

External Letter Peer Review of Report

“Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S.”

Review Report

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Background

In January 2020, the Wildland Fire Leadership Council (WFLC), which is comprised of Federal, state, tribal, county, and municipal government officials, asked the Environmental Protection Agency (EPA) to lead an effort in collaboration with United States Forest Service (USFS) and the Department of the Interior (DOI) to conduct an assessment titled: *Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S.* The report covers topics that allow for an assessment of the tradeoffs, with a focus on smoke impacts, between the different fire management strategies of wildfire and prescribed fire. Specifically, the report includes discussions of forest conditions and fire management as well as air quality monitoring as it pertains to wildfires, human health, and ecological effects of wildfire smoke. The report also addresses actions individuals can take to reduce wildfire smoke exposure, the direct and indirect effects associated with fire, and includes quantitative analyses that rely on air quality modeling to estimate the potential health impacts and economic implications of changes in air quality associated with wildfire smoke. This report is classified as Influential Scientific Information (ISI).

Westat was contracted by the EPA to provide balanced professional services sufficient for the independent expert peer review of this report. To this end, Westat compiled a list of 31 peer review nominees. Of these 31, 10 both accepted the nomination and provided signed Conflict of Interest (COI) and Destruction Agreement forms by the deadline. Westat evaluated the signed COI forms to confirm that none of the nominated reviewers appeared to have a COI that would impact this review. Of the list of 10 candidates, 8 were chosen to complete the review. These reviewers all had expertise in one or more of the areas listed below:

- Wildfires and/or Prescribed Fires
- Forest Ecology/Ecological Impacts of Fire
- Modeling Fuel, Emissions, and Air Quality
- Air Pollution/Wildfire Smoke, Epidemiology, and Exposure
- Air Quality/Wildfire Smoke Monitoring
- Fire/Smoke Damages
- Quantitative assessment of health/economic impacts of air pollution

Names and affiliations of reviewers are provided in Appendix A. Throughout this document, reviewers are referred to by number, rather than name, and specific comments are not attributed to individual reviewers by name.

Reviewers were asked to answer a series of charge questions about the report, found in Appendix B. All reviewers were expected to read and comment on the Executive Summary and Chapters 1, 2, and 9 of the report. While reviewers were encouraged to read and comment on the full report, if specific chapters or charge questions fell outside of their area of expertise, reviewers were permitted to skip them. Reviewers received the draft report and charge instructions on Monday, April 19th, 2021 and were given until Thursday, May 6th, 2021 to complete their reviews. Reviewers were asked to submit responses in Microsoft Word or Google Docs format.

This review report summarizes the combined results of the letter peer review for the CAIF report and is organized by charge question – one overarching and 9 chapter-specific. For the instructions given to reviewers and the charge questions, please see Appendix B. Full reviewer responses, with names removed, are included in Appendix C.

Comments on Overall Organization & Clarity

Review Question: Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

Summary of Reviewer Feedback:

Reviewers 1, 2, 6 and 7 all provided relatively extensive comments in response to this question, while Reviewers 3, 5, and 8 provided brief comments. Reviewers 4, 5, and 7 found the organization of this report challenging due to both its scope and the way in which the modeling exercise and case studies were broken across multiple chapters. Reviewer 1 suggested adding a section specifically on prescribed fire associated smoke impacts and Reviewer 6 suggested reordering or deleting Chapter 7. Organization was mentioned in 5 of the 8 reviews and several reviewers suggested potential improvements. Some reviewers noted that writing styles varied from chapter to chapter and an editorial review would improve the report.

Multiple reviewers mentioned the use of concentration response (CR) functions based on studies of urban air pollution and particulate matter (PM) exposure as needing stronger justification, since studies have found differences between the health impacts of wildfire smoke exposure vs. other types of air pollution. Reviewer 1 had some very pointed comments and concerns regarding the modeling analysis and lack of discounting. Reviewer 4 also had some concerns about the modeling and Reviewer 7 noted that, it was “interesting, but of limited veracity and breadth.”

Two things particularly stood out during Westat’s review of these comments:

- Reviewer 1 seemed to be the most critical of the report and gave very detailed critiques on each section reviewed, along with references, and explanations of what could be improved upon and why/how. Despite this, Reviewer 1 still issued a good deal of praise for the report and its goals.
- Reviewer 2, interestingly, noted that “the state-of-the-science part of the report should include a discussion of how fire impacts intersect with equity.” This reviewer was the only one to raise the issue of equity and very directly question how socioeconomic status (SES) might impact exposure and mitigation actions.

While the reviewers generally agreed that the executive summary was clear and well-written, some felt that it skipped some key findings of the report, such as knowledge gaps around monitoring, fully understanding health impacts, quantifying environmental effects and/or that the executive summary did not fully convey the significance of limitations and uncertainty described elsewhere in the report. Reviewers expressed some concern that those who read the executive summary in lieu of the full report, for example policy makers, may miss findings not included in the executive summary.

In their responses to each of the charge questions, reviewers provided broad substantive comments as well as specific editorial comments and questions. Comments in response to this question are listed in Table 1, below, by reviewer number.

Table 1. Review comments in response to overarching charge question

Reviewer	Comment
1	Overall, the report undertakes a rather ambitious task and makes incremental progress in our understanding of how wildfire smoke health impacts compare to prescribed fire (Rx fire) smoke health impacts. The report is generally thorough, though, it comes across as a bit too authoritative and matter-of-fact, when, in actuality, this is an area with many well-known knowledge and data gaps (and these gaps are evident in the modeling done in the report). I found the organization to be appropriate (with some exceptions, as described below, for example, the need for a section on studies that have specifically looked at Rx fire smoke health impacts) and the report is generally clear. There is some risk of the report simply being dismissed as a literature review of the wildfire and Rx fire literatures. The actual modeling and empirical analysis is relegated to a later chapter and seems almost secondary (and maybe this was the intention of the authors). While the literature review is helpful and will make a nice contribution, I'm not sure as to its policy relevance and I'm also not sure about this report's contribution to the larger literature in this area. The modeling analysis also has many limitations (and some of them are stated in the report), which makes it seem like an "add-on" at the last minute to a literature review report. Suggest that either the (weak) modeling analysis is dropped altogether, or, if it is kept, that it is beefed-up substantially, to, for example, include a much more formal benefit-cost analysis that at a minimum includes a study of intertemporal tradeoffs between smoke from Rx fires and smoke from wildfires. Discounting needs to be included and costs/benefits cannot be crudely compared for an Rx fire occurring in the same year as the wildfire.
1	I did enjoy reading the report (though I only carefully read the ES, Chapters 1-2, 6, and 9, but skimmed the other chapters; some of which are outside my area of expertise). I can't say that I learned much new material above and beyond my read of this literature over the last decade or so (which I follow closely). Again, the modeling analysis is intriguing, but crudely done with many assumptions made (some unfounded in my opinion, and see specific comments below). Perhaps it is "good enough", but I would push back some if asked to endorse the modeling analysis. The strength of this report is in the synthesis of the literature and the discussions in Ch.9 on next steps/future work/gaps in the literature.
1	The charge given was to "lead an assessment that would characterize and compare the impacts of wildland fires under different fire management strategies, including prescribed fire." Given this, focusing exclusively on smoke health impacts needs to be justified. The charge was much broader than smoke and health.

Table 1. Review comments in response to overarching charge question (continued)

Reviewer	Comment
1	p.ES-1, line 23: There is also an epidemiological literature on prescribed fire smoke health impacts, specifically, outside of wildfire smoke exposure. Both literatures should be included here.
1	p.ES-1, lines 29-36: Clarify here if both the TC6 and Rough Fires occurred on lands that had been previously the location of prescribed burns. If Yes, how much is the overlap of wildfire with prescribed burn extent? How long ago did the Rx fire occur? If Rx fires didn't occur on lands burned by the TC6 and Rough Fires, then why were these fires selected?
1	p.ES-2, line 16: The CI on TC6 is huge (\$2M to \$47M). Such imprecision in the estimates raises red flags. What is driving the huge CI? Is this indicative of a problem with the methods and/or BenMAP-CE? Similar for the Rough Fire (which has an even larger CI). The Rough Fire CI is so large as to almost make the analysis irrelevant for policymaking purposes (\$260M to \$7.9 billion; huge range). It seems to me that much more work needs to be done to reduce the variance on these estimates.
1	p.ES-2, lines 25-27: "The hypothetical scenarios for both case studies demonstrate that prescribed fires targeted for specific locations can have an effect on reducing the overall size of a wildfire." My read on this is that you assumed a hypothetical Rx fire and then attempted to simulate/model what the wildfire extent and associated smoke health impacts would have been with said fire. This is troubling to me that a hypothetical Rx fire was used and not an actual Rx fire that had been previously burned on lands where a wildfire occurred at a not-to-distant later date. Why use a hypothetical Rx fire? Why not use an actual Rx fire? The limitations of using a hypothetical Rx fire for this analysis should be clearly stated up-front. They limit the generalizability of the findings.
1	p.ES-3, lines 10-12: "Therefore, analyses do not consider how prescribed fires intersect with wildfire activity, including the probability of a wildfire occurring within the spatial domain of prescribed fires." This is a critical limitation of the current analysis. By not using an actual Rx fire for your analysis, you are unable to empirically study the linkages between Rx fire and wildfire activity on the same land. This is problematic for me because in practice, we need an answer to how actual on-the-ground Rx fires affect future wildfire extent and severity (with associated future smoke health impacts). This report is unable to address this question, which severely limits its practical usefulness, in my opinion.
2	First, the report is better understood as two reports smooshed together: a summary of the state of the science of wildfire management and impacts, and a case study of specific health impacts from two specific fires. The case studies are the main contribution of the report, but much of the rest of the report has very little to do with it. There is an entire section on wildfire air pollution monitoring that is barely relevant to the case studies. The same is true for the ecological impact section. It would be better if the two elements of the report were separated into two separate reports, or perhaps a main report and an annex. Mixing them together reads as incoherent.
2	Second, the case studies themselves are very interesting and constitute an important contribution, but their presentation is extremely confusing. Specifically, each case study of a fire includes several counterfactual versions of that fire (though a different number of counterfactuals for the bigger fire than the smaller one). Furthermore, each of the counterfactuals incorporates information from a unique combination of actual historical prescribed burns, hypothetical prescribed burns that were planned but never took place, and historical wildfire burns that had an effect similar to prescribed burns. The main wildfires under study are named, and some of these other fires or prescribed burn campaigns seem to have names, too. All of this is quite confusing to the reader. Even after reading the descriptions of all the different counterfactuals in many different places in the document I was unable to remember which counterfactual was modeled which way. The case studies desperately need some sort of overarching graphic or table that lays out all the scenarios. The maps are helpful but not enough. Using the names of the secondary fires or burn campaigns adds nothing but confusion.

Table 1. Review comments in response to overarching charge question (continued)

Reviewer	Comment
2	Third, the case studies are begging to be further interpreted. Would a prescribed burn campaign leading to a smaller fire have actually reduced the overall health impact compared to the observed fire? Somehow the report never answers this very central question, this question that the structure of the case studies appears specifically designed to answer, or, if it did, the answer was so de-emphasized that it eluded me when I was specifically looking for it.
2	Fourth, the state-of-the-science part of the report should include a discussion of how fire impacts intersect with equity. Do certain socioeconomic groups experience higher ambient concentrations, higher exposures, or stronger concentration-response relationships? Are some groups more able than others to access public health messages and act on them? Are some able to afford health risk mitigation actions that others can't afford? There is at least a little literature on this already that should be discussed and hopefully included in the mitigation modeling.
3	Enjoyed the report. It gives a good starting point for risk management decisions based on wildland fire generated smoke.
4	This report develops a conceptual framework for understanding, and potentially quantifying, the tradeoffs between prescribed burning and wildfire. The key strengths of the report include a strong background discussion and literature review of the many facets of the problem and a well thought out conceptual framework. Some chapters are excellent, and the final synthesis chapter presents the key findings and limitations well.
4	A weakness of the report is its very narrow quantitative focus. Though the conceptual framework is holistic, and the various aspects are discussed, only a small portion of the framework is quantified with a specific modeling case study. The findings of the case study are quite limited because they may not be broadly applicable to other locations or even times. To bolster the case studies, I would suggest a statistical approach, where a large number of hypothetical fires are modeled across many different locations and weather conditions to better explore the range of impacts.
4	Another important weakness of the report is its structure. The chapter progression does not make sense to me. Text switches back and forth between the broader qualitative discussion and details of the case study analysis. I would prefer the document broken into two major parts: one with the conceptual framework and background information that applies to that framework in all cases, and one on the case study, including info on the specific forests, land management, air quality modeling details, results, etc. Finally, the report could use a high-level editor. There is much repetition and significant style differences between the chapters.
5	The organization made the report difficult to follow. Some of the questions and confusion I had reading through the document weren't addressed until the final chapter. The chapters addressing the actual case study analyses are broken up and should be consecutive. There are also varying levels of detail given to factors part of the conceptual framework, but not addressed in the case study analysis, with some chapters providing in depth syntheses and others providing a brief overview. The scope of the discussion should be more consistent throughout. Overall, I found the conceptual framework hard to follow. There needs to be a better description of its intent and flow, and how it relates to the case study, early in the report.
6	This is an outstanding case study. It's interesting, and it is a useful contribution to science. I applaud the EPA scientists (as well as those from other collaborating governmental agencies) for this work.

Table 1. Review comments in response to overarching charge question (continued)

Reviewer	Comment
6	Perhaps not a “critical deficiency,” but something that I think should be addressed: I was surprised to see the list of concentration-response functions used in the “primary” analysis were from studies of urban air pollution. It’s fine, but it feels out-of-whack with Chapter 6, which didn’t really comments on these studies (at all), but instead focused on the studies of wildfire smoke. Also, when I read 8.2.3, I didn’t understand why there were CR functions for long-term PM exposure being used in this analysis – I think better justification for this is warranted – scientifically, I don’t understand the rational for applying CR functions for long-term PM exposure to a ~60 day fire event. Also, some of the CR functions (e.g., Katsouyanni et al. 2009) aren’t from the US, which seems at odds with the focus on US studies in Chapter 6, since there are a lot of international studies of health effects of fires (e.g., from Australia) that could be relevant.
6	Beyond the previous comment, I did not find any “critical deficiencies” in the report. However, I’ve provided several comments for the authors to consider.
6	Section 1.2 gets to the main contribution of the report – “the overall air quality impacts of different fire management strategies, which consist of different land management practices, including prescribed fire, are not well characterized.” This is reiterated in Section 1.3, which elaborates on the “modelling component of the analysis, which is the main focus of this report” and takes us through the hypothetical scenarios. However, the Executive Summary seems to have more of an economic value focus rather than an air quality focus, which feels a bit misaligned with the rest of the report – having read the executive summary first I wasn’t expecting such a heavy focus on the air quality modeling.
6	The Executive Summary doesn’t convey the uncertainty that is commented on extensively in Chapter 2 – perhaps one sentence to this affect could be added.
6	There are some small grammar issues in the report – I assume these will get fixed once the scientists finalize the content and it gets routed for editing.
6	Consider having Chapter 8 follow after Chapter 6. It seems like the logical next step (to me) in terms of organization. Or maybe consider having Chapter 7 come before Chapter 6.
7	This report is best when it plays to the strength of the US EPA and covers topics such as air quality monitoring and chemistry, human health effects, and water quality. When covering these subjects, this report is excellent. Where the report ventures into forest ecology, land management, and ecological effects, the text is good overall, but needs revision to correct instances where framing is incomplete or important details are lacking.
7	Organizing a report of this scope is difficult. I found the organization challenging sometimes because information about the modeling exercise was scattered across a number of chapters. EPA might consider if there is a way to reorganize the report to have the information about the wildfire modeling centralized to within a single chapter. I see that different aspects of the modeling are imbedded within chapters that provide context, but that makes it challenging to understand the full scope of the model.
7	The overall approach of focusing on two different western fires and then devising alternate scenarios for these fires to understand the potential influence of fuels management practices on public health is interesting, but of limited veracity and breadth. Rather than attempt to understand more holistically the potential costs and benefits of different fuel management strategies by integrating probabilistic estimates of fire activity and behavior, the alternate scenarios were simply created by opaque “expert judgement”. The limitations of this approach are identified in Chapter 9 and elsewhere in the text, but these limitations are significant. While the approach here is insightful, I was disappointed it was not more robust given the large number of scientists involved and the overall breadth of this report.

