemented. Based on this analysis's definition of implementability as the idea that any policy must be able to be implemented in a reasonable, unobtrusive, and seamless way in order to avoid disrupting the incredibly important mission of the USFS, the status quo is definitionally the easiest option to implemented.

Changing the apportions classification was ranked medium high given the fact that this option would not significantly alter the USFS's current mission or service provision. Instead, this option would provide additional resources to the USFS to engage in additional preventative efforts such as fuel treatment. While there would be some intended scale up period, the ultimate implementation of this option would be well aligned with the USFS and would serve as only a minor deviation from the status quo.

A wildfire risk tax receives a medium high evaluation as well. Despite the fact that this option would pose a substantial change to the affected homeowners, it would not drastically alter the USFS's mission and would make their jobs easier to perform in the long run. Given that the possibilities for implementing the tax would fall to the IRS and that Congress would structure the Wildfire Trust, the USFS would be able to continue to prevent and suppress fires at a similar rate while the policy naturally and unobtrusively reduces the risk of inhabited homes being destroyed or the loss of life.

Investment in expanding the aerial fleet and expanding state equipment partnerships as well as promoting greater controlled burns and shift responsibility to states scored medium low on implementability. Both options would require a series of new internal rule changes, greater cooperation with state and local entities, and substantial time to integrate new equipment and

best practices. All while these changes are occurring, the USFS and other fire entities will need to respond to wildfires that threaten land, property, and lives. Because of these options complexities and required resources to reach full adoption, they have a much more inhibited ability to be seamlessly and efficiently implemented.

Evaluation of Equity (5%):

As defined in the evaluative criteria portion of this analysis, equity is seen as the balancing of benefits of policy change for general citizens at the expense of property owners in fire prone regions. As such, only two policies meaningfully achieve this. By introducing a federal risk tax, the government would be able to hold the individuals responsible for escalating wildfire suppression efforts accountable, and thus increase overall equity.

Meanwhile, greater controlled burns would receive a medium for equity as it would hold states that are more fire prone and a greater contributor to suppression costs liable for a larger portion of the policy change. However, it is also less equitable as all states, not just the most fire prone, would be impacted and now be responsible for a greater degree of fire coverage, despite their reduced risk.

All other options would maintain the trends that fire suppression and prevention services are funded by the general tax payer, despite many taxpayers having a low risk of encountering a wildfire. Thus, these options would continue to be seen as an unfair burden placed on citizens who are not responsible for, nor directly benefited by, the USFS's wildfire suppression and prevention efforts.

Evaluation of Sustainability (5%):

Finally, sustainability was intended to be measure of how likely each policy was to offer a permanent solution. The federal risk tax was ranked as high as the option would be intended to be a low maintenance policy that would exist well into the future. This is aided by its targeted nature, its focus away from revenue generation, and the flexibility offered by additional revenue from the new Wildfire Trust. While the tax may need to altered in order to better target and monetize risk, the basis of the proposal appear able to be long lasting beyond the ten-year time horizon under observation by this study. Additionally, by moving the money into the Wildfire Trust, the tax revenues would be safe guarded and would be able to help support financing future wildfire suppression and prevention efforts.

Investment in expanding the aerial fleet and expanding state equipment partnerships and changing the appropriations classification both were scored as medium high. Once the investments for new aerial firefighting equipment is made, its intended that they would have a life span at or above 40 years (GAO-16-217T, 2017). Additionally, just as with the national guard, any state equipment sharing would be able to be continued into the greater time horizon. However, the need for equipment upkeep and the potential for future separation of equipment reduce the otherwise high sustainability.

Changing the appropriations classification is also billed as a highly sustainable solution. By permanently altering how extremely costly fires are funded, the hope is that preventative efforts

will permanently be protected and continue without risk of being cannibalized to fund suppression efforts. While the intention might be permanent, funding can be fickle and previous legislation aimed at a long-term fix t USFS funding (i.e. the FLAME Act) demonstrates how there can be appropriation changes that would ensure the sustainable nature of this policy.

Using greater number of controlled was ranked as medium low. Controlled burns remain a polarizing issue, and it is likely that future rules changes based on new research could indicate that it is less effective than originally intended. Additionally, while this policy aims to have states bear a greater cost burden, it is still likely that the USFS will still be necessary for extremely large fires, and that global climate change could thrust them back into a leadership role. Even if these changes are made permanent, given they would be internal rule changes would seem to indicate they could be overturned much more quickly and would be far less sustainable. Finally, the status quo has a low ranking on sustainability. Continuing the status quo fails to meaningfully resolve the issues of increasingly dangerous forest fires.

Recommendation and Implementation:

Recommendation:

After reviewing the outcomes matrix, the relative scores of each policy, and the relative weight of each criteria, it is clear that option 3, or a **federal wildfire risk tax** offers the greatest opportunity to increase effectiveness at the lowest relative cost. This option also scores high on equity and sustainability, suggesting that it is an effective long-term policy that manages to equitably determine winners and losers. While there are some concerns with political feasibility and implementability, these concerns can be mitigated through a well-constructed and detailed implementation strategy.

Implementation Strategy:

For achieving passage, this paper suggests first offering a new bill into the House to gain initial momentum. Given that this would be a new tax, it is critical to secure support on the House Ways and Means Committee and the Senate Finance Committee. This paper suggests targeting the House Tax Policy Subcommittee Chairman Vern Buchanan. While Congressman Buchanan retains a conservative voting record on ideological tax issues, he has taken relatively nonpartisan votes on issues relating to the environment and reducing the deficit (Buchanan on the Issues, 2018). By framing this policy as a responsible and common sense behavioral tax that incentives reducing risk, Congressman Buchanan may be more likely to support and champion the bill. Also, by targeting wildfire experts such as Republican Congressman Ken Calvert of California and Democratic Congresswoman Betty McCollum of Minnesota, this analysis could see a greater likelihood of forming a persuasive bipartisan coalition in the House of Representatives.