Table 1. Review comments in response to overarching charge question (continued)

Reviewer	Comment
7	One small but important issue that I see with this report is that it repeatedly frames contemporary issues with wildland fire in the U.S. as a problem of wildfires increasingly “encroaching” on human populations. In fact, and as acknowledged in the report, humans are increasingly living within wildlands that have regularly experienced fires for millennia and these humans are also a tremendous source of ignitions. The problem is not necessarily that wildfires are burning, it is that humans are now in the way of the fires. More specifically, our collective problem is that our priorities for the services that should be provided by wildlands have changed faster than our ability to manage those lands in a way that will provide these services in our contemporary ecological context. That puzzle of managing our (fire-prone) lands to provide our collective desired environmental outcomes is the foundational question of this report.
7	The executive summary was very clearly written and did a good job of synthesizing the information about the effects of the two studied wildfires and hypothetical alternatives. However, some of the most important findings of this report are the identification of knowledge gaps around monitoring, fully understanding health impacts, and quantifying environmental effects, but these topics were not covered by the executive summary. I urge you to include those items so that policymakers and others who may not read all the way through this lengthy report will also receive these key conclusions.
7	Please, more commas! I've commented on a few instances where the lack of a comma forced me to reread sentences, but there are numerous other spots that would have benefitted from the addition of a comma.
8	Overall the report does an excellent job introducing the reader to the issues involved in prescribed fires, fire management, and public health concerns. Air quality managers, especially in the western US, need to weigh the benefits and costs of prescribed fires, and to convince the public of the value of such fires as a tool to limit the potentially catastrophic impacts of large wildfires. These issues have acute importance, especially as climate change and accumulated fuel load make such large fires more likely.
8	The executive summary is well-written and convincing. This review outlines strengths and weaknesses by chapter.

Comments on Chapter 1

Review Question: Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

Summary of Reviewer Feedback:

Overall, reviewers thought Chapter 1 did a good job of providing the rationale, approach, and goals of this report, but did have comments about lack of clarity and terminology used. Reviewers 1 and 3 both asked for a definition for “resource benefits. Several reviewers mentioned ways in which sections 1.3 and 1.4 could be clarified or augmented. Some reviewers stated that sections 1.3 and 1.4 were confusing. Reviewers 5 and 8 suggested adding a table to layout/highlight differences between the various scenarios presented in the chapter and Reviewer 2 commented “The terminology and scenario numbering used in Figs 1-1 and 1-2 is inconsistent.”

Several reviewers pointed out that the report framed the issue as wildfires encroaching on communities when, as stated by Reviewer 7, “communities are encroaching on natural systems that have burned for millennia.”

Reviewers 1, 4, 5, 6, and 7 provided relatively substantial comments on Chapter 1 while Reviewers 2, 3, and 8 provided relatively brief comments. Full comments on Chapter 1 are listed by reviewer number in Table 2, below.

Table 2. Reviewer comments on Chapter 1

Reviewer	Comment
1	p.1-2: Some mention should be made here that Rx fires can (and do) sometimes get out of control and become wildfires (e.g., the Cerro Grande fire in NM). There are small probability extreme risks associated with Rx fire too.
1	p.1-2: "To date, limited information exists that allows for a direct, systematic, and comprehensive comparison of the air quality and associated health impacts of smoke from prescribed fire and wildfire." I fully agree with this statement. However, to properly address this, a comparison of wildfire smoke health impacts with Rx fire smoke health effects from Rx fires on lands where the wildfire occurs in the future is needed. There is a tradeoff here that must be studied, empirically (not hypothetically). Will tolerating a little smoke today (from Rx fires) be worth it (from a health cost-benefit perspective) compared to a lot of smoke in the future from a wildfire? This needs to be worked out.
1	p.1-3: "While all these activities have led to significant advancements in the science, the overall air quality impacts of different fire management strategies, which consist of different land management practices, including prescribed fire, are not well characterized." This seems rather harsh. There are now many papers looking specifically at prescribed fire air quality and health impacts. See the 2019 special issue of the International Journal of Environmental Research and Public Health on "Air Quality and Health Predictions" where several Rx fire specific papers were included.
1	As mentioned in my comments about the ES, I'm very concerned by the focus on hypothetical prescribed fires rather than using wildfires that occurred on previously Rx fire lands. This is especially relevant for the discussions on p. 1-4. The TC6 hypothetical scenarios pre-suppose that Rx fires can (and do) lead to the outcomes listed (e.g., a wildfire with less fuel, a smaller fire perimeter, and less daily emissions). These seem like reasonable assumptions, but they are at the end of the day only assumptions based on a limited amount of data and nascent science on our understanding the complex relationships between Rx fires and future wildfire activity. My first suggestion would be to go back to the drawing board and use actual Rx fires instead of hypothetical fires. If this cannot be done, then my next suggestion for improvement would be to better caveat the approach and to be more upfront with its limitations. Using the "hypothetical" language is a good start, but more substance should be provided in the methods section that at the end of the day, this report is modeling a fake Rx fire and is making assumptions on that fire's impacts to future wildfire activity (which are based on the best available science, but that science is currently hindered by data availability and limited understanding of the complex connections between Rx fire and future wildfire activity).
1	Figure 1-1 is nice and clear.
1	p. 1-7, line 1: Define "resource benefits"
1	p.1-8: "individuals taking precautionary measures to reduce smoke exposure can vary between wildfire and prescribed fire events depending on the presence and effectiveness of public health messaging as well as the amount of lead time available for messaging to inform the public and the public's ability to act on that messaging." Please provide citations for this statement. Seems speculative to me. We are only just beginning to understand the role that smoke alerts have on avoidance and mitigation behaviors. In fact, the latest EPA STAR grant on effective smoke communication strategies was an attempt to better understand this very point.

Table 2. Reviewer comments on Chapter 1 (continued)

Reviewer	Comment
1	p.1-8, lines 11-13: "The examination of smoke exposure reduction actions within this assessment does not reflect a formal analysis of post-fire effectiveness of public health messaging for either the TC6 or Rough Fires." I agree. Yet, a "crude estimation" is still done. Is this dangerous? Shouldn't we wait until a more "formal analysis" can be done? As stated on p.1-8, "This report represents an initial step in the process of conducting assessments to characterize the impacts of different fire management strategies to inform both public health actions to reduce population exposures to wildfire smoke, and future land management decisions." It has the potential to be extremely influential in this regard. And, as the first major EPA report on the wildfire/Rx fire tradeoff (with respect to smoke and health), it is better to be cautious than complete, especially since this is an area of study that suffers from data limitations and many knowledge gaps. I'd rather EPA not put out a report on the basis of a "crude estimation", if the assumptions and models used in the "crude estimation" turn out to be inaccurate in the future. I guess that more caution is in order. Maybe the "crude estimation" is dropped from the report. It could potentially do more harm than good is my point.
2	The terminology and scenario numbering used in Figs 1-1 and 1-2 is inconsistent (two Hypotheticals vs. three Scenarios).
2	Page 1-6 lines 8-9 are unclear.
3	Page 1.1 Section Background Line 17/18- 'NIST is an expert in the direct and indirect 17 damages attributed to fire'. What do you mean by this?
3	Page 1.1-Section 1.1, Line 23/24- 'Fire has been used as a land management tool to return nutrients to the soil and remove detritus 23 and excess fuels to reduce wildfire risk and effects.'- Think you need to use a different word for "Fire" at the start of the sentence, or add in the term prescribed fire, or add the word extreme (or something similar) to wildfire risk latter in the sentence. Fire along seems too vague.
3	Page 1-2 Section 1-2, Lines 15/17. Is this the right wording? with the rapid expansion of the WUI, wildfires are 15 increasingly encroaching on American communities, posing threats to lives, critical infrastructure, and 16 property (Lewis et al., 2018). It seems like American communities are encroaching on wildland fires. The way it is currently worded, it makes wildland fire the "bad person", is it really?
3	Page 1-4 Section 1-3 Line 1- What are "positive resource benefits"
3	Page 1-8 Section 1-3 Lines 19/20- What about local economic conditions? Large fires close down business. That can be a large driver politically.
4	Page 30, sentence beginning on line 8 is not a sentence
4	The descriptions of the scenarios in section 1.4 are confusing.
5	The authors correctly indicate that use of wildfire for resource benefit is also a critical fire management strategy on page 1-2 (lines 31-35). This concept should be carried through in the rest of the chapter. I recognize that the terminology can be confusing, as the term 'wildfire' can have a negative or positive connotation in this framework, but I strongly encourage the authors to adopt a terminology throughout the document that acknowledges that wildfire, more than being at times beneficial, is actually a a critical fire management strategy. Some examples of where this can be more strongly incorporated:
5	Page 1-3 line 1: 'To ensure the effective use of prescribed fires and wildfire to reduce the risk of catastrophic fire' (or use agreed upon terminology to describe the beneficial use of wildfire.
5	Page 1-3 line 13 'including prescribed fire and wildfire'
5	Since this is the primary portion of the report where the scenarios are discussed, it would be useful to have more detail. How much prescribed fire is in each scenario, what are the sizes of wildfire in each scenario, etc. A table highlighting the details of the different scenarios would be useful and provide a quick reference the reader could refer back to throughout the report. There also needs to be more discussion of linking these scenarios to pieces in the conceptual and expected value framework.

Table 2. Reviewer comments on Chapter 1 (continued)

Reviewer	Comment
5	Other comments on chapter 1 Page 1-1 line 17: 'incident management'
5	Page 1-1 line 20: delete the
5	Page 1-1 lines 21-22: 'linkages needed to address identified research gaps'
5	Page 1-1 lines 8-12: Important to note that spread of invasive species has also changed fire regimes, by increasing fuel continuity, not necessarily fuel loading.
5	Page 1-1 line 24: The goal of fuel treatments is not always to reduce wildfire size, more often it is to reduce fire intensity and severity
5	Page 1-3 lines 9-10: and wildland firefighter health impacts?
5	Page 1-4 line 2: consider using 'periodic' instead of 'episodic'
5	Page 1-4 line 15: was compared
5	Page 1-4 lines 20-27: what do these different scenarios mean for fire intensity? Instead of indicating less or more fuel, wouldn't less or more fuel consumption be a better descriptor?
5	Figures 1-1, 1-2, and 1-3: It would be better if these figures were consistent across the two fire case studies. Figure 1-1 is repetitive and doesn't add much value. Would it be possible to show prescribed fire areas in figure 1-2? In addition, figure 1-1 includes a baseline scenario, which is not described in the text.
5	Pages 1-4 and 1-5: Descriptions of the different fires and their scenarios read as if they were written by different authors. It would be helpful to the reader if there was more consistency in language and structure of the descriptions of the different modeling scenarios.
5	Page 1-8: Lines 21-28: Consider introducing the goals of the report prior to the 'novel approach' section, especially the first paragraph of this section. The second paragraph (lines 29-34) is more appropriate for the end of this chapter.
6	I think Chapter 1 is effective in introducing the assessment. I like the figures showing the hypothetical smaller/larger scenarios relative to the "baseline" scenario (perhaps a better description than "baseline" is "actual fire scenario" or something like that, although "baseline" was also clear to me).
6	Section 1.3 is titled "Novel Approach." It might be worth being explicit as to what exactly is novel (this is not a criticism that the work isn't novel; I am asking for clarity in the authors articulating what specifically about the work is novel).
6	Clearly, there are details that aren't developed in Chapter 1. For example, there is virtually no discussion of how the public health impacts / effectiveness of public health messaging are modeled, where those estimates come from, and so on. But I think this is fine for Chapter 1 – saving these kinds of details for later chapters makes sense to me.
7	I think Chapter 1 is successful in providing the rationale, approach, and goals for the report. I have some comments about how this work and contemporary issues are framed, which are detailed below. I don't see need for fundamental changes to this chapter, only changes in language.
7	P1-1 L24: Not just wildlife habitat, but also habitat for plants and other organisms.
7	P1-2 L2-7: Fire suppression isn't an ignition source and climate change isn't an ignition source, except for possible changes in lightning frequency. However, all of these things influence the occurrence of wildfire. Also, this sentence implies that the occurrence of wildfires has increased, but that contradicts line 10 in the next paragraph. I realize the two statements have different time frames, but it is still a contradiction.
7	P1-2 L13: Animal and plant habitats
7	P1-2 L15-17: I disagree with the framing that fires are encroaching on communities. Communities are encroaching on natural systems that have burned for millennia. I would suggest deleting "encroaching on American communities" and simply say that wildfires are increasingly posing threats to lives, etc.

Table 2. Reviewer comments on Chapter 1 (continued)

Reviewer	Comment
7	P1-2 L21-22: This is a good and important sentence, but I think there is an equal need to recognize that the accumulation of wildfire fuels is also inevitable and that without extensive intervention, wildfires themselves are inevitable. This is a crucial point that needs to be made prominently in this report.
7	P1-6 L1: Every fire will increase some ecosystem process/function/service that has a value to someone, so it is a bit imprecise to say a fire “resulted in resource benefits”. It would be more appropriate to say the fire was “managed for resource benefits”. Some organisms, like the black-backed woodpecker, like extensive stands of dead trees killed by wildfire. High-severity fires would also likely increase streamflow, a benefit to downstream water users.
8	Chapter 1 does a good job laying out the rationale, approach, and goals of the report, and this reader was impressed by the intra-agency effort to address the issue of prescribed fires in the western United States.
8	Section 1.3. A table or bullet list of the different scenarios for each fire would be helpful. Such bullet lists appear in Chapters 8 and 9. Also, the text states that the scenarios “equate to” specific conditions, but “represent” would be the better word choice.
8	Page 1-7. Describing more exactly the “resource benefits” of the Sheep Complex Fire would be helpful.

Comments on Chapter 2

Review Question: The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed from the framework? How well does the text support the overall framework? Please explain.

Summary of Reviewer Feedback:

In general, reviewers found the conceptual framework to be appropriate, understandable, and comprehensive, though some noted the study itself was more narrowly focused. Several commented that sections of equation 2-1 and the associated text should be clarified. Reviewers also noted inconsistencies and issues of clarity in Figure 2-1. Several reviewers commented on the presence of ash and greenhouse gas (GHG) emissions in the Figure.

Reviewer 1 was especially forceful regarding the lack of discounting of future costs and benefits, stating, “An undiscounted comparison of these two sets of monetized estimates should not be done, full stop.” In contrast, Reviewer 2 appreciated the lack of discounting as, “people in the future will value breathing just as much as people in the past.” Reviewers 1, 5, and 7 provided the most extensive and detailed comments on Chapter 2. Full comments on Chapter 2 are listed by reviewer number in Table 3, below.

Table 3. Reviewer comments on Chapter 2

Reviewer	Comment
1	p.2-2: “The overarching question that guides the evaluation conducted within this framework is What are the expected effects (both positive and negative) of alternative fire management strategies over both short (during the event) and long term (post-event) time horizons? with an emphasis within this assessment on the smoke impacts.” This is exactly the right question that should be asked and I applaud the report to taking this issue on. It is relevant to on-going discussions both at the Federal and state level as well as in the academic community. What are the benefits and costs of Rx fires in the short-term and in the long-term and how do these compare to what would have happened in the absence of Rx fire (i.e., in terms of future wildfire smoke and health impacts)?
1	The discussion in section 2.2 “Expected Value Framework” is good. One thing that should be added and discussed is the literature on the expected returns on fire management strategies on future avoided suppression costs (see Sanchez et al., 2019). The focus on this report on smoke and health is fine, but one must acknowledge other avenues that the broad charge to investigate fire management strategies can take (such as on future property damages and suppression).
1	p.2-3, line 20: Recommend adding the Sanchez et al. (2019) cite to this sentence.
1	The implicit functions in Equation 2-1 need to be written in the equation. The text on line 24 says that PF is a function of M, but that is not shown in Eq. 2-1, for example. It should be. Similarly for NF, conditional on M.
1	Another concern that I have with Eq. 2-1 is that there is an inherent temporal component that is missing here. Rx fire effects are immediate, but wildfire impacts are delayed, perhaps by years or even decades into the future (depending on the ignition probability). Economists use discounting to relate dollar benefits/costs over time. Yet, no discounting is presented in Eq. 2-1 (and it should be). Suggest a more formal equation be written that incorporates best practices from the Expected Net Present Value (ENPV) economics literature. You cannot simply compare costs and benefits together when they occur at different points in time. This is incorrect. Specifically, the EV-C equation on line 3 of p.2-4 is not valid, unless the individual EV and C terms are in present value terms (and no mention is made in the text that they are).
1	Figure 2-1: Define “non-fire adverse impacts”. Ash, GHG emissions, and smoke emissions are all fire impacts. They don’t occur without fire, so I don’t understand what is meant by “non-fire” in this context. Second, I would argue that the green box “Improved forest health” should be linked to the “Probability of wildfire ignition” box. Rx fires affect future fire ignition precisely because they do improve the overall health of the forest. These two things are connected and cannot be separated as they are in the figure. A similar argument could also be made to connect “Ecological benefits” and “probability of wildfire ignition”. Third, it is not clear what is meant by “ability to mitigate impacts” or “ability to mitigate exposure”. How does wildfire mitigate impacts to, for example, firefighter health and safety? If anything, wildfire is harmful to firefighter health. I’m missing the link. When I think of mitigation, I think of public health advisories or smoke alerts that provide people with information so that they can take actions to limit/reduce their exposure to smoke/fire. Similar for the link between Prescribed fire and “Ability to mitigate exposure”; what is meant by this? As in Rx fires can reduce future exposure to smoke from wildfires since those wildfires will be less severe due to past Rx fires? Please clarify. Finally, mortality and morbidity are not the only effects of fire and smoke. Labor market effects, education effects, productivity effects, and other economic outcomes have been shown to be affected by smoke exposure. Suggest broadening your assessment (or explicitly state that you are ignoring them).
1	p.2-8, line 12: P(control) was not defined in Eq. 2-1. Please clarify or define.
1	p.2-9, lines 26-27: “About 89% of the fuel treatments were effective in changing fire behavior or helping with management of the wildfire or both” This needs to be significantly expanded and elaborated on. One of the central assumptions made in this report is that a hypothetical Rx fire will measurably affect future wildfire extent, emissions, etc. This assumptions needs to be carefully explained and defended.

Table 3. Reviewer comments on Chapter 2 (continued)

Reviewer	Comment
1	Table 2-1: The list of “Unquantified Effects” are not all actually unquantified in the relevant literatures, its only that this report has made the choice not the quantify them. This is an important distinction that should be made clear. For example, the economics literature provides estimates of property, timber, tourism, etc. costs of wildfire. This report is simply focusing on smoke and health. Please don’t give the impression that some of these other impacts are unquantified in the literature (which is not accurate). Additionally, under the “Public Health: Air Quality” effects, there are many more that are not stated here (e.g., labor market effects, educational effects, etc.). Similar for air quality (i.e., other pollutants created by fire). This is an incomplete list. Suggest listing other Air Quality and Public Health impacts, but then state that this report only focuses on xyz. Otherwise, the impression is given that fire is only associated with those impacts listed (which is not true).
1	p.2-15, lines 12-15: “Because of uncertainty regarding when wildfires occur relative to when prescribed fires occur, it is challenging to determine the timeframes for comparing the two types of fires. For this assessment, we present undiscounted dollar values, which assumes that benefits and costs of fire management strategies all occur in the same current year.” This is extremely problematic and cannot be done in the final report. Prescribed fire effects are immediate whereas wildfire impacts are years, if not decades, in the future. An undiscounted comparison of these two sets of monetized estimates should not be done, full stop. Some assumption needs to be made on the timeframes involved (with a sensitivity analysis performed on that assumption) so that a net present value analysis can be performed. Benefits and costs do not occur in the same year, as stated on line 15. This is a major shortcoming of the report that must be addressed. Wrong conclusions and policy implications can be reached from not incorporating discounting.
2	I liked the conceptual framework for how it shed light on the choices made in the case studies. For example, page 2-2 lines 1-12 are much clearer than section 1-4. However, I don’t think the framework requires that the report spend so many pages in later section on aspects of fires that aren’t captured in the case studies anyway. I also think the framework needs to include some indication that impacts are filtered through existing socioeconomic inequities.
2	Equation 2-1: if all the terms in the equation are conditioned on M this should be reflected in the notation.
2	Fig 2-1: Do thinning or prescribed fire reduce the probability of wildfire to zero? Why isn’t the Wildfire box connected to Mitigation Decision if Wildfire explicitly conditioned on it in equation 2-1? Also, the position of “Ability to mitigate impact” and “Ability to mitigate exposure” on top of arrows is unclear.
2	Page 2-8 line 12: If Pr (control) is being modeled perhaps it should appear in Fig 2-1?
2	Table 2-1: Emergency department visits are list as both “quantified” and “unquantified”. Which is it?
2	Page 2-15: I appreciate the lack of discounting. People in the future will value breathing just as much as people in the past.
3	Page 2-3 Section 2-1 Line 9/10. You state “framework that gives 9 primary consideration to public and firefighter safety”, can you have both or does one need to take priority over the other? Someone has to take the risk?
3	Page 206 Section 2-3 Line 27- You talk about “Effects are expected to vary based on characteristics “ but do not reference fuel model, you kinda do as biomass burned, but might want to clarify with a reference to fuel model. A lodgepole stand fire is a stand replacement vs a ponderosa pine stand is typically undergrowth. The fuel model typically dictates the fire conditions.
3	Page 2-08 Lines 30/31- You state: It is only implemented when conditions meet preplanned elements”. I would reword to state that it is only implemented when the resource benefit as outlined in the burn plan is meet.
3	Page2-13, Section 2.3.5 -Lines 4/5: You state “using 4 N95 facemasks when outdoors to mitigate exposures” is this recommended across the country? Many public health agencies do not recommend masks.

Table 3. Reviewer comments on Chapter 2 (continued)

Reviewer	Comment
4	The overall conceptual framework is appropriate, understandable, and comprehensive. However, while the framework itself is comprehensive, the study is not, being narrowly focused on public health impacts from smoke. The authors acknowledge this, and the framework will hopefully be useful for future work. This study just scratches the surface.
4	Page 41, line 3. Aren't there multiple possible goals for prescribed burning? Not just reducing wildfire?
4	Section 2.3.5 paragraph 1. This paragraph asserts that more public actions can be taken to mitigate smoke impacts from prescribed fires than wildfires because of the potential to plan health messaging campaigns, but is that borne out? My experience is that the public takes more mitigation measures during wildfires. Also, why can't these communication and public awareness activities take place during wildfires?
5	Several things make the graphical representation of the conceptual framework difficult to understand and follow. For one, the authors go straight to a detailed description of the expected value framework to a graphical representation of the conceptual framework, without a clear description of how these relate. There is also no description of what the graphical representation is meant to convey, other than a long section defining and describing terms, some of which are inconsistent with what is shown in the graphic. Is the graphic meant to convey the expected value framework in the context of smoke and air quality? If so, that is not clear and the terminology between the expected value framework and the conceptual diagram is inconsistent. In addition, there are many aspects of the conceptual diagram are confusing. For example, why is there not a relationship between baseline conditions and wildfire, as is described in the text? What does the 'ability to mitigate' box connected to wildfire refer to? Why are ash, GHG emissions, and smoke emissions considered non-fire impacts? Why doesn't prescribed fire have the ability to mitigate non-smoke fire impacts? I suggest greater thought and attention to detail put into a revised conceptual diagram, that is more clearly linked to the expected value framework (if indeed that is the intent), is consistent in terminology, and perhaps a simpler design. A simpler design could be achieved by omitting examples from the diagram itself (e.g., GHG, ash) and leaving those in the descriptions of broader terms (e.g., direct and indirect impacts or effects).
5	In general, I'm not convinced that there is value in adding a detailed description of the expected value framework, when it does not appear to have been used in this case study analysis. The discussion of this should either be minimized, or somewhere in this report there needs to be a discussion of how the case study analysis links to pieces of this expected value framework and what pieces are missing and would need to be included in order to complete the framework.
5	Page 2-2 lines 18-19: Instead of 'reduction or increase in fuel loads', consider change in fuel characteristics, since some changes in fire behavior and effects are due to changes in fuel continuity, or other characteristic, and not always due to increases or decreases in fuel loading.
5	Page 2-2 lines 18-22: The example of maintenance burns in the Southeast as an example of the previous statement is confusing, as the previous statement refers to wildfires, not prescribed fire. This in addition to the sentence starting with "the range of periodicity...", while correct, seems misplaced and disrupts the flow the paragraph. I suggest deleting these sentences and start again with "the management of wildland fire"
5	Page 2-2 line 23-24: Delete "Fire management strategies such as". You've already separated wildfire in the previous sentence, and established that it has positive and negative effects.
5	Page 2-2 line 24: change "fire" to "wildfire"
5	Page 2-3 lines 3-4: pick impacts or effects, don't include both
5	Page 2-3 line 13: By management do you mean the opportunity to manage wildfire? This is unclear.
5	Page 2-3 equation 2-1: Should F be WF? The equation already has prescribed fire related effects, shouldn't the last part refer to wildfire related effects?

Table 3. Reviewer comments on Chapter 2 (continued)

Reviewer	Comment
5	Page 2-3 line 25 and 26: specify that F is referring to wildfire -related effects once a wildfire is ignited
5	Page 2-3 line 27: positive and negative effects associated with fire management strategy and wildfire?
5	Page 2-8 line 12: this is the first mention of P(control), it is not listed in the EV equation or the conceptual framework diagram
5	Page 2-9 lines 12-16: There is lots of data on the degree to which mechanical thinning, alone or in conjunction with prescribed fire changes the probability of ignition or intensity and severity of wildfires and many studies published since Agee and Skinner 2005.
5	Section 2.3.3.3 – I suggest deleting this section and adding a statement to the section above about the effectiveness of mechanical treatments. You could certainly still cite IFTDSS 2021, but I see no need to highlight this particular program in this report.
5	Section 2.3.4 – should this be titled the effects of wildland fire?
5	Page 2-10 line 33: Cheatgrass is not a good example of an invasive species that fire helps control. Yellow star thistle might be a better example.
5	Section 2.3.4.1.2 – Why not call this ability to mitigate impacts, to be consistent with the conceptual diagram
5	Page 2-11 line 28: Here and throughout, I would argue that fire effects do not depend on the type of fire (prescribed vs. wildfire), but on the burn conditions, because both types of fire can have a wide range of burn conditions.
5	Page 2-14 Table 2-1: Loss of ecosystem services is listed as an example of effects on property. Is this correct? I'm not sure what this would entail outside of other listed economic effects – timber and grazing, municipal watersheds, aesthetics, tourism, natural and cultural resources. Should biodiversity be included under ecological?
6	Chapter 2 covers a lot of the background that goes along with the conceptual framework. I am realizing that several of my comments are on the figures and tables, and I think the authors have done a good job with these. Sometimes reading a big report it's hard to keep track of everything, and the figures and tables help a lot. Even something like Table 2-1 – which might seem unnecessary given what is in the text – I found it was very efficient at helping me understand what is going on.
6	Equation 2-1 seems inconsistent with the written description as to whether certain terms are conditional on Mi – somethings are written in the equation as not being conditional whereas the description says they are conditional.
6	Figure 2-1 is helpful, although some things are a little unclear (e.g., the difference between ecological impacts and ecosystem impacts). Also the two categories of “non-smoke impacts” and “non-fire impacts” is a little confusing...would it be more straightforward to call them “smoke impacts,” “fire impacts,” and “other” (if a third category is needed)?

Table 3. Reviewer comments on Chapter 2 (continued)

Reviewer	Comment
7	Although there are issues with some of the text framing wildfires, the chapter is successful in providing context for subsequent chapters. Figure 2-1 matches the structure of the chapter, but it also does not fully describe interactions between prescribed fire, “resource benefits”, non-smoke fire impacts, and risk of wildfire. As currently constructed, figure 2-1 is bit confusing. For instance, the “Management Decision” box has a number of arrows coming out of it. All of the green arrows and the orange arrow appear to be coming out of only “Prescribed fire”, while “probability of wildfire ignition” seems to be flowing from the “Management Decision” box as a whole. In reality, there would be some benefits also from mechanical thinning or even from “no action” (lower implementation costs). I would suggest either making this diagram more complete to show those benefits/costs or removing “mechanical thinning” from the list. I would also remove “ash” and “GHG emissions”, or at least make them a different color than the smoke boxes. Ash and GHG emissions are both certainly components of smoke plumes, but GHG emissions have no direct human health effects, while ash has a number of negative (contributes to smoke, decreases water quality, etc) and positive (soil nutrient cycling) effects. Ash and GHGs are also components of smoke emissions, which makes unclear why they are distinct from the smoke emissions box. (Though arguably, ecosystems will remain a net GHG source to the atmosphere for some time following a severe wildfire.)
7	P2-3 L11: Intensity is energy output, but over a defined space and time. It is possible for fires to release a lot of energy over a long period of time in a low intensity fire. For the text, I would suggest providing example units of W m ⁻² to better convey the nature of fire intensity.
7	P2-4 Footnote: Some of these effects, such as air pollutant emissions from heavy equipment, chainsaws, and trucks could be quite easy to quantify; others have quantified these emissions.
7	P2-6 L11: The word legacy is unnecessary and should be struck; contaminants are problematic no matter their age or source.
7	P2-6 L26: I realize this is an existing definition, but this is problematic given human influence on virtually every part of the natural world. Is a fire sparked by a car on the side of a highway in eastern Oregon, which burns non-native cheatgrass in a sagebrush ecosystem that would otherwise not frequently have fire, a “natural event”?
7	P2-7 L12-15: This sentence should be rearranged to simply its construction.
7	P2-8 L17-19: This understates the evidence and implies uncertainty that prescribed fire can achieve these objectives. Suggest changing to “There are decades of evidence that...”
7	2.3.3.2: It should be noted that in many arid forests in the western US, forest management practice regulations require that residues from harvest or thinning be treated in reduce fire danger. In many areas, that treatment is achieved through pile burning or (less frequently) broadcast burning. Thinning is often done in combination with prescribed burning, often as a first step.
7	P2-10 L24: This sentence is somewhat awkward because “pine” is not a species, but a genus (Pinus) and a family of trees (Pinaceae). Not all pines depend on fire for reproduction.
7	P2-10 L27-29: This can be true, but fires can also lead the loss of nutrients from ecosystems, particularly nitrogen. The supply of nitrogen is often the nutrient most limiting to growth in temperate ecosystems. However, in some cases this loss of nutrients could be helpful for plants and other organisms favored by nutrient-poor conditions.
7	P2-10 L33: Under the right circumstance this is true, but fires can also increase the dominance of cheatgrass. Also, provide a scientific name (Bromus tectorum).
7	P2-12 L30: It is also recognized that fuels treatments can decrease carbon sequestration, but increase the stability (decrease the vulnerability) of the remaining forest carbon. https://ww3.arb.ca.gov/cc/inventory/pubs/wildfire_emissions_faq.pdf
8	Overall, Chapter 2 does a good job “setting the stage” for subsequent chapters. Comments are as follows.
8	Page 2.3. It would be helpful to know earlier in the chapter whether or not the fire-related effects include health impacts.

Table 3. Reviewer comments on Chapter 2 (continued)

Reviewer	Comment
8	Page 2.9. The reader is puzzled why over 14,000 assessments have not sufficed to characterize the effectiveness of fuel treatments. The text reports that these assessments have suffered from an “under sampling of fuel treatment effectiveness monitoring, mostly on the smaller fires (less than 1,000 acres).”
8	Page 2-12, Section 2.3.4.2.3, Effects on greenhouse gas (GHG) emissions. The text should acknowledge that in a natural fire regime, the CO ₂ emitted through biomass burning is taken up again by the subsequent regrowth of vegetation, with a net impact on CO ₂ concentrations of zero. Only when a forest is replaced by less dense vegetation – e.g., savannah – are fires are source of greenhouse gases. Indeed, the forests in the western US are likely functioning as unnatural CO ₂ reservoirs, sequestering carbon due to the decades-long fire deficit in this region.
8	Figure 2.1. See comment above on greenhouse gas emissions from fires.

Comments on Chapter 3

Review Question: Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

Summary of Reviewer Feedback:

Reviewers 5 and 7 provided substantive comments on Chapter 3, and Reviewers 4 and 8 also provided minor comments. There is very little overlap in the comments, aside from both noting that the word “settlement” on page 3-7, line 24 be changed to specify “European” or “widespread Euro-American” settlement. Reviewers 1, 2, 3, and 6 did not provide comments on Chapter 3. Full comments on Chapter 3 are listed by reviewer number in Table 4, below.

Table 4. Reviewer comments on Chapter 3

Reviewer	Comment
4	This is not my area of expertise, but the chapter seems to provide an adequate introduction. Like other chapters in the report, it is confusing that some of the content is general overview, while some is specific to the case studies, and these are somewhat jumbled. For example, 3.1.1 is specific information that applies to the case studies.
5	Page 3-7 line 24: European settlement
5	Section 3.1.5 – Since this is touched on in the next section, shouldn't there be a discussion in this section on the role of insect and disease outbreaks in changing fire regimes?
5	Page 3-9 section 3.2: This paragraph seems misplaced. There instead should be a subsection on use of wildfire as a land management approach to reduce fire risk. The introduction to this section should introduce the various land management approaches to reducing fire risk – fuel treatments, prescribed fire, wildfire.
5	Page 3-9 lines 18-21: This language is taken almost directly from Young et al. 2020 (Effects of policy change on wildland fire management strategies: evidence for a paradigm shift in western US?) without attribution. This would also be a good paper to cite here to show the growing use of strategies other than full suppression after the 2009 policy guidance. Young J.D. et al. 2020. Effects of policy change on wildland fire management strategies: evidence for a paradigm shift in the western US? International Journal of Wildland Fire 29: 857-877.
5	Page 3-9 section 3.2.1: This subsection is not needed. Instead, parts of it could be incorporated in an introduction to the section on land management approaches to reducing fire risk.
5	Section 3.2.2 – This is repetitive with section 3.1.5. Some of what is in this section could be included in section 3.1.5 (e.g., cultural burning). Otherwise, this section should focus on land management approaches to reducing fire risk.