In the Senate, it would be critical to target the 17 bipartisan cosponsors of S.1842. These are Senators who have distinguished themselves as advocated for wildfire policy and hold influential positions that will be necessary for the bill's passage. For instance, Senator Orin Hatch chairs the Senate Finance Committee, and Cory Gardner sits on the Senate Committee on Energy and

Natural Resources. By utilizing these members and encouraging them to send "Dear Colleague" letters to garner additional support, there appears to be a strong initial coalition to push for bipartisan support of a risk tax bill.

Assuming that the bill passes the House and Senate, it seems likely that President Trump would sign it. This bill would not conflict with any specified priorities of the President, and also lacks a constituency group that could reduce his support. Additionally, by framing it as common-sense legislation that can help combat the human and property costs of increasingly dangerous fires, the President would be more likely to lend his support.

Assuming the bill was signed, it would then be up to the IRS to begin to implement the policy. This analysis provides a 5-year timeline to reach full policy implementation. During the first year, the IRS should use US Census data to identify the impacted regions and begin to communicate to homeowners and real-estate developers what the impact of the new tax law would be. Then, it seems productive to roll out the policy in stages, perhaps introducing the policy to high risk states first, and low risk states later. This tiered implementation could allow for the policy impacts and costs to be observed and calibrated before an entire country wide roll out by 2023.

During this period, it will be critical for the USFS and IRS work closely to monitor and share information when assessing the policy's relative effectiveness. As a secondary objective, the USFS, Census, and IRS could work to create a centralized database of home locations contingent on fire risk and risk tax cost. This would allow for additional information to be available to firefighters when assessing how to fight wildfires, as well as to potential future homeowners and insurers.

Finally, the Wildfire Trust Fund should be established with the initial revenues from the tax over the first ten-year period. Following those ten years, any revenue generation from the Trust could be used to support future programs, such as land buyback programs, greater fire suppression efforts, or subsidies to individuals and companies that complete preventative related activities. This allows the Trust Fund to effectively serve as a potential cushion for future unanticipated costs or externalities from the policy. While this paper did not conduct an official sensitivity analysis, investment in aerial fleet and state partnership had a similar cost effectiveness and generally appeared as a very legitimate policy solution. Perhaps a successful rollout of a federal risk tax could be used to increase the likelihood of implementing this alternative option at a later date.

In summary, this option will require a diligent implementation plan to ensure its complete and timely passage, as well as methods to implement the policy in a manner that maximizes benefits and minimizes costs. Creating a bipartisan and targeted political coalition in both the House and Senate will be essential to ensuring passage. Meanwhile, cooperation between the USFS, US Census, and IRS will be necessary to correctly identify and targeting those impacted by the new risk tax. A tiered roll out beginning in high risk states like California and Colorado could serve as successful test cases to implement the basic assumptions of the policy and rectify any

inefficiencies. Additionally, resources from the Wildfire Trust should serve as useful funding source that can help future policies that target wildfire suppression and prevention efforts.

Appendix A:

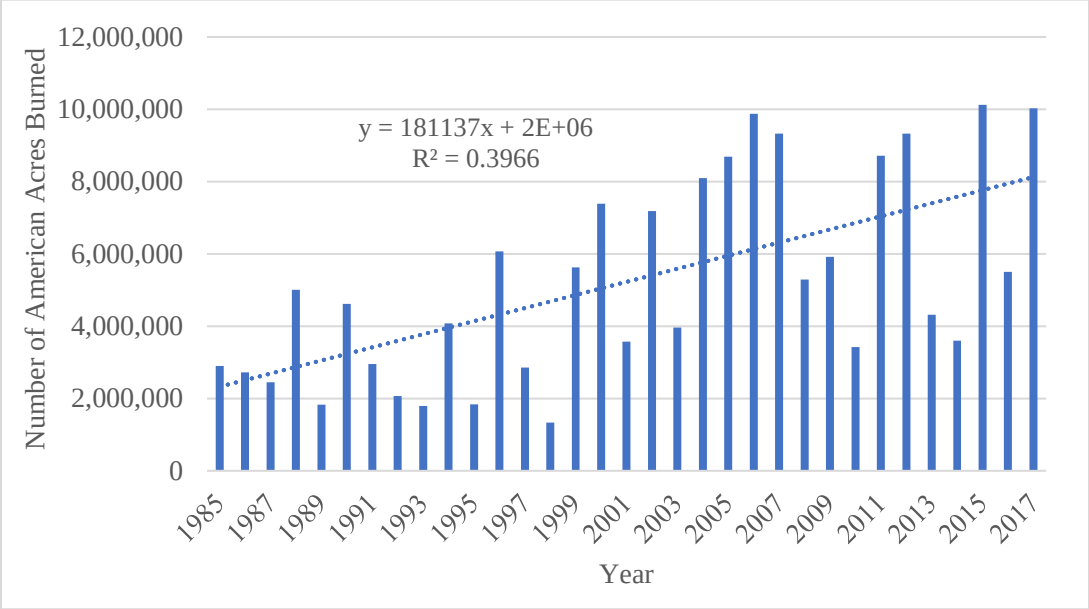
Cost Effectiveness of Baseline/ Status Quo:

- Under the status quo, the current trends in wildfire prevalence, damage, and cost would be anticipated to continue. Macro level factors such as global climate change lead many scientists to expect longer and more dangerous fire seasons to continue (Liu, Stanturf, and Goodrick, 2010). However, uncertainty and a high degree of variability in fire seasons can make it difficult to accurately predict the specific outcome of each fire season. While complex modeling to try and predict the effects of each wildfire season does exist, this paper has opted to use multiple simple time series linear regressions in order to estimate the general trends in future baselines of lives lost, homes destroyed, and acres burned.
- Using data from the National Interagency Fire Center (NIFC) dating back to the 1930's, this paper found that lives lost was, on average, correlated with 0.1365 lives multiplied by the number of years since 1929, plus 6.2826 lives ($y = 0.1365x + 6.2826$). This paper then used this regression to estimate the anticipated number of lives lost we would expect to observe for each year between 2018 and 2027. Then, taking a simple average of these calculated number allows us to estimate that an effectives baseline for the average number of observed lives lost each year is 18.64 lives lost per year. This means that any anticipated policy change to the number of lives lost should be compared to the 18.64 lives lost value.
- Next, using data from fire and aviation management web applications (FAMWEB) dating back to the mid 1980's, this paper found that number of homes destroyed, on average, correlated with 53.92 homes multiplied by the number of years since 1998, plus 868.3 homes ($y = 53.922x + 868.3$). This paper then used this regression to estimate the anticipated number of acres burned we would expect to observe for each year between 2018 and 2027. Then, taking a simple average of these calculated values allows us to estimate that an effectives baseline for the average number of observed homes destroyed each year is roughly 2,189. This means that any anticipated policy change to the number of homes destroyed should be compared to the 2,189 values.
- Finally, using data from the National Interagency Fire Center (NIFC) dating back to 1999, this paper found that number of homes destroyed due to wildfire, on average, correlated with 181137 multiplied by the number of years since 1984, plus 2,000,000 ($y = 53.922x + 868.3$). This paper then used this regression to estimate the anticipated number of acres burned we would expect to observe for each year between 2018 and 2027. Then, taking a simple average of these calculated values allows us to estimate that an effectives baseline for the average number of observed acres burned each year is roughly 8,973,774. This means that any anticipated policy change to the number of acres burned should be compared to the 8,973,774 values.
- Cost, meanwhile, can be considered to the USFS's fire suppression costs. In 2017, the USFS spent 2,833,415,000 on fire suppression, preparedness, research, and other fire management responsibilities according to the USFS FY 2019 Report. This included

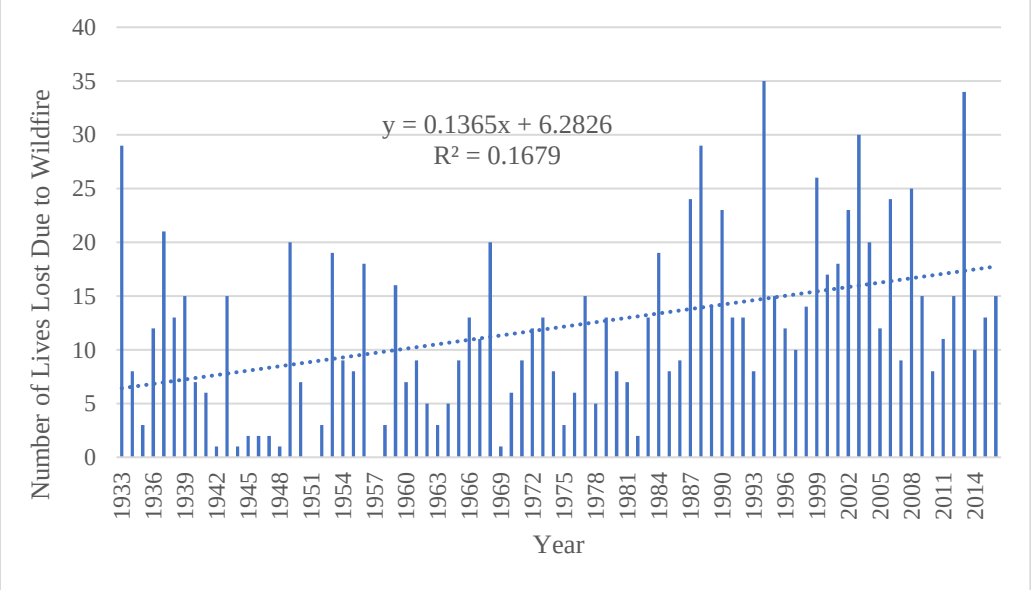
salary, benefits, material costs, volunteer payments, and operation fees. Using the OMB determined discount rate of 3% (2018), we can calculate the opportunity costs of these investments relative to their appreciation over a ten-year period, or the total net present value of 24,894,692,811

- In total, these calculations provide a baseline for comparing any changes that are the result of a new policy initiative. Now, using the best data available and key assumptions, this paper aims to evaluate the relative cost-effectiveness of each option.

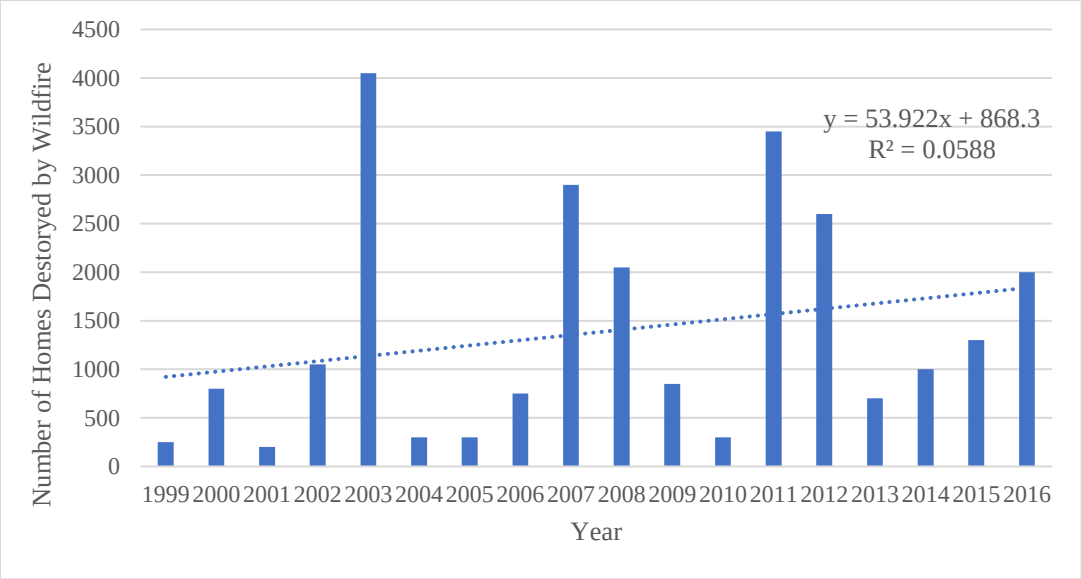
Appendix Graph 1: Acres Burned Over Time



Appendix Graph 2: Lives Lost Over Time



Appendix Graph 3: Homes Destroyed Over Time



Cost Effectiveness of Option 2:

- A basic outcome would be that the funding for preventive efforts would receive a significant boost, essentially equivalent to a 30% increase in funding (Super, 2017). A 30% increase in funding for preventative efforts would be equivalent to 109,800,000 dollars in new resources to dedicate to fire prevention and fuel treatment in order to prevent future forest fires per the USFS FY 2019 budget justification data.
- A paper by Calkin and Gebert (2006) estimates that the average cost of treatment per acre to be 60 dollars through use of controlled burns, and 213 dollars for mechanical treatment. These treatments incorporate the labor, benefits, and material costs. If both practices are used roughly proportionally, then the average cost of treatment per acre is 136.5 dollars. This means that an additional 109,800,000 dollars would result in 804,395 additional acres being treated.
- According to an effectiveness evaluation paper by Vaillant and Reinhardt, only 55% of treated acres were not burned in a period between 2008 and 2012 (2017). Given this information, it is logical to assume that only 442,417 of the 804,395 additional acres being treated will not be burned. This translates to a 4.9% total reduction in acres burned from our calculated ten-year average. If we assume that this 4.9% reduction in acres burned also translates to a 4.9% reduction in lives lost and homes destroyed, we could expect this policy to save .91 additional lives and save 107 additional homes.
- Given these anticipated outcomes, using the previously listed indexing formula, the ultimate units of effectiveness anticipated per year would be 0.91 for lives saved

(.91/1=1), 2.55 for homes saved (107/42=2.55), and 92.17 (442,417/4,800=108.93) meaning the total number of effectiveness is 95.63.

- Meanwhile, the anticipated annual cost is the 109,800,000-dollar increase, discounted over 10 years by the OMB guidelines of 1.8% to represent the opportunity cost. While other costs such as the opportunity cost to pass the legislation, the cost of internal change at the USFS, and deadweight loss costs from collecting the additional revenue are present, they are difficult to calculate and seen as negligible This average annual cost comes out to 131,244,200 dollars. Thus, the cost effectiveness ratio of changing the appropriations classification is 1,372,416 dollars per 1 unit of effectiveness.

Appendix Table 1: Option 2 Calculation Table

Year	1	2	3	4	5	6	7	8	9	10	**Total after 10 Years:**
Adoption %	50%	100%	100%	100%	100%	100%	100%	100%	100%	100%	NA
Effectiveness Per Year	47.815	95.63	95.63	95.63	95.63	95.63	95.63	95.63	95.63	95.63	NA
Cost Per Year	54,900,000	109,800,000	109,800,000	109,800,000	109,800,000	109,800,000	109,800,000	109,800,000	109,800,000	109,800,000	NA
PVC	926850.6	106601941.7	103497030.8	100482554.2	97555877.86	94714444.53	91955771.38	89277447.95	86677133.93	84152557.21	855841610.2
PVB	47.815	92.84466019	90.14044679	87.51499688	84.96601639	82.49127805	80.08861947	77.75594123	75.49120508	73.29243211	792.4005962
Ratio	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	1080061.795

Cost Effectiveness of Option 3**:**

- Imposing a federal home ownership tax will specifically be designed to pressure behavioral change away from living and constructing homes by and near the WUI. Using data from Verisk Analytics, this paper found 4,481,500 homes are in "high wildfire risk" areas (FireLine State Risk Report, 2018). Verisk uses a variety of factors when assessing which homes are in high risk areas, but one key criteria is their relative distance to the WUI. Of these homes, roughly half (or 2,240,750) would be located in the within six miles of the federal WUI.
- Using the Verisk Analytics data, this paper roughly assumes that there will be an even distribution of homes across the three established costing regimes, meaning 746,916 homes are located in each of the following areas across the country:
    - Homes within 2 miles of federal WUI (Highest Risk Homes): **0.8%** annual federal property tax rate
    - Homes within 2-4 miles of federal WUI (Medium Risk Homes): **0.4%** annual federal property tax rate
    - Homes within 4-6 miles of federal WUI (Lower Risk Homes): **0.2%** annual federal property tax rate
- While specific knowledge over the expected willingness to pay for each of these costing regimes is difficult to know and will differ drastically depending on region, this paper will use data from two articles to attempt to anticipate the likely behavioral change. Specifically, willingness to pay research by Kaval, Loomis, and Seidl (2007) and Loomis, and González-Cabán (2009) suggest that over a ten-year period, homeowners would opt to leave in proportions similar to the following:
    - 0.8% annual federal property tax rate: 55% mitigation rate, or 410,804 fewer homes inhabited in the highest risk areas over ten years

    - 0.4% annual federal property tax rate: 40% mitigation rate, or 298,767 fewer homes inhabited in medium risk areas over ten years
    - 0.2% annual federal property tax rate: 25% mitigation rate or 186,729 fewer homes inhabited in the lowest risk areas over ten years
- 896,300 fewer inhabited homes within six miles of WUI would be a 40% reduction of inhabited homes in the costliest and most fire prone regions. Given that these homes are often the most likely to be destroyed by present day wildfires, it seems safe to assume that a 40% reduction in inhabited homes in these regions would likely translate to a 30% reduction in the overall number of lives lost and houses destroyed (Gude and Rasker, 2013). Using our baseline calculations, we would expect on average to see this policy save 657 additional homes, and 5.6 additional lives.
- Additionally, the revenues raised from the tax would be placed into the newly created Forest Fire Suppression Trust Fund that could be used to fight large and costly wildfires. While this taxable income could simply be seen as a transfer payment, using the assigned values, it would generate new government revenue in upwards of 1,273,305,903 dollars by the end of the ten-year period. This money could be used to prevent and suppress future wildfires. However, while this policy is most targeted in saving future homes and lives, it is unlikely to save a significant number of acres burned in the initial 10 years. Thus, the total effectiveness is calculated at the ultimate units of effectiveness anticipated per year would be 5.6 for lives saved (5.6/1=5.6), 15.6 for homes saved (657/42=15.6), and 0 for acres saved, given that is not anticipated that policy would significantly alter the number of acres burned. This results in a 21.2 effectiveness score.
- Given that these taxes would need to be enforced, collected, and tabulated, it is important to consider the cost to the Internal Revenue Service for preforming these functions. In 2016, the IRS tabulated just over 3.4 trillion dollars in revenue on a total budget of 12,374,450,000. That means ever dollar used to by the IRS allowed for around 275 dollars of revenue to be accounted for. Using this metric and observing the expected revenue from this property tax regime, we would expect the average annual cost to the IRS would be 4,634,253. This means the average annual cost effectiveness ratio for instituting a national risk tax is 218,597 dollars per unit increase in effectiveness.