Table 4. Reviewer comments on Chapter 3 (continued)

Reviewer	Comment
5	Section 3.2.2.4 – see comments related to page 3-9. I don't agree with the language stating this is mostly limited to wilderness areas and national parks. Young et al. 2020 shows that strategies beyond full suppression are becoming much more common in general. Consider calling this section “use of wildfire” rather than just natural ignitions, to be more consistent with the previous chapter.
5	Page 3-16 lines 28-31: It would be so much more powerful if there was greater information on the fuel treatment activities. How many acres were treated and when? Can these be displayed on the map? This would be more informative than the modeling scenarios, since those are already shown elsewhere in this report.
5	Page 3-21 lines 1-2: change to where wildfires can be safely managed to achieve resource benefit.
7	This chapter provides a broad background that is important context for the understanding the Rough and TC-6 fires. I think this chapter is well-written and complete except that while the “historic” conditions here are well described, there is no time period identified for when these conditions occurred. I have a number of comments, but these are minor remarks.
7	P3-1 Line 10-13 notes that climate is a key driver of fire regimes, but should have also mentioned that fire regimes are also strongly influenced by human actions, including those of indigenous people.
7	P3-3 L2: Rather than visual or measured, I think you mean qualitative and quantitative. If you count something you see with your eyes, that is both visual and measured.
7	P3-3 L8-9: I disagree with this statement. It is relatively easy to estimate flame length, which is a proxy for fireline intensity. However, estimation of duration and actual intensity are of similar difficulty.
7	P3-4 L8: Scientific name should be provided at first use in the report.
7	Figure 3-2: It feels somewhat misleading to show a large map extent and show WUI area across all of that map, but only show ponderosa pine distribution across part of that map.
7	P3-6 L4: Here and throughout the report, Douglas-fir should be spelled with a hyphen to denote that it is not a true fir (it is not member of the genus Abies).
7	P3-6 L7-8: This is not true for the ponderosa pine forests that would have been part of the Rough Fire. The lower elevation boundary of ponderosa pine forests in that area abuts forests and savannahs composed to oaks (<i>Quercus</i> spp.) and grey pine (<i>Pinus sabiniana</i>).
7	Figure 3-3: This is an odd choice of photos. (1) These do not appear to be the same locations, making it difficult to make a direction comparison. Photo pairs of the same locations are available. (2) This contemporary ponderosa pine stand 10-15 years after a fire does represent some portion of the landscape, but arguably larger portions of the landscape have not experienced recent fire or have experienced recent fires of greater severity. In short, the contemporary image is not indicative of current conditions.
7	P3-7 L24: change “settlement” to “widespread Euro-American settlement”. Indigenous people had lived in these regions for millennia; European settlers arrived in the 1700s and 1800s.
7	P3-8 L18-20: Relative to grasslands and deserts, the spread of invasive species has been lower. However, I would not describe the abundance of invasive plants within ponderosa pine forests as “minimal”. There are numerous published reports of invasive annual grasses in ponderosa pine forests in Oregon and California. Keeley and McGinnis (2007) specifically note cheatgrass invasions were considered problematic in the vicinity of the Rough Fire as far back as the late 1990s. I would also refer you to Kern et al. Forest Ecology and Management 463 (2020) 117985
7	3.1.5.2: Some mention of the role of humans in igniting fires should be added here.
7	P3-10 L12-15: I'm confused. An effect of prescribed fire is the lack of advanced fire suppression?
7	P3-10 L15: Lightning
7	P3-16 L24: I'm confused by “the montane chaparral shrub”. Is that a descriptor of bitterbrush? If so, I suggest reconstructing the sentence to improve clarity.
7	P3-17 L6: Fire should be capitalized.

Table 4. Reviewer comments on Chapter 3 (continued)

Reviewer	Comment
7	P3-18 L9-10: The units here are way off. I think Mg is what is intended. It'd be hard to carry much fire with a couple of grams of fuel per km2!
7	P3-18 L13 & L17: These dates do not align and it seems likely that the 2011-2014 should be changed to 2012-2015. However, there is no direct citation given for the tree mortality in the Rough Fire area.
8	This chapter presents an excellent overview of fire regimes and the vulnerabilities of forests to wildfire after decades of fire suppression. This reader, whose expertise is air quality, learned a lot. The recent fire history of the Rough Fire area was especially enlightening.
8	Authors might consider specifying whether the fire regimes described in Table 1 are all natural, or a mix of natural and unnatural regimes. Given the caption to Figure 3-1, it sounds like these are natural regimes.

Comments on Chapter 4

Review Question: Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

Summary of Reviewer Feedback:

Reviewers had relatively few comments on Chapter 4. Most seemed to agree that this chapter provided sufficient detail on monitoring capabilities and Reviewers 4 and 7 actually thought that this chapter might contain too much detail. Reviewer 1 noted that Chapter 4 should include a discussion of the National Oceanic and Atmospheric Administration (NOAA) High Resolution Rapid Refresh Smoke Model (HRRR). Reviewer 8 pointed out that the chapter did not mention the “key challenge” posed by the difficulty of attributing PM_{2.5} measurements to smoke or other species. Reviewer 4 also touched on PM speciation and the Chemical Speciation Network.

Several reviewers raised questions about the colors used in the Figures. Reviewers 4, 6, and 8 provided both substantive and editorial comments on Chapter 4 while other reviewers provided primarily editorial comments. Full comments on Chapter 4 are listed by reviewer number in Table 5, below.

Table 5. Reviewer comments on Chapter 4

Reviewer	Comment
1	My only comment on Ch. 4 would be the need to include a discussion of the NOAA HRRR (High Resolution Rapid Refresh) Smoke model, which provides sub-daily estimates of surface-level PM2.5 from wildfires (including Rx fires). As the HRRR-Smoke model is fine-tuned, it will increasingly play an important role in measuring PM2.5 smoke health impacts. Monitored data will increasingly be complemented with remote sensed data and modeled data on smoke exposure. Some discussion of this in Ch. 4 is warranted.
2	This section is very informative but hardly relevant to the case studies. The split personality of the report as a whole is most glaring here.
3	Page 4-7, Section 4.2.3, Lines 5, you state “focus of fire management” is it really or is it just a part of the risk management? It seems like smoke is not really the focus.
4	For the most part, this chapter covers the subject of air quality monitoring in more than enough detail. In fact, I think that it has too many details that contribute to the unnecessary length of the document overall. For example, is Table 4-1 necessary? Why does this document tell me all the things I can learn from the EPA trends report visualization tools?
4	One type of air quality monitoring that is not really discussed is PM speciation, such as from the Chemical Speciation Network. This data is useful for apportioning PM to different sources, including wildland fire, and should be discussed.
4	Page 85, line 33. The statement is true that there are no existing national monitoring programs specifically designed to evaluate smoke impacts from fires. However, this is true of most all emissions sectors. To my knowledge, there is no national-scale monitoring program designed to capture any one specific source.
5	This is not my area of expertise. I provide a few suggested edits to improve readability, as the chapter is pretty jargon and acronym heavy. I wonder if this level of detail on this topic is really needed for this report.
5	Page 4-8 line 36 change contribute to contributed
5	Page 4-10 lines 9-12: Consider changing to EPA has established one or more FRMs, including specific measurement techniques and instruments, for measuring each of the six criteria pollutants (U.S. EPA, ...).
5	Page 4-10 line 13: consider deleting 40 CFR Part 53
5	Page 4-10 lines 19-21: consider deleting “these FEM requirements are also detailed in 40 CFR Part 53 (U.S. EPA, 2019a), and. Begin next sentence with “A monitor”
6	In my opinion, this section of the report contains plenty of detail.
6	One comment – which the authors can consider and which is by no means essential for them to address right now – is the question of “how good of a measurement is good enough?” As a member of the general public living downwind of a fire, does it really matter if the true AQI is 400 and it gets misreported as 300 or 500? Either way it is a lot of PM, and some measurement error doesn’t really matter – the tools we currently have available might be perfectly adequate. Whereas for a scientific researcher, very accurate species concentrations measurements might be quite important, and we often don’t have those, and even when we do we know the aerosol composition of the plume changes with aging, etc. so one monitor isn’t enough. So different goals might necessitate different investments into the monitoring network, and this point could be made in section 4.5 or 4.6.
6	Figure 4-1 – what are the colors? The shapes are explained in the figure description but not the colors.
7	Although I have some experience with air monitoring research, I am not an expert in this field. I found this chapter to be an interesting read and a comprehensive and honest assessment of the strengths and limitations of current monitoring capabilities. The information in this chapter helps inform some of the subsequent approaches and analyses. I thought this chapter was perhaps too detailed, particularly in the discussion of some of the remote sensing techniques that have less direct relevance to public health. However, this information is useful if the purpose of this chapter is to provide a comprehensive assessment of monitoring capabilities.

Table 5. Reviewer comments on Chapter 4 (continued)

Reviewer	Comment
8	Chapter 4 does a good job describing current efforts to monitor smoke air quality with in situ sensors, ground-based measurements such as AERONET, and satellite observations. In particular, the challenge of translating aerosol optical depths (AOD) as viewed by satellites into surface concentrations of smoke PM _{2.5} was well described.
8	Figure 4.2. The colors in this figure do not match those of Table 4.1.
8	Page 4-17. The text describes current efforts to combine satellite measurements of AOD with results from chemical transport models (e.g., GEOS-Chem) to derive surface values of smoke PM _{2.5} . Figure 4.3 shows of such an effort for one day in 2020. The reader is curious if efforts are being made to validate such maps of daily surface PM _{2.5} . As the text makes clear, most (successful) efforts to combine satellite AOD and GEOS-Chem results have led to estimates of annual or seasonal mean PM _{2.5} at the surface, not daily concentrations.
8	Section 4.5. A key challenge not mentioned in this section is the difficulty of attributing PM _{2.5} measurements to smoke or to some other species. Even if sensors were placed close to wildfire-prone regions, the challenge of distinguishing smoke from other kinds of PM _{2.5} would remain. Aguilera et al. (2021) used a combination of surface EPA-AQS measurements with HMS smoke plumes to attribute surface PM _{2.5} to smoke or not-smoke in southern California. But the HMS smoke product, as the CAIF report rightly mentions, may not reflect surface concentrations. Aguilera, R., T. Corringham, A. Gershunov, and T. Benmarhnia, Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California, <i>Nature Commun.</i> 12, 1493, 2021.
8	One way to resolve this issue would be for EPA/AQS to routinely measure tracers of biomass burning such as levoglucosan. Other species currently measured – including black carbon and organic carbon – are emitted by both wildfires and other anthropogenic and/or biogenic sources.

Comments on Chapter 5

Review Question: The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?

Summary of Reviewer Feedback:

Among the reviewers who addressed the overall modeling approach, their comments indicated that they found it “sound” and “reasonable.” Several reviewers raised the issues of fuel moisture and meteorological patterns/conditions. Reviewer 5, in particular, wondered why the fire effects had not been assessed cumulatively. Other reviewers provided relatively minor comments and nearly all expressed some confusion over the formatting, scale, and labeling of the figures in this chapter. Reviewers also commented on the coarseness of the scale used in the model/figures.

Reviewer 4 made a potentially important comment regarding page 126, line 3, which reads as follows: “This is not quite correct. The original BlueSky framework was written primarily in PERL, with some C and Java; however, the most widely used version of BlueSky prior to BlueSky Pipeline was BlueSky version 3, which was written in Python.”

Reviewers 4, 5, 7, and 8 provided the most comprehensive reviews of this chapter and the modeling approach therein, while Reviewers 1, 3, and 6 abstained from commenting. Full comments on Chapter 5 are listed by reviewer number in Table 6, below.

Table 6. Reviewer comments on Chapter 5

Reviewer	Comment
2	Table 5-2: Inconsistent and/or confusing terminology: “Actual fire”, “Actual wildfire”, and “Actual prescribed fire” are all in the same table. The report as a whole needs to be edited for consistent use of terminology.
2	The plots in chapter 5 are poorly formatted. If the row location and column location of a panel in the multipanel plot are informative, why aren't the row and column headers shown?
2	Figs 5-8, 5-9: Where did scenario to 2a go?
2	Fig 5-13: Appears to be missing a row.
2	Fig 5-18: Does color correspond to vertical position? Why? This is very confusing.
2	Fig 5-19: Formatting is all over the place.
3	Page 5.2 Section 5.11. Lines 1 /2- What about ignition pattern as a factor for combustion intensity?
3	Page 5-10, Section 5.1.5, Lines 5-7, Might want to try and get a copy of the burn plan to attach as a reference.
4	The modeling approach is mostly reasonable, as are the inputs developed for fuel loading and emissions. Fire emissions modeling, and chemical transport modeling are only briefly explained here. This is OK, but it is jarringly different from the sometimes excruciating detail of other chapters (3 and 4, for example). It would be good to at least include the equation used to calculate emissions.
4	One troubling point is the last line in section 5.2.5, which states that “fuel moisture is a global parameter that only varies by fire type (wildfire or prescribed).” Fuel moisture has a very significant impact on modeled consumption in the Consume model and thus will strongly affect the resulting emissions and downwind PM2.5 concentrations. What is the justification for using static fuel moistures, and how were they selected? This detail is important to include. The model validation statistics are important and should be in the main text instead of the appendix. They show that this model is only modestly successful at replicating observed PM2.5 and help the reader understand how to assess the results. The population exposure plots don't make sense (the scaling of 1 ug or 1 ppb === 1 person is arbitrary) and should be removed. This topic is better addressed in Chapter 8. I don't understand how the pile burn emissions exercise fits into the larger study.
4	Page 119, line 22. Fix link label.
4	Figures 5-1, 5-2, 5-3. These maps needs a scale bar. Also the grid is not explained.
4	Figure 5-4. This map is at too large a scale to be useful and should be zoomed in. It also needs a scale bar.
4	5.2. How was plume injection height estimated?
4	Page 126, line 3. This is not quite correct. The original BlueSky framework was written primarily in PERL, with some C and Java; however, the most widely used version of BlueSky prior to BlueSky Pipeline was BlueSky version 3, which was written in Python.
4	Section 5.2.3. This paragraph is repetitive of information provided earlier in the chapter.
4	Section 5.2.3.1 explains how the temporal profile for the TC6 case was developed. What about the Rough fire?
4	Figure 5-8. The difference plots should have the same scales between the large and small cases so they can be compared.
4	Figure 5-9. Same as 5-8.
4	Figure 5-12. The units on the lower left plot are incorrect (although I think the population exposure plots should be removed). Why are the scales so large?
4	Figure 5-12. It is unclear from the text how the pile burn estimates contribute to the case study. Are they included in the health effects portion (chapter 8)?
4	Figure 5-13. Caption does not match the figures (there is no middle row).
4	Figure 5-16. The meteorological pattern and resulting population impacts are quite different from some other events (e.g., 2020). This highlights the limitations to the conclusions one can draw from this study.

Table 6. Reviewer comments on Chapter 5 (continued)

Reviewer	Comment
5	The modeling approach is reasonable and well described and the authors include an honest assessment of the limitations of this approach, especially as related to the different time horizons of prescribed fire and wildfire. Even with this limitation, given the attention paid to the expected value framework in chapter 2, I was expecting the scenarios with wildfire and prescribed fire to have results presented as a cumulative effects. For example, hypothetical smaller TC6 fire is assumed to be smaller because of implemented prescribed fires. To evaluate expected value of this scenario, wouldn't you need to examine the emissions of the wildfire as well as all the prescribed fires combined, even if they occur over different time periods? Here or elsewhere in the report, I'm seeking some explanation for why each of these scenarios display outputs from individual fires, when there are basic assumptions behind the scenarios that the prescribed fires and wildfires are not acting independently.
5	Page 5-2 line 18. Carbon should be capitalized
5	Page 5-2 line 19: Should emission factor be defined?
5	Page 5-4 line 21: suppression and fuels management efforts.
5	Figure 5-3: Why isn't the 2019 Rx Fire on this map?
5	Figure 5-4: It would be better if the scale of this figure could be more akin to that of figure 5-3.
7	I think the modeling approaches that were used were sound. In general, the assumptions and the source data driving the modeling is clearly described. However, while I see where the meteorological data driving the atmospheric transport is described and I see where the fuel load and type data are described, I do not see any description of the meteorological inputs to the fire modeling (no description of fire weather) and I do not see a description of fuel moisture. Presumably, these are handled in the BlueSky Pipeline/Consume because it is producing estimates of fuel consumption and emissions. While presumably the modeling reflected the conditions of the actual burns, conditions would have to be assumed for the other burns. Some description of these assumptions would be insightful.
7	P5-18 L8: All land is managed and all USFS and NPS lands should have management plans. Even wilderness lands are managed!
7	Figure 5-14 needs better labeling, particularly the panels on the left side that are all have the same heading.
7	Figures 5-15 and 5-16: The color ramps are similar for the absolute concentrations (left panels) and the differenced concentrations (middle and right panels), which is unintuitive given that the scales are quite different. I think it would be easier to understand that the middle panels are lower and right panels are higher if a different color scheme was used.
7	P5-31, L 9-14: It is good to note this limitation because a 12-km grid size does seem like it would be too coarse to accurately model and quantify the impacts of fire emissions on downwind communities.
7	P5-33, L3: This sentence desperately needs a comma after "population"
7	P5-37: Given that there are large population centers near the Rough Fire and that a higher resolution (finer scale) model may be much more accurate, why not also do a finer scale model run instead of only relying on the coarse 12 km grid?
8	Chapter 5 lays out the design of the model simulations and presents results in terms of the PM _{2.5} and ozone enhancements from the different kinds of fires – wildfire vs. prescribed, actual vs. hypothetical. Overall the modeling approach is sound, and the authors seem very aware of both the strengths and the limitations of this approach. For example, the chapter mentions how the interannual variability of meteorology is not captured by this approach, and how the spatial resolution of the model may fail to capture steep gradients in both topography and in concentrations. The chapter is also very clearly written, with a nice introduction to the challenges of modeling fires – e.g., the limited knowledge of emission factors, especially from smoldering vs. flaming fires.
8	Section 5.1.3. As mentioned for a previous chapter, it might be helpful to include a table describing the characteristics of the different scenarios and the timeframes of these scenarios.

Table 6. Reviewer comments on Chapter 5 (continued)

Reviewer	Comment
8	Sections 5.2.1 and 5.2.2. There seems to be some overlap between the two sections. For example, FCCS is introduced to the reader twice. Perhaps some effort could be made to better harmonize this text.
8	Section 5.2.3.1. This section presents the temporal profile for the Timber Crater Fire. I didn't see a similar description of the profile for the Rough Fire.
8	Page 5.18. This reader is surprised that modeled fuel moisture is not a function of meteorological variables like relative humidity or recent precipitation. Is this typical for fire models?
8	Table 5.2. The authors might consider adding a footnote to explain that the 1978 and 2001 Timber Crater fires and the 2007 Cornerstone fires are actual fires, occurring in the past. Also the designation of "Timber Crater 1/2" is confusing. The reader thinks "1/2" means one-half.
8	Figures 5.8 and others. A note explaining that the colorbars differ among panels would be helpful.
8	Figure 5.10. Again a note explaining the different extents of the y-axes would be helpful.
8	Page 5.25. The text states that the daily impacts of MDA8 ozone from prescribed fire were sometimes comparable or even larger than that in the wildfire scenarios. The first reason given for this increase – that the model burned all the fuel in one day – seems unconvincing, as the same phenomenon is not seen for the PM _{2.5} results. Perhaps this reviewer is missing something.
8	Figure 5.13. The caption seems not to match the Figure.
8	Page 5.35. The text points out that the model sometimes overestimates PM _{2.5} compared to that measured by the sensors. A potential reason given for this overestimate is that the model does not take into account the volatilization of primary organic aerosol (POA). That could be true, although Palm et al. (2020) found that much of the volatilized POA actually re-condenses to produce an equivalent mass of secondary organic aerosol. A more likely reason for the mismatch could be the coarse model resolution, as the authors also note. Palm, B.B. Quantification of organic aerosol and brown carbon evolution in fresh wildfire plumes, <i>PNAS</i> , 117 (47), 29469-29477, 2020.
8	Section 5.4. This section nicely summarizes the approaches and limitations of the study.

Comments on Chapter 6

Review Question: Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

- The health effects discussion focuses on U.S.-based epidemiologic studies to support the BenMAP – CE analysis discussed in Chapter 8. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health impacts in BenMAP – CE. Have any U.S.-based studies been excluded from the discussion that should be included?
- The discussion of actions that can be taken to reduce wildfire smoke exposure is aimed at supporting the development of sensitivity analyses in BenMAP – CE to estimate the potential reduction in PM_{2.5} exposure from wildfire smoke that could be experienced due to specific actions by the public. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.
- The ecological impacts discussion focuses on those effects attributed to wildfire smoke exposure and deposition. Please comment on the ecological impacts highlighted and whether additional studies/citations should be considered within this section.

Summary of Reviewer Feedback:

Seven of the eight reviewers submitted comments on Chapter 6. Most reviewers responded to only part of the question series for this chapter, pointing out that their expertise did not cover one or more portions of the subject material within the chapter. Reviewer 4 questioned why all of the material was included in one chapter, since each section of the chapter “seemed quite different.” Several reviewers commented on the thoroughness of the literature review and noted that they enjoyed reading the chapter. Not all agreed with the assessment of the literature on the health effects of smoke vs. PM from urban sources. Reviewer 8 listed several studies that contradict the text on page 6-14, which reads, “current evidence does not indicate a difference in health effects between ambient PM_{2.5} exposure and other source-based exposures, such as wildfire smoke,” noting that the studies, “suggest that wildfire smoke may be more deleterious than anthropogenic PM_{2.5}.” Reviewer 1 made similar comments and also noted that “the smoke health impacts from Rx fires may be

meaningfully different” than those from wildfires and provided supporting citations. Please see Appendix C for the list of citations Reviewers 1 and 8 provided to support their comments.

Reviewer 2 noted that, while the literature review on health effects was appropriate for the chosen health endpoints, those endpoints were too narrow and might result in underestimates of the true health impacts of wildfires. This reviewer again raised the issue of equity regarding information and mitigation actions and how those might vary between different socioeconomic groups. While the reviewer noted that the chapter did not include a discussion of equity issues or “research on air infiltration in homes by SES or race,” no specific citations were provided. Reviewer 7 also commented that Chapter 6, specifically section 6.4, was missing information. In particular, this reviewer mentioned two points not covered in this chapter: “(1) The ability of smoke to create diffuse radiation, which can increase photo synthesis (2) The effect of smoke on air temperature and vapor pressure deficit.”

Reviewers 1, 2, 6, 7, and 8 provided the most extensive comments on Chapter 6 and Reviewers 4 and 5 provided relatively minor comments. Reviewer 3 did not provide comments on Chapter 6. Full comments on Chapter 6 are listed by reviewer number in Table 7, below.

Table 7. Reviewer comments on Chapter 6

Reviewer	Comment
1	My only general comment on Ch. 6 is the need to have a dedicated section in this chapter on the health impacts of prescribed fires, specifically. There is now a growing literature on Rx fire health impacts, separate from the general wildfire health impacts literature (see Jones & Berrens, 2021 for infant health and Rx fire; ER visits and Rx fire in Huang et al. 2019; and a discussion of environmental justice dimensions of Rx fire exposure in Gaither et al. 2019). The current focus on the wildfire smoke health literature in the report is too limited and needs to be expanded.
1	Additionally, some discussion is needed in Ch. 6 on the potential differences in public health impacts between smoke from Rx fires compared to smoke from wildfires. A recent piece in Nature Communications by Aguilera et al. would be a good starting point. As would the paper by Haikerwal et al. (2015) that discusses Rx fire health impacts compared to wildfire health impacts. My point here is that smoke health impacts from Rx fires may be meaningfully different than the smoke health impacts of wildfires and some detailed discussion of this is needed in Ch.6. Not all smoke is created equal.
1	Figure 6-6: Jones et al. (2016) also looked at the population of people taking action in response to smoke from the Wallow Fire in Albuquerque, NM (see Table 1 of their paper). Suggest their data also be included here.
1	Overall, Ch. 6 does a nice job of covering the literature, but several relevant studies are omitted and the literature specific to Rx impacts and health needs a dedicated section in Ch. 6.

Table 7. Reviewer comments on Chapter 6 (continued)

Reviewer	Comment
1	This discussion is good, though I agree that our understanding of how people differentially respond to Rx fires vs. wildfires is a large knowledge gap. We know very little about Rx fire responses/behavioral changes at this point in time. This limits any empirical analysis in BenMAP.
1	The ecological impacts discussion focuses on those effects attributed to wildfire smoke exposure and deposition. Please comment on the ecological impacts highlighted and whether additional studies/citations should be considered within this section. Ecological impacts are outside of my area of expertise.
2	The studies included are appropriate for the chosen endpoints, but the EPA's assessment of which concentration-response relationships are "causal" and "likely causal" is a trailing indicator of the state of the science, in this case by about a decade. There are other endpoints (I'm thinking of neurological and pregnancy outcomes) that should either be incorporated or their absence should be addressed. It should be stated clearly that narrowing the health endpoints to only those used will underestimate the true health impacts of wildfires.
2	While much more research on this topic is needed, this section does a good job of incorporating what information exists. However, this is where a thorough discussion of equity issues should be brought in. Information and mitigation actions available to the public may differ widely between socioeconomic groups. Some groups may not know about public health warnings, know where to look for them, be able to read them in their native language, or be able to act on them. Home's air infiltration rates are not uniformly distributed across the population, nor is the money to tighten air envelopes or purchase air purifiers. There probably exists some research on air infiltration in homes by SES or race that this report should try to highlight if not incorporate.
2	The ecological impacts discussion focuses on those effects attributed to wildfire smoke exposure and deposition. Please comment on the ecological impacts highlighted and whether additional studies/citations should be considered within this section.
4	I'm not sure why this is all in the same chapter. These three sections seem quite different. The first section is very well researched, written, and organized, and I enjoyed reading it. I do not know the literature well enough to comment on if it included every relevant study. The section on actions to reduce wildfire smoke was also well presented, though the evidence there is much more tenuous. The section on ecological impacts was interesting, but outside my knowledge and I have no specific comments.
5	The ecological impacts discussion focuses on those effects attributed to wildfire smoke exposure and deposition. Please comment on the ecological impacts highlighted and whether additional studies/citations should be considered within this section.
5	I'm not sure why ash impacts are singled out and included in this section and in the conceptual framework. It seems like this should be included in the broader discussion of ecological fire effects.
6	My reading of the literature is that the short-term health effects of PM from smoke are a bit different from the short-term health effect of PM from typical urban sources – the systematic reviews suggests show that smoke is strongly associated with respiratory events (and the consistency across epidemiologic studies of wildfire smoke is remarkable), and that smoke is less strongly associated with cardiovascular events (compared to PM from traffic sources). This seems to be supported by the forest plots shown in the chapter as well. Whereas the intro of chapter 6 seems to suggest that the findings for smoke are similar to what we see for PM in general.

Table 7. Reviewer comments on Chapter 6 (continued)

Reviewer	Comment
6	The review of the epidemiologic literature seems solid – the forest plots are good to show how the results from the different studies compare. One thought is that in earlier chapters the report makes a clear point to restrict focus & generalization to Ponderosa pine forests, but the CR functions are coming from U.S. studies where the fires occurred in a variety of ecosystems – presumably because we don't have enough restricted to Ponderosa pine forests, but perhaps it makes sense to justify this explicitly in the report given what is written in earlier chapters.
6	The section on the public health actions is good, but it's hard to think about how to use this alongside the concentration-response functions described earlier in the chapter with BenMAP. One reason is that in the epidemiologic studies, these exposure reduction actions were already employed (to various unquantified extents) in the populations in which the epi studies were conducted. Perhaps this will be clearer to me how the authors use this once I get to the BenMAP chapters, but it is something I was thinking about while reading section 6-3. Another challenge is that Table 6-3 is about in-home exposures, whereas the CR functions are about ambient concentrations.
7	Sections 6.2 and 6.3 are great. I am not a researcher of the health effects of smoke, but I am familiar with the literature and I think these sections are really excellent syntheses. Section 6.2 is a good concise survey of the available evidence for wildland fire smoke health effects that I think produced a very balanced assessment of the state of the science on this topic. Section 6.3 is the best synthesis of mitigation measures that I've seen. Section 6.4 was well written, but missed some important context and neglected a couple of important environmental effects of smoke. In particular, section 6.4 is missing two components: (1) The ability of smoke to create diffuse radiation, which can increase photosynthesis (2) The effect of smoke on air temperature and vapor pressure deficit.
7	P6-1 L2: "ecological benefits" would be better phrased as "environmental benefits", particularly given the potential positive impacts on streamflow. Watershed yield is a critical environmental parameter in the water-limited western US.
7	P6-3 L8: Comma needed after "exposure"
7	P6-28 L29-30: I'm confused by the redundancy of "particulate matter" in this sentence.
7	P6-29 L1: "It is"
7	6.4.2: The effects of ozone on plants tends to be a result of cumulative exposure and uptake, which is relevant here for two reasons. (1) Smoke from wildland fires is highly episodic. (2) Wildland fires tend to burn during episodes of especially dry conditions and during periods of the year in dry (western) ecosystems when growth and carbon assimilation are limited and many plants have senesced; both of these would limit plant ozone uptake. Therefore, although this section does provide a concise review of the effects of ozone on plants, it should be caveated with the fact that wildland fire smoke itself is unlikely to produce the cumulative ozone exposures necessary to create these effects. However, there is potential for wildland fire smoke to exacerbate ozone effects in environments already suffering from ozone pollution.
8	Yes, this section does a good job providing an overview of the health impacts of smoke exposure. The summary of different metric of smoke exposure was helpful.
8	One recent study examining the health impacts of smoke is Aguilera et al. (2021). Also, Liu et al. (2017a) is cited but not Liu et al. (2017b), which investigated the health impacts of smoke on different populations. References listed below. The authors might consider including all three references in the Figures showing odds ratios.
8	Page 6-5. The authors might consider mentioning the modeling approach of Liu et al. (2017a), in which the modeled PM _{2.5} was calibrated with observations.
8	Figures 6-1, 6-2, 6-3. The tiny text is difficult to read.

Table 7. Reviewer comments on Chapter 6 (continued)

Reviewer	Comment
8	Page 6-14. The text states that “current evidence does not indicate a difference in the health effects between ambient PM _{2.5} exposure and other source-based exposures, such as wildfire smoke...” However both Liu et al. (2017a) and especially Aguilera et al. (2021) suggest that wildfire smoke may be more deleterious than anthropogenic PM _{2.5} .
8	However, a discussion of the differences between ash and black carbon particles would have been helpful.

Comments on Chapter 7

Review Question: In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

Summary of Reviewer Feedback:

Several reviewers commented unfavorably on the organization and flow of Chapter 7. While Reviewer 6 felt the chapter detracted from the new work presented in the report and should be omitted, other reviewers suggested areas where information should be added, including:

- Acknowledgement that the regrowth of forests can draw CO₂ levels back down resulting in a net zero impact of fires (Reviewer 8).
- Structure hardening as a mitigation measure (Reviewer 7).
- Decreased precipitation interception due to vegetation and plant litter loss (Reviewer 7).
- The point that low and moderate severity wildfires may positively impact downstream water users (Reviewer 7).
- The point that fuels treatments can lead to increasing suppression costs (Reviewer 5 offered multiple citations to support this point).
- Reservoir dredging cost due to fire-related sediment (Reviewer 5).

In addition to the comments on structure and flow, several reviewers commented on the readability, text size, and resolution of the figures in this chapter. Reviewers 3, 5, 7, and 8 provided the most substantive comments on Chapter 7 and Reviewers 2, 4, and 6 provided relatively minor comments. Reviewer 1 declined to comment on Chapter 7. Full comments on Chapter 7 are listed by reviewer number in Table 8, below.

Table 8. Reviewer comments on Chapter 7

Reviewer	Comment
2	Page 7-4 line 11: This is the only reference to crystalline silica in the document. Why is it important?
3	Section 7.2.1, Page 7-2, Lines 17/18: Do you have data to support this statement: "The main 17 inhalation hazards for wildland firefighters and other personnel at fire camp". Most data collection has been on the fire line, not at camp.
3	Would also be good to state in section 7.2.1 that OSHA standard is PM4, not PM2.5 like the general public.
3	Section 7.2.2.1, Page 7-3, Lines 26-28: Do you have a source for this? "For example, if the Air Quality Index (AQI) during off-duty 26 exceeds 100 (i.e., orange: unhealthy for sensitive groups) due to PM in the fire camp, this can result in 27 firefighters experiencing continuous exposure to high PM concentrations." Some camps are smokey, but most crews try not to sleep in them if that are smoked in.
3	Section 7.3.2.5, Page 7-13, Line 30: Do they specify wildland "which include arson", would a majority be structure fire arson arrests?
4	Though it is outside my area of expertise, this chapter seems disorganized and rough. The two main sections seem quite unrelated. Figure 7-2 is not well explained (and too low resolution).
4	Page 210, line 13. This is not a sentence.
5	Table 7-1: Disaster resilience – should this be disaster assistance?
5	Page 7-11 lines 11-26: This paragraph omits the argument, which some studies support, that fuels treatments can lead to increasing suppression costs because it provides opportunities for more aggressive and expensive fire suppression response. Other studies to consider: Bevel, E.J., C.D. O'Connor, M.P. Thompson, and M.S. Hand. 2019. The role of previous fires in the management and expenditures of subsequent large wildfires. Fire 2 doi.org/10.3390%2Ffire2040057. Loomis, J., J.J. Sánchez, A. González-Cabán, D. Rideout, and R. Reich. 2019. Do fuel treatments reduce wildfire suppression costs and property damages? Analysis of suppression costs and property damages in U.S. National Forests. USDA Forest Service Pacific Southwest Research Station Gen. Tech. Rep. PSW-GTR-261. Albany, CA. Rideout, D.B. and P.S. Ziesler. 2004. Three great myths of wildland fire management. In: González-Cabán, A. (technical coordinator) Proceedings of the II International symposium on fire economics, planning, and policy: A world view, April 19-22, 2004 Córdoba, Spain. USDA Forest Service Pacific Southwest Research Station Gen. Tech. Rep. PSW-GTR-208, Albany, CA. Thompson, M.P. and N.M. Anderson. 2015. Modeling fuel treatment impacts on fire suppression cost savings: A review. California Agriculture 69: 164-170.
5	Section 7.3.2.4 – Either here or somewhere in the report, there should be a brief discussion of what types of activities are included under these costs.
5	Page 7-13 line 28: "In 2019, there were 785,500 prisoners in local prisons" – What is this referring to, the number in prison for arson?
5	Page 7-15 line 15: change 'mudslide' to 'flooding and debris flow'
5	Section 7.3.3.1.4 – Also the costs of dredging reservoirs that experience reduced water capacity from increased sediment transport due to fire.
6	I don't have comments on this chapter. While it's undeniably true that these are real issues, they are separate from the air quality and health impacts work that comprise the new science that this report is contributing to the literature. I get that the authors are trying to be holistic and encompassing with this report, but in some ways it distracts from the new work that was actually done. I paged through it to get to Chapter 8, which is the chapter that (in my mind) should logically come after Chapter 6.
6	Some of the sections in Chapter 7 are terse (e.g., 7.3.3.1.3). Even so, I am not convinced that expanding Chapter 7 would meaningfully add to the value of the overall report.