Appendix Table 2: Option 3 Calculation Table

Year	1	2	3	4	5	6	7	8	9	10	**Total after 10 Years:**
Adoption %	20%	40%	60%	80%	100%	100%	100%	100%	100%	100%	NA
Effectiveness Per Year	4.24	8.48	12.72	16.96	21.2	21.2	21.2	21.2	21.2	21.2	NA
Cost Per Year	926,851	1,853,701	2,780,552	3,707,402	4,634,253	4,634,253	4,634,253	4,634,253	4,634,253	4,634,253	NA
PVC	926850.6	1799709.9	2620936.8	3392798.4	4117473.8	3997547.3	3881113.9	3768071.8	3658322.1	3551769	31714593.61
PVB	4.24	8.2330097	11.98982	15.520803	18.835925	18.287306	17.754666	17.23754	16.735476	16.248035	145.0825806
Ratio	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	218596.8396

Cost-Effectiveness of Option 4:

- By internal rules changes to promote a greater number of controlled burns, and permitting none threaten wildfires to continue to burn, this policy option would consist of a number of internal changes. First, this policy would shift internal prevention tactics towards a greater use of controlled burns instead of mechanical fuel treatment (Wildfire, Wildlands,

and People, 2013). Currently, this paper assume controlled burns and mechanical treatment are used proportionally. Instead, this internal shift in wildfire management would aim to use controlled burns as a means to 80% of hazardous fuel treatment, while mechanical fuel treatment would be used for 20% of all fuel treatment.

- Based on data from the USFS's FY2017 Budget Justification, its clear that in FY 2017 the USFS spent a total of 390,000,000 on hazardous fuel treatment. Of that money, 117,000,000 would now be spent on controlled burns instead of mechanical fuel processing. Assuming the costs of controlled burns average 60 dollars per acre, and mechanical fuel processing costs average 2013 dollars per acre, this shift will result in 1,400,704 additional acres being treated. Assuming an effectiveness rate of 55%, this will result in 770,387 additional acres being treated on average per year. This represents an 8.6% decrease from the expected average baseline number of acres burned. However, this 8.6% reduction should not be expected to be equivalent to lives saved and homes preserved.
- A paper by Reisen, Hansen, and Meyer's (2011) notes that controlled burns carry a number of risks to the fire fighters controlling them and can seriously threaten local homes if they escape containment. If we assume that this 8.6% reduction in acres burned due to policy change is only able to translate into half the reduction in lives lost and homes destroyed, we could expect this policy to save 0.80 additional lives and save 94 additional homes. Given these anticipated outcomes, using the previously listed indexing formula, the ultimate units of effectiveness anticipated per year would be .80 for lives saved (.80/1=1), 2.32 for homes saved (94/42=2.32), and 160.49 (770,387/4,800=160.49) meaning the total number of effectiveness is 163.62.
- Meanwhile, this policy is expected to have serious costs. While shifting internal resources is relatively costless (minus some internal costs to shifting management preferences and expertise), the cost of increasing the fire burden on states could be significant. A white paper by Headwater Economics found that increasing the state burden for greater wildfire prevalence and responsibility could cost the average state 12,000,000 additional dollars per year to fight and manage wildfires (Gude and Rasker, 2013). While this might save the USFS money on suppression costs, the average cost per year could be as high as 600 million additional dollars spent to address the greater prevalence of fires. However, given the uncertainty for the average state cost, this paper would expect total cost to be around 450 million dollars once this program reaches its maturity. This means the average annual cost effectiveness ratio for instituting for moving to greater use of controlled burns, and increased burden to the states would be 2,580,014 dollars per unit increase in effectiveness.

Appendix Table 3: Option 4 Calculation Table

Year	1	2	3	4	5	6	7	8	9	10	**Total after 10 Years:**
Adoption %	50%	75%	100%	100%	100%	100%	100%	100%	100%	100%	NA
Effectiveness Per Year	81.81	122.715	163.62	163.62	163.62	163.62	163.62	163.62	163.62	163.62	NA
Cost Per Year	225,000,000	337,500,000	450,000,000	450,000,000	450,000,000	450,000,000	450,000,000	450,000,000	450,000,000	450,000,000	NA
PVC	926850.6	327669902.9	424168159.1	411813746.7	399819171.6	388173953	376867915.5	365891180.1	355234155.4	344887529.6	3395452564
PVB	81.81	119.1407767	154.2275427	149.7354783	145.3742508	141.1400493	137.0291741	133.0380331	129.1631389	125.4011057	1316.05955
Ratio	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2580014.381

Cost Effectiveness of Option 5**:**

- GAO report 16-217T notes the need of the USFS to substantially upgrade its aerial firefighting fleet (2015). The report calls for a 65-million-dollar investment aimed at acquiring new aerial firefighting resources such as air tankers and scoopers, while reducing the dependency on contracting. While it is difficult to quantify the exact potential impact this investment would have, a RAND report from Keating et al. (2012) notes the significant impact a modern and optimized fleet could have on reducing the early impact of potentially dangerous fires.
- As such, this paper aims to assume that this 65-dollar initial investment, when matured, would yield a 3% decrease in lives lost, homes destroyed, and acres burned. Given these anticipated outcomes, using the previously listed indexing formula, the ultimate units of effectiveness anticipated per year once this policy reached maturity would be 1.40 for lives saved (1.40/1=1), 3.90 for homes saved (164/42=3.90), and 140.22 (673,033/4,800=140.22) meaning the total average level of effectiveness once the program reaches maturity is 145.52.
- Costing this option is made more difficult by the intended saving of creating equipment sharing services with state and local entities. Based on a GAO report on equipment sharing practices for the National Guard, the USFS could save 25% on its overall maintenance and operations costs for its aerial equipment (Curtin, 1997).
- Assuming the 65 million initial investment expands the aerial fleet and its average annual maintenance and operations cost by 15%, then this new policy would have the additional cost of 9,352,409 for maintaining and operating the new fleet. Additionally, this paper assumes 1 million additional dollars per year in additional manpower, communication, and coordination efforts in order to ensure the effective integration of the cost savings measures.