Table 8. Reviewer comments on Chapter 7 (continued)

Reviewer	Comment
7	This chapter discusses numerous aspects of fire-related damage. The coverage of these topics is broad and often brief. However, I don't disagree with this strategy and I think the text provides sufficient depth. I observed only a few concepts that had been omitted or described insufficiently. First, there should be some discussion of structure hardening as a mitigation measure. While the focus of this chapter seems to mitigation of fires on wildlands, inclusion of structure hardening would seem appropriate given the inclusion of defensible space because both are about limiting ignition to build infrastructure. Second, the description of hydrologic impacts of fire could be expanded to be more robust, as detailed below.
7	In late 2020, the California Council on Science & Technology produced a report on the costs of wildfire that would be a very relevant contribution to many aspects of this chapter.
7	7.3.3.1.5: In areas experiencing extensive wildfire, the sudden surge in timber availability from salvage logging can saturate local markets (mill capacity). This has two effects (1) It decreases the immediate value of timber from unburned areas and (2) It can limit opportunities and financial incentives to conduct salvage harvests.
7	P7-16, L12: Spelling: Hayman, not Haymen
7	P7-19 L30: This section neglects to mention the decrease in precipitation interception created by the loss of vegetation and plant litter material. Interception of precipitation can have a tremendous effect on both the quantity and timing of water delivery to the soil surface and subsequent run-off.
7	7.3.3.2.5 The section on Water Resources neglects to mention that low and moderate severity wildfires can have a positive impact on downstream water users because water quality impacts may be low, but the decrease in vegetation can increase the supply of water (stream flow).
8	The reviewer has little expertise in the topics discussed in this chapter. However, the descriptions of the costs and benefits of fires seemed relatively clear. For example, the authors point out that low-intensity prescribed fires coupled with mechanical thinning can reduce the risk of catastrophic fire, and thus lead to a net benefit. The chapter also makes clear the resistance that some landowners have toward prescribed fire.
8	Figure 7-1. Axis labels are too small to read.
8	Section 7.3.1. This section was hard to follow. The notion of prefire suppression is introduced but not defined until later in the chapter. It wasn't clear what the difference is between C+L and C+NVC. How do prescribed fires fit into Figure 7-2?
8	Section 7.3.2.3. Do suppression efforts include prescribed fires?
8	Page 7-15. The text mentions that trees sequester carbon, and that this carbon can be released during burning, implying that forest fires can affect CO ₂ concentrations. The text should acknowledge that the regrowth of forests can draw CO ₂ levels back down, with a net zero impact of fires on CO ₂ .
8	Page 7-19. Two more recent papers that predict increasing fire under a climate change regime include Ford et al. (2018) and Li et al. (2020)

Comments on Chapter 8

Review Question: Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

Summary of Reviewer Feedback:

Several reviewers referred to the analysis in Chapter 8 as appropriate and/or reasonable, though most also noted the limitations of the analysis. Most who provided substantive comments questioned the CR functions used and assumptions made about them. Both Reviewer 5 and Reviewer 7 wondered about why smaller fires and prescribed fires were not assessed in a combined or cumulative manner. Reviewers also raised some questions about the figures and tables in the chapter. Only Reviewer 3 declined to comment on this chapter, while Reviewers 6 and 8 provided the most substantive comments. Full comments on Chapter 8 are listed by reviewer number in Table 9, below.

Table 9. Reviewer comments on Chapter 8

Reviewer	Comment
1	I did not thoroughly review Ch. 8 (instead I focused on the Chapters that I was directly asked to review). However, I will note that I did not see Jones et al. (2016) or Jones & Berrens (2017) cited in Ch. 8; both also use BenMAP-CE to evaluate wildfire smoke health impacts in the Western US. I would think they should be included in this chapter as background (or in another chapter, if more relevant).
1	I will also note that in section 8.2.3. it appears that the effect coefficients used are from the general air quality and health literatures and are not specific to the wildfire smoke and health literature. Suggest that the authors review Aguilera et al. (2021) in Nature Communications and also see Jones et al. (2016) for why smoke from wildfires may be different such that using general air quality coefficients may be incorrect. It is at least worth commenting on in the report (if not more fully incorporating wildfire smoke-specific coefficients).
2	Page 8-4 lines 28-34: The reasoning for using the short-term effects in one case study and the long-term effects in the other deserves a bit more explanation.
2	Figs 8-1, 8-2: How are the filled circles and empty circles different? Needs a legend.
2	Figs 8-6, 8-7: What is being counted here? What do these numbers represent?

Table 9. Reviewer comments on Chapter 8 (continued)

Reviewer	Comment
4	The approach for the main BenMAP analysis is appropriate, but the results are limited in applicability. The case studies are quite narrow. Not only can they not be broadly applied to cases in other locations and ecosystems, they can't really be applied to the same locations for different dates. A more statistical approach, looking at a wide range of fire locations and weather patterns would provide a more useful quantification of the differences between prescribed burns and wildfires. The resulting costs are highly dependent on wind direction and meteorology generally. Perhaps this is the biggest takeaway from the study for me. The air quality benefit of simply being able to select the meteorological conditions for prescribed burning can be huge, and I think is not stressed enough in the study.
4	It is very difficult to compare the results of the sensitivity analysis (section 8.3.2) from those of the "main results" because they are presented so differently. It would be very helpful for those to be parallel or, even better, on the same graphic or table. I am personally better able to understand the graphical presentation, such as in Figure 8-1, than the tabular presentation of Table 8-2.
4	Page 236, line 14. Fix broken link label.
5	My comments for this chapter are very similar to that of chapter 5. While the modeling approach seems appropriate, it don't understand why the effects of the smaller wildfires and prescribed fires are not assessed in a cumulative manner, to be more consistent with the expected value framework. It would also make more sense to me if this chapter were to follow chapter 5, as it is an extension of the modeling effort presented in that framework.
6	Major comment (repeated from earlier in the document): I was surprised to see the list of concentration-response functions used in the "primary" analysis were from studies of urban air pollution. It's fine, but it feels out-of-whack with Chapter 6, which didn't really comment on these studies (at all), but instead focused on the studies of wildfire smoke. Also, when I read 8.2.3, I didn't understand why there were CR functions for long-term PM exposure being used in this analysis – I think better justification for this is warranted – scientifically, I don't understand the rational for applying CR functions for long-term PM exposure to a ~60 day fire event. Also, some of the CR functions (e.g., Katsouyanni et al. 2009) aren't from the US, which seems at odds with the focus on US studies in Chapter 6.
6	Table 8-6...are the authors assuming that the prevalence of these actions in the studies that provided the CR functions is 0%? If so, that assumption is wrong for the studies of wildfire smoke health associations...although I guess the authors could argue that by using the CR functions from the urban air pollution studies that it's a reasonable assumption. But that sort of argument also highlights the disconnect between Table 8-6 and the health impact estimates that are ACTUALLY being generated vs. the ones that we wish we were in a position to generate...
6	I don't want to be too critical about Chapter 8 – I think it's great work, and there is value in understanding the relative magnitude of differences in impacts across the scenarios (getting the numbers right is scientifically interesting, but also a lot harder to do, and ultimately may not be necessary to inform forest management practices). Using the estimates from the epidemiologic studies of wildfire smoke won't necessarily get better estimates, since the literature is smaller and also the random errors are larger owing to smaller sample size. But it does have the advantage of being a bit more logically connected to the science, particularly for some of the sensitivity analyses. The authors are upfront and transparent about this in the Summary, which is good.
7	P8-4 L31-34: It is true that the Rough Fire lasted for multiple months, but most of the population exposure (Figure 5-17) was limited to a few distinct episodes. Would combining the short-term exposure effects of these episodes have resulted in stronger or weaker effects relative to modeling the effects of long-term exposure?
7	Figure 8-1 and Figure 8-2: Some of the symbols are empty and some filled, but I don't see any text explaining the significance of this. Please explain or change.

Table 9. Reviewer comments on Chapter 8 (continued)

Reviewer	Comment
8	The authors take a very reasonable approach to estimate the health effects of the Rough and TimberCrater Fires and possible scenarios for both these fires. Writing was very clear, and the bullet list of the different fires and scenarios was helpful. This reader was glad to see a distinction made between the long- and short-term health effects of fires.
8	Table 8-1 and Section 8.3.2. The text states that concentration response (CR) functions for wildfire-specific PM _{2.5} were applied in the sensitivity studies, and the discussion of such functions in Chapter 6 is referenced. But there exist many such wildfire-specific CR functions, as Chapter 6 reports. The reader wonders which of these many CR functions were applied here.
8	Section 8.2.6. This section introduces the concept of Value of a Statistical Life (VSL), and more information is provided in Section 8.3.1. Perhaps the authors would consider consolidating this text. Not all readers are familiar with VSL. Does VSL vary with age?
8	Figure 8-1. A note about the meaning of the filled and open circles would be helpful.
8	Table 8-6. The caption should make clear what is meant by “impacts.” It took this reader some time to realize that “impacts” referred to the sum of ER visits, hospital admissions, and deaths for each scenario – i.e., the sum of counts going across Table 8-2 for the actual fires and scenarios.
8	Section 8.4. The impacts of the actual Rough Fire are large – 80 deaths due to long-term effects and \$3 billion in costs. The summary may want to quote these values in an effort to emphasize the huge cost of wildfires to human health and welfare.

Comments on Chapter 9

Review Question: Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

Summary of Reviewer Feedback:

Reviewers described the synthesis provided in Chapter 9 effective, well written, nice, and enjoyable. Most thought it did a good job of summarizing major findings and limitations. Some reviewers had specific questions about the conceptual diagram and the meaning of certain terminology. Reviewer 1 reiterated several criticisms from previous chapters, particularly regarding the impacts of certain modeling assumptions and specific limitations of the report. Reviewer 1 also supported the suggestion of a centralized repository specific to prescribed fires. Several reviewers praised the text and discussion on page 9-15. Reviewer 2 pointed out, once again, the research gap in “how equity intersects with exposure, public health information delivery, and access to protection and mitigation actions.” Reviewers 1, 5, 6, 7, and 8 all provided substantive comments on this. Full comments on Chapter 9 are listed by reviewer number in Table 10, below.

Table 10. Reviewer comments on Chapter 9

Reviewer	Comment
1	p.9-1, lines 5-8: grammatical errors. Reword.
1	p.9-1, second paragraph: I think the report is underselling how consequential the rather strong assumptions made are at affecting the results. I agree that expert judgment was used, but the required assumptions were both many and were very strong, in my opinion. Simply making a few other assumptions (that would also be expert, in my opinion) would likely change the results by a lot (e.g., using wildfire-specific CR function beta coefficients, looking at an actual Rx fire instead of a hypothetical one, etc.). Suggest that the statement “required assumptions and decisions based on expert judgment” on line 18 be re-worded to convey just how strong some of these assumptions made were. Overall, the report comes across as a little too authoritative for my taste when, in reality, so much remains unknown and so many assumptions were made (where equally justified assumptions could have been made and that would have affected the results).
1	p.9-2: Are there plans by the EPA, USFS, and others to conduct similar investigations on the other components of the conceptual framework (e.g., direct fire effects, ecological effects, other health effects, non-health impacts on society, etc.)?

Table 10. Reviewer comments on Chapter 9 (continued)

Reviewer	Comment
1	I enjoyed the detailed summaries of the work performed for the TC6 and Rough Fires (sections 9.2.1 and 9.2.2). I found them useful and the discussions to be relevant when contextualizing this work within the larger literature in this area.
1	Figure 9-4 (which is the same as Figure 2-1) should be updated per my earlier comments on Ch.2.
1	Section 9.3.2: In my mind, the main overarching limitation is that the analysis performed in this report does not address the larger question as to the intertemporal benefits and costs of Rx fire. Using prescribed fire generates immediate costs on society (in terms of smoke health impacts), but, also generates long-term benefits to society (in terms of reduced future wildfire severity and risk). The long-term benefits also include the potential for reduced future smoke health impacts from wildfires occurring on Rx lands. This intertemporal benefit-cost analysis is needed in future work to address the role of Rx fire within the larger fire policy context. Net present values will be needed to do this (which this report also does not consider). Figure 9-5 begins to get at this, but it's missing the smoke health component and the role that Rx fires today have on future emissions and future health impacts through wildfire severity. The discussion on p.9-15 is a good starting point, but must more emphasis should be placed on the critical need for future work to address the smoke health tradeoffs between wildfire and Rx fire.
1	Another overarching limitation that should be expounded upon in Ch.9 is that we frankly do not know the full extent of the economic costs associated with smoke exposure. Yes, premature mortality and morbidity, but what about impacts to the labor market, education, test scores, recreation and exercise, obesity, and minor effects on people such as headaches and slightly reduced productivity? There are many dimensions of smoke impacts that we simply do not know and need data to fill these gaps. Suggest that some of these other dimensions are discussed, specifically, as avenues for future work.
1	p.9-20, lines 35-38: The suggestion for a centralized respiratory specific to prescribed fires is an excellent one. We need a NIFC for Rx fires, complete with start/end times, acres burned, spatial characteristics, etc. for all Rx fires in the US each day. Fully agree with this recommendation. Maybe EPA or USFS can look more into collecting such data. We have to begin to get a handle on the actual smoke health impacts of Rx fires that occur more often than wildfires. Data is key to this.
2	Fig 9-1: Shouldn't this be in the modeling chapter?
2	Section 9.3.3: There is a research gap on how equity intersects with exposure, public health information delivery, and access to protection and mitigation actions.
3	I enjoyed this final discussion in the paper. Really will help lay out options for additional discussion on both human and forest health.
4	The synthesis is well written and does a good job of highlighting the strengths and limitations of the assessment.
5	Page 9-1 lines 20-28: This is a good description of the intent of the report and I wish this had been articulated in this manner earlier in the report. I think the report overall however, fails to fully meet the goal of describing "the state of the science with respect to implementing this framework with the goal of employing the best available science and data to estimate many of those impacts and goals". Many of the chapters do not explicitly address the framework. The authors should carefully review each chapter, especially those not pertaining to the novel modeling approach, with this larger goal in mind.
5	Page 9-13 Line 20: This part of the conceptual diagram is very confusing. What is meant by the ability to mitigate the direct effects of wildfire? I'm assuming this is referring to the line that goes from wildfire to ability to mitigate impacts to non-smoke fire impacts. Is this referring to suppression actions, wildfire use for resource benefit. That flow in the diagram doesn't make a lot of sense and I don't recall seeing a good explanation for what it is referring to.
5	Page 9-13 line 21: Why are these considered "nonfire effects"? They are certainly related to fire.

Table 10. Reviewer comments on Chapter 9 (continued)

Reviewer	Comment
5	Page 9-13 line 23: It seems strange to me to pull out ash deposition as such a prominent fire effect in the conceptual diagram.
5	Page 9-15 middle of last paragraph: Consider this edit: “although prescribed fires may reduce both the ignition probabilities and severity of fires, they produce smoke that may, or may not, mitigate the smoke output of a potential future wildfire”
6	My feeling is that Chapter 9 is a nice summary of the information presented within this report. I really don't have comments here – I think it is well-written and comprehensive. My understanding is that the datasets for prescribed fires are lacking and not systematically collected, and that this is really a big limitation for the air quality modelers. I appreciate that this is mentioned in Section 9.5 as well as in the Executive Summary.
7	Chapter 9 is an effective synthesis, though the length and breadth of the report makes it difficult to provide much substantive information about the individual chapters. I think the emphasis on (1) the main conclusions regarding the smoke produced in these fires and the subsequent public health effects (2) the limitations of this work (3) research gaps, was appropriate.
7	I'm not sure the Introduction section (9.1) adds much value because it restates what was previously written and then simply outlines the rest of the chapter.
7	Figure 9-1: What are the error bars? Standard error? 95% CI? Other?
7	Figure 9-2: What are the white portions of the bars?
7	Page 9-15: This text is excellent, important, and should be elevated to more prominence within this analysis.
7	P9-19 L1-3: Rephrase to “As human development extends further into fire-prone wildlands, it can lead to a change in the composition...” The wildfires have (essentially) always been there. Humans and their stuff are now in the way of those fires.
7	P9-19 L33: I think “can” should be deleted from this sentence.
8	Chapter 9 does a good job synthesizing information in this document, including a description of the approach taken and the results obtained. The rationale for the modeling approach is clearly laid out, and the background information on prescribed fires in the Timber Crater area is detailed. There is also a nice summary of fire reduction efforts around Timber Crater. The limitations of the study and data gaps are well described.
8	The authors might consider including here a more quantitative description of the various impacts of the two fires. Those readers who cannot peruse every section will expect the summary to quantify some of the public health impacts reported in Chapter 8. For example, the public would likely be astonished to learn that the Rough fire may have led to as many as 80 deaths and \$3 billion in damages. The take home message that prescribed fires can substantially reduce morbidity and mortality from fires, especially in populated areas, should be more strongly emphasized.
8	Section 9.2.2. As stated above, more quantitative information on the impacts of the Rough fire would be appreciated by readers. Page 9-9 states that the hypothetical scenario yields a 40% reduction in fire “impacts,” but these impacts are not defined. Is this meant as the sum of emergency visits, hospital admissions, and deaths? Also effective would be a statement of the number of lives saved in the smaller-fire scenario.
8	Section 9.2.2. This section seems wordy and hastily written and so could be more carefully written.
8	Page 9-9. The text states that fires occurred more frequently in the Sierra Nevada in the past relative to today. It would be helpful to know just how frequently such fires occurred.
8	Page 9-10. The text states: “Impacts to air quality from these fires...” What is meant by “these fires”? Fires prior to 1900? In any event, the text further states that these fires would have been similar to the prescribed fires because they spread more slowly <i>and</i> because less fuel was available to burn. But isn't the spread related to the fuel availability? Or is there another reason for the slowspread? Further down the page, the text states “...daily emissions were much lower compared to those during the Rim fire...” Again, are these daily emissions from the pre-1900 fires?

Table 10. Reviewer comments on Chapter 9 (continued)

Reviewer	Comment
8	Page 9-11. The text states: "In summary, in dry forest ecosystems, such as in the area of the RoughFire, these landscapes will experience some combination of prescribed fire and wildfire." This seems to be a weak conclusion, and the authors might consider strengthening the concluding remarks. The health impact of the Rough Fire is probably much larger than the public expects, and an emphasis on the benefits of prescribed fires for public health seems warranted.

Appendix A

Reviewers

The reviewers who participated in the External Letter Peer Review for the report *Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S.* are listed below, along with their current affiliations.

- James L. Crooks, Ph.D.; National Jewish Health and Colorado School of Public Health.
- Joseph Wiman Domitrovich, Ph.D.; USDA, Forest Service Office of Work and Environmental Performance, and Forest Service National Technology and Development Program.
- Molly E. Hunter, Ph.D.; University of Arizona.
- Benjamin A. Jones, Ph.D.; University of New Mexico, University of Oklahoma, Editorial Council for *Journal of Environmental Economics and Management*.
- Loretta J. Mickley, Ph.D.; Harvard University, Conservation Law Foundation Board of Trustees.
- Sean M. Raffuse, M.S.; University of California Davis, Air Quality Research Center.
- Matthew J. Strickland, Ph.D.; University of Nevada-Reno.
- Alan F. Talhelm, Ph.D.; California Air Resources Board, Associate Editor for *Fire* (Research Journal)

Appendix B

Charge Instructions and Questions

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
CENTER FOR PUBLIC HEALTH AND ENVIRONMENTAL ASSESSMENT
RESEARCH TRIANGLE PARK, NC

External Letter Peer Review of Report “Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western US.”

Charge to the Peer Reviewers

Background

You have been asked to review the Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S. Westat has been contracted to conduct this External Letter Peer Review on behalf of the Environmental Protection Agency (EPA).

In January 2020, the Wildland Fire Leadership Council (WFLC), which is comprised of Federal, state, tribal, county, and municipal government officials, asked EPA to lead an effort in collaboration with USFS and DOI to conduct an assessment titled: Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S.. The report contains 9 chapters ranging in length from 9 to 41 pages. The report covers topics that allow for an assessment of the tradeoffs, with a focus on smoke impacts, between different fire management strategies, wildfire, and prescribed fire. Specifically, the report includes discussions of forest conditions and fire management as well as air quality monitoring as it pertains to wildfires, human health, and ecological effects of wildfire smoke. The report also addresses actions individuals can take to reduce wildfire smoke exposure the direct and indirect effects associated with fire, and includes quantitative analyses that rely on air quality modeling to estimate the potential health impacts and economic implications of changes in air quality associated with wildfire smoke. There are approximately 80 pages of supplemental material in an appendix which provide either background information on some of the modeling components used in the quantitative analyses, or additional information on some of the studies referenced within the main body of the report. This report is classified as Influential Scientific Information (ISI).

Reviewers are asked to answer a series of charge questions about the report, found below. In responding to charge questions, please differentiate between those comments that identify critical deficiencies within the report, and therefore should be addressed prior to finalization; and those comments that identify issues that could be addressed in future analyses. All reviewers are expected to read and comment on the Executive Summary and Chapters 1, 2, and 9 of the report. While reviewers are encouraged to read and review the full report, if specific chapters or charge questions are outside of your area of expertise, you may skip those.

Please provide responses to charge questions in Microsoft Word or Google Docs format.

Charge Questions

Overarching Charge Question

1. Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

Chapter Specific Charge Questions

If a question is beyond your technical expertise, please skip it.

1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.
2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed from the framework? How well does the text support the overall framework? Please explain.
3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.
4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.
5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?
6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:
 - The health effects discussion focuses on U.S.-based epidemiologic studies to support the BenMAP – CE analysis discussed in Chapter 8. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health

impacts in BenMAP – CE. Have any U.S.- based studies been excluded from the discussion that should be included?

- The discussion of actions that can be taken to reduce wildfire smoke exposure is aimed at supporting the development of sensitivity analyses in BenMAP – CE to estimate the potential reduction in PM_{2.5} exposure from wildfire smoke that could be experienced due to specific actions by the public. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.
 - The ecological impacts discussion focuses on those effects attributed to wildfire smoke exposure and deposition. Please comment on the ecological impacts highlighted and whether additional studies/citations should be considered within this section.
7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?
 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.
 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

Appendix C

Original Reviewer Comments

Reviewer 1

Overarching Charge Question

Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

Overall, the report undertakes a rather ambitious task and makes incremental progress in our understanding of how wildfire smoke health impacts compare to prescribed fire (Rx fire) smoke health impacts. The report is generally thorough, though, it comes across as a bit too authoritative and matter-of-fact, when, in actuality, this is an area with many well-known knowledge and data gaps (and these gaps are evident in the modeling done in the report). I found the organization to be appropriate (with some exceptions, as described below, for example, the need for a section on studies that have specifically looked at Rx fire smoke health impacts) and the report is generally clear. There is some risk of the report simply being dismissed as a literature review of the wildfire and Rx fire literatures. The actual modeling and empirical analysis is relegated to a later chapter and seems almost secondary (and maybe this was the intention of the authors). While the literature review is helpful and will make a nice contribution, I'm not sure as to its policy relevance and I'm also not sure about this report's contribution to the larger literature in this area. The modeling analysis also has many limitations (and some of them are stated in the report), which makes it seem like an "add-on" at the last minute to a literature review report. Suggest that either the (weak) modeling analysis is dropped altogether, or, if it is kept, that it is beefed-up substantially, to, for example, include a much more formal benefit-cost analysis that at a minimum includes a study of intertemporal tradeoffs between smoke from Rx fires and smoke from wildfires. Discounting needs to be included and costs/benefits cannot be crudely compared for an Rx fire occurring in the same year as the wildfire.

I did enjoy reading the report (though I only carefully read the ES, Chapters 1-2, 6, and 9, but skimmed the other chapters; some of which are outside my area of expertise). I can't say that I learned much new material above and beyond my read of this literature over the last decade or so (which I follow closely). Again, the modeling analysis is intriguing, but crudely done with many assumptions made (some unfounded in my opinion, and see specific comments below). Perhaps it is "good enough", but I would push back some if asked to endorse the modeling analysis. The strength

of this report is in the synthesis of the literature and the discussions in Ch.9 on next steps/future work/gaps in the literature.

Below are my comments on the Executive Summary:

- The charge given was to “lead an assessment that would characterize and compare the impacts of wildland fires under different fire management strategies, including prescribed fire.” Given this, focusing exclusively on smoke health impacts needs to be justified. The charge was much broader than smoke and health.
- p.ES-1, line 23: There is also an epidemiological literature on prescribed fire smoke health impacts, specifically, outside of wildfire smoke exposure. Both literatures should be included here.
- p.ES-1, lines 29-36: Clarify here if both the TC6 and Rough Fires occurred on lands that had been previously the location of prescribed burns. If Yes, how much is the overlap of wildfire with prescribed burn extent? How long ago did the Rx fire occur? If Rx fires didn’t occur on lands burned by the TC6 and Rough Fires, then why were these fires selected?
- p.ES-2, line 16: The CI on TC6 is huge (\$2M to \$47M). Such imprecision in the estimates raises red flags. What is driving the huge CI? Is this indicative of a problem with the methods and/or BenMAP-CE? Similar for the Rough Fire (which has an even larger CI). The Rough Fire CI is so large as to almost make the analysis irrelevant for policymaking purposes (\$260M to \$7.9 billion; huge range). It seems to me that much more work needs to be done to reduce the variance on these estimates.
- p.ES-2, lines 25-27: “The hypothetical scenarios for both case studies demonstrate that prescribed fires targeted for specific locations can have an effect on reducing the overall size of a wildfire.” My read on this is that you assumed a hypothetical Rx fire and then attempted to simulate/model what the wildfire extent and associated smoke health impacts would have been with said fire. This is troubling to me that a hypothetical Rx fire was used and not an actual Rx fire that had been previously burned on lands where a wildfire occurred at a not-to-distant later date. Why use a hypothetical Rx fire? Why not use an actual Rx fire? The limitations of using a hypothetical Rx fire for this analysis should be clearly stated up-front. They limit the generalizability of the findings.
- p.ES-3, lines 10-12: “Therefore, analyses do not consider how prescribed fires intersect with wildfire activity, including the probability of a wildfire occurring within the spatial domain of prescribed fires.” This is a critical limitation of the current analysis. By not using an actual Rx fire for your analysis, you are unable to empirically study the linkages between Rx fire and wildfire activity on the same land. This is problematic for me because in practice, we need an answer to how actual on-the-ground Rx fires affect future wildfire extent and severity (with associated future smoke health impacts). This report is unable to address this question, which severely limits its practical usefulness, in my opinion.

Chapter Specific Charge Questions

If a question is beyond your technical expertise, please skip it.

Chapter 1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

Below are my comments on Ch. 1:

- p.1-2: Some mention should be made here that Rx fires can (and do) sometimes get out of control and become wildfires (e.g., the Cerro Grande fire in NM). There are small probability extreme risks associated with Rx fire too.
- p.1-2: “To date, limited information exists that allows for a direct, systematic, and comprehensive comparison of the air quality and associated health impacts of smoke from prescribed fire and wildfire.” I fully agree with this statement. However, to properly address this, a comparison of wildfire smoke health impacts with Rx fire smoke health effects from Rx fires on lands where the wildfire occurs in the future is needed. There is a tradeoff here that must be studied, empirically (not hypothetically). Will tolerating a little smoke today (from Rx fires) be worth it (from a health cost-benefit perspective) compared to a lot of smoke in the future from a wildfire? This needs to be worked out.
- p.1-3: “While all these activities have led to significant advancements in the science, the overall air quality impacts of different fire management strategies, which consist of different land management practices, including prescribed fire, are not well characterized.” This seems rather harsh. There are now many papers looking specifically at prescribed fire air quality and health impacts. See the 2019 special issue of the International Journal of Environmental Research and Public Health on “Air Quality and Health Predictions” where several Rx fire specific papers were included.
- As mentioned in my comments about the ES, I’m very concerned by the focus on hypothetical prescribed fires rather than using wildfires that occurred on previously Rx fire lands. This is especially relevant for the discussions on p. 1-4. The TC6 hypothetical scenarios pre-suppose that Rx fires can (and do) lead to the outcomes listed (e.g., a wildfire with less fuel, a smaller fire perimeter, and less daily emissions). These seem like reasonable assumptions, but they are at the end of the day only assumptions based on a limited amount of data and nascent science on our understanding the complex relationships between Rx fires and future wildfire activity. My first suggestion would be to go back to the drawing board and use actual Rx fires instead of hypothetical fires. If this cannot be done, then my next suggestion for improvement would be to better caveat the approach and to be more upfront with its limitations. Using the “hypothetical” language is a good start, but more substance should be provided in the

methods section that at the end of the day, this report is modeling a fake Rx fire and is making assumptions on that fire's impacts to future wildfire activity (which are based on the best available science, but that science is currently hindered by data availability and limited understanding of the complex connections between Rx fire and future wildfire activity).

- Figure 1-1 is nice and clear.
- p. 1-7, line 1: Define “resource benefits”
- p.1-8: “individuals taking precautionary measures to reduce smoke exposure can vary between wildfire and prescribed fire events depending on the presence and effectiveness of public health messaging as well as the amount of lead time available for messaging to inform the public and the public’s ability to act on that messaging.” Please provide citations for this statement. Seems speculative to me. We are only just beginning to understand the role that smoke alerts have on avoidance and mitigation behaviors. In fact, the latest EPA STAR grant on effective smoke communication strategies was an attempt to better understand this very point.
- p.1-8, lines 11-13: “The examination of smoke exposure reduction actions within this assessment does not reflect a formal analysis of post-fire effectiveness of public health messaging for either the TC6 or Rough Fires.” I agree. Yet, a “crude estimation” is still done. Is this dangerous? Shouldn’t we wait until a more “formal analysis” can be done? As stated on p.1-8, “This report represents an initial step in the process of conducting assessments to characterize the impacts of different fire management strategies to inform both public health actions to reduce population exposures to wildfire smoke, and future land management decisions.” It has the potential to be extremely influential in this regard. And, as the first major EPA report on the wildfire/Rx fire tradeoff (with respect to smoke and health), it is better to be cautious than complete, especially since this is an area of study that suffers from data limitations and many knowledge gaps. I’d rather EPA not put out a report on the basis of a “crude estimation”, if the assumptions and models used in the “crude estimation” turn out to be inaccurate in the future. I guess that more caution is in order. Maybe the “crude estimation” is dropped from the report. It could potentially do more harm than good is my point.

Chapter 2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed

**from the framework? How well does the text support the overall framework?
Please explain.**

My comments on Ch. 2 are below:

- p.2-2: “The overarching question that guides the evaluation conducted within this framework is What are the expected effects (both positive and negative) of alternative fire management strategies over both short (during the event) and long term (post-event) time horizons? with an emphasis within this assessment on the smoke impacts.” This is exactly the right question that should be asked and I applaud the report to taking this issue on. It is relevant to on-going discussions both at the Federal and state level as well as in the academic community. What are the benefits and costs of Rx fires in the short-term and in the long-term and how do these compare to what would have happened in the absence of Rx fire (i.e., in terms of future wildfire smoke and health impacts)?
- The discussion in section 2.2 “Expected Value Framework” is good. One thing that should be added and discussed is the literature on the expected returns on fire management strategies on future avoided suppression costs (see Sanchez et al., 2019).¹ The focus on this report on smoke and health is fine, but one must acknowledge other avenues that the broad charge to investigate fire management strategies can take (such as on future property damages and suppression).
- p.2-3, line 20: Recommend adding the Sanchez et al. (2019) cite to this sentence.
- The implicit functions in Equation 2-1 need to be written in the equation. The text on line 24 says that PF is a function of M, but that is not shown in Eq. 2-1, for example. It should be. Similarly for NF, conditional on M.
- Another concern that I have with Eq. 2-1 is that there is an inherent temporal component that is missing here. Rx fire effects are immediate, but wildfire impacts are delayed, perhaps by years or even decades into the future (depending on the ignition probability). Economists use discounting to relate dollar benefits/costs over time. Yet, no discounting is presented in Eq. 2-1 (and it should be). Suggest a more formal equation be written that incorporates best practices from the Expected Net Present Value (ENPV) economics literature. You cannot simply compare costs and benefits together when they occur at different points in time. This is incorrect. Specifically, the EV-C equation on line 3 of p.2-4 is not valid, unless the individual EV and C terms are in present value terms (and no mention is made in the text that they are).
- Figure 2-1: Define “non-fire adverse impacts”. Ash, GHG emissions, and smoke emissions are all fire impacts. They don’t occur without fire, so I don’t understand what is meant by “non-fire” in this context. Second, I would argue that the green box

¹ Sánchez, J. J., Loomis, J., González-Cabán, A., Rideout, D., & Reich, R. (2019). Do fuel treatments in US national forests reduce wildfire suppression costs and property damage?. *Journal of Natural Resources Policy Research*, 9(1), 42-73.

“Improved forest health” should be linked to the “Probability of wildfire ignition” box. Rx fires affect future fire ignition precisely because they do improve the overall health of the forest. These two things are connected and cannot be separated as they are in the figure. A similar argument could also be made to connect “Ecological benefits” and “probability of wildfire ignition”. Third, it is not clear what is meant by “ability to mitigate impacts” or “ability to mitigate exposure”. How does wildfire mitigate impacts to, for example, firefighter health and safety? If anything, wildfire is harmful to firefighter health. I’m missing the link. When I think of mitigation, I think of public health advisories or smoke alerts that provide people with information so that they can take actions to limit/reduce their exposure to smoke/fire. Similar for the link between Prescribed fire and “Ability to mitigate exposure”; what is meant by this? As in Rx fires can reduce future exposure to smoke from wildfires since those wildfires will be less severe due to past Rx fires? Please clarify. Finally, mortality and morbidity are not the only effects of fire and smoke. Labor market effects, education effects, productivity effects, and other economic outcomes have been shown to be affected by smoke exposure. Suggest broadening your assessment (or explicitly state that you are ignoring them).