Appendix Table 4: Option 5 Calculation Table

Year	1	2	3	4	5	6	7	8	9	10	**Total after 10 Years:**
Adoption %	0%	50%	100%	100%	100%	100%	100%	100%	100%	100%	NA
Effectiveness Per Year	0	29.1045077	58.2090154	58.2090154	58.2090154	58.2090154	58.2090154	58.2090154	58.2090154	58.2090154	NA
Cost Per Year	65,000,000	5,176,205	10,352,410	10,352,410	10,352,410	10,352,410	10,352,410	10,352,410	10,352,410	10,352,410	NA
PVC	65,000,000	5025441.57	9758138.97	9473921.33	9197981.88	8930079.49	8669980.09	8417456.4	8172287.77	7934259.97	140579547.5
PVB	0	28.2568036	54.8675798	53.269495	51.7179563	50.211608	48.749134	47.3292563	45.9507343	44.6123634	424.9649306
Ratio	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	330802.7024

References:

Agency Organization. (2018). *United States Department of Agriculture*. Retrieved from https://www.fs.fed.us/about-agency/organization#block-menu-service-footer-three-id

Ager, A. A., Vaillant, N. M., and Finney, M. A. (2010). A comparison of landscape fuel treatment strategies to mitigate wildland fire risk in the urban interface and preserve old forest structure. *Forest Ecology and Management*, 259(8), 1556-1570.

Anand, B. N., and Khanna, T. (2000). The structure of licensing contracts. *The Journal of Industrial Economics*, *48*(1), 103-135.

Armstrong, M., and Wright, J. (2007). Two-sided markets, competitive bottlenecks and exclusive contracts. *Economic Theory*, *32*(2), 353-380.

Bowden, J. (2011). Department of Natural Resources helicopter cost and use: Report 11-3. *State of Washington Joint Legislative Audit and Review Committee (JLARC)*.

Busby, G., and Albers, H. J. (2010). Wildfire risk management on a landscape with public and private ownership: who pays for protection?. *Environmental Management*, *45*(2), 296-310.

Busenberg, G. (2004). Wildfire management in the United States: the evolution of a policy failure. *Review of policy research*, 21(2), 145-156.

Calkin, D. E., Thompson, M. P., and Finney, M. A. (2015). Negative consequences of positive feedbacks in US wildfire management. *Forest Ecosystems*, 2(1), 9.

Calkin, D., and Gebert, K. (2006). Modeling fuel treatment costs on Forest Service lands in the western United States. *Western Journal of Applied Forestry*, *21*(4), 217-221.

Campbell, J. L., Harmon, M. E., and Mitchell, S. R. (2012). Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions*?*. *Frontiers in Ecology and the Environment*, 10(2), 83-90.

Cook, P. S., and Becker, D. R. (2017). State Funding for Wildfire Suppression in the Western US.

Council, F. E. (2009). Guidance for implementation of federal wildland fire management policy. US Department of Agriculture and US Department of the Interior, Washington, DC, USA.

Council, W. F. L. (2009). The Federal Land Assistance, Management and Enhancement Act of 2009: Report to Congress.

Cristan, R., Aust, W. M., Bolding, M. C., Barrett, S. M., Munsell, J. F., and Schilling, E. (2016). Effectiveness of forestry best management practices in the United States: Literature review. *Forest Ecology and Management*, *360*, 133-151.

Dale, L. (2009). *The true cost of wildfire in the Western US*. Western Forestry Leadership Coalition.

Decentis, A. (2018). Existing-home sales slip 3.2 percent in January. *National Realtors Association Data*.

Disis, J. (2017). *Wildfire property damage could reach $65 billion in Northern California*. CNN Money.

Donovan, G. H., Noordijk, P., and Radeloff, V. (2004, April). Estimating the impact of proximity of houses on wildfire suppression costs in Oregon and Washington. In Proceedings of the Second International Symposium on Fire Economics, Planning, and Policy: A Global View.

Federal Firefighting Costs (Suppression Only). (2017). National Interagency Fire Center.

Fernandes, P. M., and Botelho, H. S. (2003). A review of prescribed burning effectiveness in fire hazard reduction. *International Journal of wildland fire*, *12*(2), 117-128.

Fire science: advances in fire practice. (2018). *Wildland Fire Lessons Learned Center*.

FireLine State Risk Report. (2018). Verisk Analytics. Retrieved from https://www.verisk.com/insurance/campaigns/fireline-state-risk-report-downloads-thank-you/

Fiscal Year 2018 Budget. (2017). *USDA Forest Service*.

Fischhoff, B. (1975). Hindsight is not equal to foresight: The effect of outcome knowledge on judgment under uncertainty. *Journal of Experimental Psychology: Human perception and performance*, *1*(3), 288.

Fried, J. S., Winter, G. J., and Gilless, J. K. (1999). Assessing the benefits of reducing fire risk in the wildland-urban interface: A contingent valuation approach. *International Journal of Wildland Fire*, 9(1), 9-20.

FY 2018 Budget Justification. (2017). *United States Department of Agriculture*.

FY 2019 Budget Justification. (2018). *United States Department of Agriculture*.

Gabbert, B. (2018). *Fire aviation: contracting*. Fire Aviation News and Opinions.

GAO/NSIAD-97-206. (1997). *Army national guard: sharing unit training equipment would help avoid maintenance costs*. U.S. Government Accountability Office.

GAO-16-217T. (2015). *Wildland fire management: agencies' efforts to assess program effectiveness and modernize the firefighting aviation fleet.* U.S. Government Accountability Office.

Gonzalez, P., Battles, J. J., Collins, B. M., Robards, T., and Saah, D. S. (2015). Aboveground live carbon stock changes of California wildland ecosystems, 2001–2010. *Forest Ecology and Management*, *348*, 68-77.

Gorte, R. (2013). The rising cost of wildfire protection. *Bozeman: Headwaters Economics*.

Gorte, R. W. (2011). Federal funding for wildfire control and management. *Congressional Research Service, RL33990.(Washington, DC, USA)*.

Grossman, M., and Chaloupka, F. J. (1997). Cigarette taxes. The straw to break the camel's back. *Public health reports*, 112(4), 290.

Gude, P. and Rasker, R. (2013). *Summary: wildland fire research*. Headwater Economics.

Gude, P. H., Jones, K., Rasker, R., and Greenwood, M. C. (2013). Evidence for the effect of homes on wildfire suppression costs. *International journal of wildland fire*, 22(4), 537-548.

Haas, J. R., Calkin, D. E., and Thompson, M. P. (2013). A national approach for integrating wildfire simulation modeling into Wildland Urban Interface risk assessments within the United States. *Landscape and Urban Planning*, 119, 44-53.

Hart, O., Shleifer, A., and Vishny, R. W. (1997). The proper scope of government: theory and an application to prisons. *The Quarterly Journal of Economics*, *112*(4), 1127-1161.

Haynes, H. (2012). *More than 2,600 structures lost per year due to wildfire.* National Fire Protection Association.

Hefetz, A., and Warner, M. (2004). Privatization and its reverse: Explaining the dynamics of the government contracting process. *Journal of public administration research and theory*, *14*(2), 171-190.

Hoover, K. (2016). Forest service appropriations: five-year data and trends and fy2017 budget request. *Congressional Research Service, R43417.(Washington, DC, USA)*.

Hope, E. S., McKenney, D. W., Pedlar, J. H., Stocks, B. J., and Gauthier, S. (2016). Wildfire suppression costs for Canada under a changing climate. *PloS one*, *11*(8), e0157425.

Houtman, R. M., Montgomery, C. A., Gagnon, A. R., Calkin, D. E., Dietterich, T. G., McGregor, S., and Crowley, M. (2013). Allowing a wildfire to burn: estimating the effect on future fire suppression costs. *International Journal of Wildland Fire*, 22(7), 871-882.

Huggett Jr, R. J. (2004). Fire in the Wildland-Urban Interface: An Examination of the Effects of Wildfire on Residential Property Markets. North Carolina State University.

International Cooperation. (2018). *United States Department of Agriculture*. Retrieved from https://www.fs.fed.us/managing-land/international-cooperation

Jacobson, M. (2017). Forest finance, to cut or not to cut: tree value and deciding when to harvest timber. *Penn State College of Agricultural Sciences*.

Katuwal, H., Calkin, D. E., and Hand, M. S. (2016). Production and efficiency of large wildland fire suppression effort: a stochastic frontier analysis. *Journal of environmental management*, 166, 227-236.

Kaval, P., Loomis, J., and Seidl, A. (2007). Willingness-to-pay for prescribed fire in the Colorado (USA) wildland urban interface. *Forest Policy and Economics*, *9*(8), 928-937.

Keating, E. G., Morral, A. R., Price, C. C., Woods, D., Norton, D. M., Panis, C., ... and Sanchez, R. (2012). Air Attack Against Wildfires. *RAND.*

Kennedy, J. J., and Quigley, T. M. (1998). Evolution of USDA Forest Service organizational culture and adaptation issues in embracing an ecosystem management paradigm1. *Landscape and Urban Planning*, *40*(1-3), 113-122.

Larrick, R. P. (2004). Debiasing. *Blackwell handbook of judgment and decision making*, 316-338.

Lavender, G. (2013). Fighting fires is big business for private companies. *Earth Island Journal.*

Lavery, K. (1999). *Smart contracting for local government services: Processes and experience.* Greenwood Publishing Group.

Liu, Y., Stanturf, J., and Goodrick, S. (2010). Trends in global wildfire potential in a changing climate. *Forest ecology and management*, *259*(4), 685-697.

Loomis, J. B., and González-Cabán, A. (2009). Willingness to pay function for two fuel treatments to reduce wildfire acreage burned: a scope test and comparison of White and Hispanic households. *Forest policy and economics*, *11*(3), 155-160.

Loomis, J. B., Le, H. T., and Gonzáles-Cabán, A. (2005). Testing transferability of willingness to pay for forest fire prevention among three states of California, Florida and Montana. *Journal of Forest Economics*, 11(3), 125-140.

Lueck, D., and Yoder, J. (2016). Clearing the Smoke from Wildfire Policy: An Economic Perspective. Perc Policy Series No. 56.

Manning, W. G., Keeler, E. B., Newhouse, J. P., Sloss, E. M., and Wasserman, J. (1989). The taxes of sin. *Jama*, 261, 1604-1609.

Meldrum, J. R., Champ, P. A., Warziniack, T., Brenkert-Smith, H., Barth, C. M., and Falk, L. C. (2014). Cost shared wildfire risk mitigation in Log Hill Mesa, Colorado: survey evidence on participation and willingness to pay. *International journal of wildland fire*, *23*(4), 567-576.

Millar, C. I., Stephenson, N. L., and Stephens, S. L. (2007). Climate change and forests of the future: managing in the face of uncertainty. *Ecological applications*, *17*(8), 2145-2151.

Mitchell, S. R., Harmon, M. E., and O'connell, K. E. (2009). Forest fuel reduction alters fire severity and long-term carbon storage in three Pacific Northwest ecosystems. *Ecological Applications*, 19(3), 643-655.

Molteni, M. (2017). *The science of fighting wildfires gets a satellite boost*. Wired Magazine.

Montiel, C., and Kraus, D. T. (2010). *Best practices of fire use: prescribed burning and suppression: fire programmes in selected case-study regions in Europe*. European Forest Institute.

Mowery, D. C. (1983). Economic theory and government technology policy. *Policy sciences*, *16*(1), 27-43.

Nelson, R. H. (2000). *A burning issue: A case for abolishing the US Forest Service*. Rowman and Littlefield.

O'Toole, R. (2007). The perfect firestorm: bringing Forest Service wildfire costs under control. Cato Institute Policy Analysis Series, No. 591

Perdue Calls on Congress to Fix Forest Service Fire Funding Problem. (2017). *United States Department of Agriculture Press Release.*

Phan, C., and Liu, H. H. (2008, October). A cooperative UAV/UGV platform for wildfire detection and fighting. In System Simulation and Scientific Computing, 2008. ICSC 2008. Asia Simulation Conference-7th International Conference on (pp. 494-498). IEEE.

Post, W. M., and Kwon, K. C. (2000). Soil carbon sequestration and land-use change: processes and potential. *Global change biology*, *6*(3), 317-327.

Prager, J. (1994). Contracting out government services: Lessons from the private sector. *Public administration review*, 176-184.

Program Summary by Appropriations Account and Budget Activity. (2018). *Internal Revenue Service*. Retrieved from https://www.irs.gov/pub/newsroom/IRS%20FY%202017%20BIB.pdf

Radner, R. (1968). Competitive equilibrium under uncertainty. *Econometrica: Journal of the Econometric Society*, 31-58.

Reisen, F., Hansen, D., and Meyer, C. M. (2011). Exposure to bushfire smoke during prescribed burns and wildfires: Firefighters' exposure risks and options. *Environment international*, *37*(2), 314-321.

Revised value of a statistical life guidance. (2016). *US Department of Transportation.*

S.1842 - Wildfire Disaster Funding Act. (2017-2018). *115th Congress*.

Samanta, B. (2017). *Key findings from the 2017 Verisk wildfire risk analysis*. Verisk Analytics.

Schooner, S. L. (2011). Desiderata: Objectives for a system of government contract law. *George*

Schullery, P. (1989). The fires and fire policy. *BioScience*, *39*(10), 686-694.

Serna, J. (2018). *Nearly $12 billion in insurance claims have been filed due to California wildfires*. Los Angeles Times.

Shleifer, A. (1998). *State versus private ownership* (No. w6665). National bureau of economic research.

SOI Tax Stats - IRS Data Book. (2018). *Internal Revenue Service*. Retrieved from https://www.irs.gov/statistics/soi-tax-stats-irs-data-book

Sosa, I., and Keenan, K. (2001). *Impact benefit agreements between aboriginal communities and mining companies: Their use in Canada* (p. 2). Ottawa: Canadian Environmental Law Association.

Stein, S. M., Menakis, J., Carr, M. A., Comas, S. J., Stewart, S. I., Cleveland, H., ... and Radeloff, V. C. (2013). Wildfire, wildlands, and people: understanding and preparing for wildfire in the wildland-urban interface-a Forests on the Edge report. *Gen. Tech. Rep. RMRS-GTR-299. Fort Collins, CO. US Department of Agriculture, Forest Service, Rocky Mountain Research Station. 36 p., 299*.

Steiner, S., and Zagorec, V. (2005). Prospects of emergency aviation development as part of the Civil Defence System in Croatia. *WIT Transactions on The Built Environment*, *82*.

Stephens, S. L., McIver, J. D., Boerner, R. E., Fettig, C. J., Fontaine, J. B., Hartsough, B. R., ... and Schwilk, D. W. (2012). The effects of forest fuel-reduction treatments in the United States. *BioScience*, 62(6), 549-560.

Stetler, K. M., Venn, T. J., and Calkin, D. E. (2010). The effects of wildfire and environmental amenities on property values in northwest Montana, USA. *Ecological Economics*, 69(11), 2233-2243.

Super, D. O. (2017). *Don't let funding for US Forest Service go up in flames*. The Hill.

Syphard, A. D., Massada, A. B., Butsic, V., and Keeley, J. E. (2013). Land use planning and wildfire: development policies influence future probability of housing loss. *PloS one*, *8*(8), e71708.

The Rising Cost of Fire Operations: Effects on the Forest Service's Non-Fire Work. (2015). *USDA Forest Service*. Retrieved from https://www.fs.fed.us/sites/default/files/2015-Fire-Budget-Report.pdf

The U.S. Forest Service - An Overview. (2009). *USDA Forest Service*. Retrieved from https://www.fs.fed.us/documents/USFS_An_Overview_0106MJS.pdf

Theobald, D. M., and Romme, W. H. (2007). Expansion of the US wildland–urban interface. *Landscape and Urban Planning*, 83(4), 340-354.

Thompson, M. P., Vaillant, N. M., Haas, J. R., Gebert, K. M., and Stockmann, K. D. (2013). Quantifying the potential impacts of fuel treatments on wildfire suppression costs. *Journal of Forestry*, 111(1), 49-58.

Tversky, A., and Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *science*, *185*(4157), 1124-1131.

Unmanned Aircraft Systems. (2017). *USFS Fire and Aviation's Management*. Retrieved from https://www.fs.fed.us/fire/aviation/uas.html

Vaillant, N. M., and Reinhardt, E. D. (2017). An Evaluation of the Forest Service Hazardous Fuels Treatment Program—Are We Treating Enough to Promote Resiliency or Reduce Hazard?. *Journal of Forestry*, *115*(4), 300-308.

Valkó, O., Török, P., Deák, B., and Tóthmérész, B. (2014). Prospects and limitations of prescribed burning as a management tool in European grasslands. *Basic and Applied Ecology*, *15*(1), 26-33.

Wenders, J. T. (1976). Peak load pricing in the electric utility industry. *The Bell Journal of Economics*, 232-241.

Wildland Fire Fatalities by Year. (2017). *National Interagency Fire Center*. Retrieved from https://www.nifc.gov/safety/safety_documents/Fatalities-by-Year.pdf

Windterton, D. (2016). County considers fire prevention instead of insurance policy. *The Morgan County News*. Retrieved from https://morgannews.com/2016/07/28/county-considers-fire-prevention-instead-of-insurance-policy/

Winter, G. J., Vogt, C., and Fried, J. S. (2002). Fuel treatments at the wildland-urban interface: common concerns in diverse regions. *Journal of Forestry*, 100(1), 15-21.

Zybach, B., Dubrasich, M., Brenner, G., and Marker, J. (2009). US Wildfire Cost-Plus-Loss Economics Project: the "One-Pager" checklist. John Wildland Fire Lessons Learned Center, 20.