- p.2-8, line 12: P(control) was not defined in Eq. 2-1. Please clarify or define.
- p.2-9, lines 26-27: “About 89% of the fuel treatments were effective in changing fire behavior or helping with management of the wildfire or both” This needs to be significantly expanded and elaborated on. One of the central assumptions made in this report is that a hypothetical Rx fire will measurably affect future wildfire extent, emissions, etc. This assumptions needs to be carefully explained and defended.
- Table 2-1: The list of “Unquantified Effects” are not all actually unquantified in the relevant literatures, its only that this report has made the choice not the quantify them. This is an important distinction that should be made clear. For example, the economics literature provides estimates of property, timber, tourism, etc. costs of wildfire. This report is simply focusing on smoke and health. Please don’t give the impression that some of these other impacts are unquantified in the literature (which is not accurate). Additionally, under the “Public Health: Air Quality” effects, there are many more that are not stated here (e.g., labor market effects, educational effects, etc.). Similar for air quality (i.e., other pollutants created by fire). This is an incomplete list. Suggest listing other Air Quality and Public Health impacts, but then state that this report only focuses on xyz. Otherwise, the impression is given that fire is only associated with those impacts listed (which is not true).
- p.2-15, lines 12-15: “Because of uncertainty regarding when wildfires occur relative to when prescribed fires occur, it is challenging to determine the timeframes for comparing the two types of fires. For this assessment, we present undiscounted dollar values, which assumes that benefits and costs of fire management strategies all occur in the same current year.” This is extremely problematic and cannot be done in the final report. Prescribed fire effects are immediate whereas wildfire impacts are years, if not decades, in the future. An undiscounted comparison of these two sets of monetized estimates should not be done, full stop. Some assumption needs to be made on the

timeframes involved (with a sensitivity analysis performed on that assumption) so that a net present value analysis can be performed. Benefits and costs do not occur in the same year, as stated on line 15. This is a major shortcoming of the report that must be addressed. Wrong conclusions and policy implications can be reached from not incorporating discounting.

Chapter 3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

This is outside my area of expertise and thus no comments are given on Ch. 3.

Chapter 4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

My only comment on Ch. 4 would be the need to include a discussion of the NOAA HRRR (High Resolution Rapid Refresh) Smoke model, which provides sub-daily estimates of surface-level PM2.5 from wildfires (including Rx fires). As the HRRR-Smoke model is fine-tuned, it will increasingly play an important role in measuring PM2.5 smoke health impacts. Monitored data will increasingly be complemented with remote sensed data and modeled data on smoke exposure. Some discussion of this in Ch. 4 is warranted.

Chapter 5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not

been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?

My expertise is not in air quality modeling, so I have no comments to make on Ch. 5.

My only general comment on Ch. 6 is the need to have a dedicated section in this chapter on the health impacts of prescribed fires, specifically. There is now a growing literature on Rx fire health impacts, separate from the general wildfire health impacts literature (see Jones & Berrens, 2021 for infant health and Rx fire; ER visits and Rx fire in Huang et al. 2019; and a discussion of environmental justice dimensions of Rx fire exposure in Gaither et al. 2019).² The current focus on the wildfire smoke health literature in the report is too limited and needs to be expanded.

Additionally, some discussion is needed in Ch. 6 on the potential differences in public health impacts between smoke from Rx fires compared to smoke from wildfires. A recent piece in *Nature Communications* by Aguilera et al. would be a good starting point.³ As would the paper by Haikerwal et al. (2015) that discusses Rx fire health impacts compared to wildfire health impacts.⁴ My point here is that smoke health impacts from Rx fires may be meaningfully different than the smoke health impacts of wildfires and some detailed discussion of this is needed in Ch.6. Not all smoke is created equal.

² Jones, B. A., & Berrens, R. P. (2021). Prescribed Burns, Smoke Exposure, And Infant Health. *Contemporary Economic Policy*, 39(2), 292-309.

Huang, R., Hu, Y., Russell, A. G., Mulholland, J. A., & Odman, M. T. (2019). The impacts of prescribed fire on PM_{2.5} air quality and human health: application to asthma-related emergency room visits in Georgia, USA. *International journal of environmental research and public health*, 16(13), 2312.

Gaither, C., Afrin, S., Garcia-Menendez, F., Odman, M. T., Huang, R., Goodrick, S., & Ricardo da Silva, A. (2019). African American exposure to prescribed fire smoke in Georgia, USA. *International Journal of Environmental Research and Public Health*, 16(17), 3079.

³ Aguilera, R., Corringham, T., Gershunov, A., & Benmarhnia, T. (2021). Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California. *Nature communications*, 12(1), 1-8.

⁴ Haikerwal, A., Reisen, F., Sim, M. R., Abramson, M. J., Meyer, C. P., Johnston, F. H., & Dennekamp, M. (2015). Impact of smoke from prescribed burning: Is it a public health concern?. *Journal of the Air & Waste Management Association*, 65(5), 592-598.

- Figure 6-6: Jones et al. (2016) also looked at the population of people taking action in response to smoke from the Wallow Fire in Albuquerque, NM (see Table 1 of their paper). Suggest their data also be included here.⁵

Chapter 6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

6a. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health impacts in BenMAP – CE. Have any U.S.- based studies been excluded from the discussion that should be included?

See my comments in response to Q5 above. Overall, Ch. 6 does a nice job of covering the literature, but several relevant studies are omitted and the literature specific to Rx impacts and health needs a dedicated section in Ch. 6.

6b. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.

This discussion is good, though I agree that our understanding of how people differentially respond to Rx fires vs. wildfires is a large knowledge gap. We know very little about Rx fire responses/behavioral changes at this point in time. This limits any empirical analysis in BenMAP.

6c. Please comment on the ecological impacts highlighted and whether additional studies/citations should be considered within this section.

Ecological impacts are outside of my area of expertise.

Chapter 7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations

⁵ Jones, B. A., Thacher, J. A., Chermak, J. M., & Berrens, R. P. (2016). Wildfire smoke health costs: a methods case study for a Southwestern US 'mega-fire'. *Journal of Environmental Economics and Policy*, 5(2), 181-199.

or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

I'm assuming that this question is referring to Ch. 7 (though it is not stated). I did not review this chapter and therefore cannot comment on it.

Chapter 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

I did not thoroughly review Ch. 8 (instead I focused on the Chapters that I was directly asked to review). However, I will note that I did not see Jones et al. (2016) or Jones & Berrens (2017) cited in Ch. 8; both also use BenMAP-CE to evaluate wildfire smoke health impacts in the Western US. I would think they should be included in this chapter as background (or in another chapter, if more relevant).⁶

I will also note that in section 8.2.3. it appears that the effect coefficients used are from the general air quality and health literatures and are not specific to the wildfire smoke and health literature. Suggest that the authors review Aguilera et al. (2021) in Nature Communications and also see Jones et al. (2016) for why smoke from wildfires may be different such that using general air quality coefficients may be incorrect. It is at least worth commenting on in the report (if not more fully incorporating wildfire smoke-specific coefficients).⁷

Chapter 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does

⁶ Jones, B. A., Thacher, J. A., Chermak, J. M., & Berrens, R. P. (2016). Wildfire smoke health costs: a methods case study for a Southwestern US 'mega-fire'. *Journal of Environmental Economics and Policy*, 5(2), 181-199.

Jones, B. A., & Berrens, R. P. (2017). Application of an original wildfire smoke health cost benefits transfer protocol to the western US, 2005–2015. *Environmental management*, 60(5), 809-822.

⁷ Aguilera, R., Corringham, T., Gershunov, A., & Benmarhnia, T. (2021). Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California. *Nature communications*, 12(1), 1-8.

it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

My comments on Ch. 9 are below:

p.9-1, lines 5-8: grammatical errors. Reword.

p.9-1, second paragraph: I think the report is underselling how consequential the rather strong assumptions made are at affecting the results. I agree that expert judgment was used, but the required assumptions were both many and were very strong, in my opinion. Simply making a few other assumptions (that would also be expert, in my opinion) would likely change the results by a lot (e.g., using wildfire-specific CR function beta coefficients, looking at an actual Rx fire instead of a hypothetical one, etc.). Suggest that the statement “required assumptions and decisions based on expert judgment” on line 18 be re-worded to convey just how strong some of these assumptions made were. Overall, the report comes across as a little too authoritative for my taste when, in reality, so much remains unknown and so many assumptions were made (where equally justified assumptions could have been made and that would have affected the results).

p.9-2: Are there plans by the EPA, USFS, and others to conduct similar investigations on the other components of the conceptual framework (e.g., direct fire effects, ecological effects, other health effects, non-health impacts on society, etc.)?

I enjoyed the detailed summaries of the work performed for the TC6 and Rough Fires (sections 9.2.1 and 9.2.2). I found them useful and the discussions to be relevant when contextualizing this work within the larger literature in this area.

Figure 9-4 (which is the same as Figure 2-1) should be updated per my earlier comments on Ch.2.

Section 9.3.2: In my mind, the main overarching limitation is that the analysis performed in this report does not address the larger question as to the intertemporal benefits and costs of Rx fire. Using prescribed fire generates immediate costs on society (in terms of smoke health impacts), but, also generates long-term benefits to society (in terms of reduced future wildfire severity and risk). The long-term benefits also include the potential for reduced future smoke health impacts from wildfires occurring on Rx lands. This intertemporal benefit-cost analysis is needed in future work to address the role of Rx fire within the larger fire policy context. Net present values will be needed to

do this (which this report also does not consider). Figure 9-5 begins to get at this, but it's missing the smoke health component and the role that Rx fires today have on future emissions and future health impacts through wildfire severity. The discussion on p.9-15 is a good starting point, but must more emphasis should be placed on the critical need for future work to address the smoke health tradeoffs between wildfire and Rx fire.

Another overarching limitation that should be expounded upon in Ch.9 is that we frankly do not know the full extent of the economic costs associated with smoke exposure. Yes, premature mortality and morbidity, but what about impacts to the labor market, education, test scores, recreation and exercise, obesity, and minor effects on people such as headaches and slightly reduced productivity? There are many dimensions of smoke impacts that we simply do not know and need data to fill these gaps. Suggest that some of these other dimensions are discussed, specifically, as avenues for future work.

p.9-20, lines 35-38: The suggestion for a centralized respiratory specific to prescribed fires is an excellent one. We need a NIFC for Rx fires, complete with start/end times, acres burned, spatial characteristics, etc. for all Rx fires in the US each day. Fully agree with this recommendation. Maybe EPA or USFS can look more into collecting such data. We have to begin to get a handle on the actual smoke health impacts of Rx fires that occur more often than wildfires. Data is key to this.

Reviewer 2

Overarching Charge Question

Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

I have four broad comments about this report.

First, the report is better understood as two reports smooshed together: a summary of the state of the science of wildfire management and impacts, and a case study of specific health impacts from two specific fires. The case studies are the main contribution of the report, but much of the rest of the report has very little to do with it. There is an entire section on wildfire air pollution monitoring that is barely relevant to the case studies. The same is true for the ecological impact section. It would be better if the two elements of the report were separated into two separate reports, or perhaps a main report and an annex. Mixing them together reads as incoherent.

Second, the case studies themselves are very interesting and constitute an important contribution, but their presentation is extremely confusing. Specifically, each case study of a fire includes several counterfactual versions of that fire (though a different number of counterfactuals for the bigger fire than the smaller one). Furthermore, each of the counterfactuals incorporates information from a unique combination of actual historical prescribed burns, hypothetical prescribed burns that were planned but never took place, and historical wildfire burns that had an effect similar to prescribed burns. The main wildfires under study are named, and some of these other fires or prescribed burn campaigns seem to have names, too. All of this is quite confusing to the reader. Even after reading the descriptions of all the different counterfactuals in many different places in the document I was unable to remember which counterfactual was modeled which way. The case studies desperately need some sort of overarching graphic or table that lays out all the scenarios. The maps are helpful but not enough. Using the names of the secondary fires or burn campaigns adds nothing but confusion.

Third, the case studies are begging to be further interpreted. Would a prescribed burn campaign leading to a smaller fire have actually reduced the overall health impact compared to the observed fire? Somehow the report never answers this very central question, this question that the structure of

the case studies appears specifically designed to answer, or, if it did, the answer was so de-emphasized that it eluded me when I was specifically looking for it.

Fourth, the state-of-the-science part of the report should include a discussion of how fire impacts intersect with equity. Do certain socioeconomic groups experience higher ambient concentrations, higher exposures, or stronger concentration-response relationships? Are some groups more able than others to access public health messages and act on them? Are some able to afford health risk mitigation actions that others can't afford? There is at least a little literature on this already that should be discussed and hopefully included in the mitigation modeling.

Chapter Specific Charge Questions

If a question is beyond your technical expertise, please skip it.

Chapter 1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

See my above comments on the confusing scenario construction.

- Page 1-4 lines 20-30 are unclear.
- The terminology and scenario numbering used in Figs 1-1 and 1-2 is inconsistent (two Hypotheticals vs. three Scenarios).
- Page 1-6 lines 8-9 are unclear.

Chapter 2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed

**from the framework? How well does the text support the overall framework?
Please explain.**

I liked the conceptual framework for how it shed light on the choices made in the case studies. For example, page 2-2 lines 1-12 are much clearer than section 1-4. However, I don't think the framework requires that the report spend so many pages in later section on aspects of fires that aren't captured in the case studies anyway. I also think the framework needs to include some indication that impacts are filtered through existing socioeconomic inequities.

Equation 2-1: if all the terms in the equation are conditioned on M this should be reflected in the notation.

Fig 2-1: Do thinning or prescribed fire reduce the probability of wildfire to zero? Why isn't the Wildfire box connected to Mitigation Decision if Wildfire explicitly conditioned on it in equation 2-1? Also, the position of "Ability to mitigate impact" and "Ability to mitigate exposure" on top of arrows is unclear.

Page 2-8 line 12: If Pr (control) is being modeled perhaps it should appear in Fig 2-1?

Table 2-1: Emergency department visits are list as both "quantified" and "unquantified". Which is it?

Page 2-15: I appreciate the lack of discounting. People in the future will value breathing just as much as people in the past.

Chapter 3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

Chapter 4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information

on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

This section is very informative but hardly relevant to the case studies. The split personality of the report as a whole is most glaring here.

Chapter 5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?

Table 5-2: Inconsistent and/or confusing terminology: “Actual fire”, “Actual wildfire”, and “Actual prescribed fire” are all in the same table. The report as a whole needs to be edited for consistent use of terminology.

The plots in chapter 5 are poorly formatted. If the row location and column location of a panel in the multipanel plot are informative, why aren’t the row and column headers shown?

- Figs 5-8, 5-9: Where did scenario to 2a go?
- Fig 5-13: Appears to be missing a row.
- Fig 5-18: Does color correspond to vertical position? Why? This is very confusing.
- Fig 5-19: Formatting is all over the place.

Chapter 6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

6a. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health impacts in BenMAP – CE. Have

any U.S.- based studies been excluded from the discussion that should be included?

The studies included are appropriate for the chosen endpoints, but the EPA's assessment of which concentration-response relationships are "causal" and "likely causal" is a trailing indicator of the state of the science, in this case by about a decade. There are other endpoints (I'm thinking of neurological and pregnancy outcomes) that should either be incorporated or their absence should be addressed. It should be stated clearly that narrowing the health endpoints to only those used will underestimate the true health impacts of wildfires.

6b. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.

While much more research on this topic is needed, this section does a good job of incorporating what information exists.

However, this is where a thorough discussion of equity issues should be brought in. Information and mitigation actions available to the public may differ widely between socioeconomic groups. Some groups may not know about public health warnings, know where to look for them, be able to read them in their native language, or be able to act on them. Home's air infiltration rates are not uniformly distributed across the population, nor is the money to tighten air envelopes or purchase air purifiers. There probably exists some research on air infiltration in homes by SES or race that this report should try to highlight if not incorporate.

6c. Please comment on the ecological impacts highlighted and whether additional studies/citationssould be considered within this section.

Chapter 7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

Page 7-4 line 11: This is the only reference to crystalline silica in the document. Why is it important?

Chapter 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

Page 8-4 lines 28-34: The reasoning for using the short-term effects in one case study and the long-term effects in the other deserves a bit more explanation.

Figs 8-1, 8-2: How are the filled circles and empty circles different? Needs a legend.

Figs 8-6, 8-7: What is being counted here? What do these numbers represent?

Chapter 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

Fig 9-1: Shouldn't this be in the modeling chapter?

Section 9.3.3: There is a research gap on how equity intersects with exposure, public health information delivery, and access to protection and mitigation actions.

Reviewer 3

Overarching Charge Question

Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

Enjoyed the report. It gives a good starting point for risk management decisions based on wildland fire generated smoke.

Chapter Specific Charge Questions

If a question is beyond your technical expertise, please skip it.

Chapter 1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

- Page 1.1 Section Background Line 17/18- ‘NIST is an expert in the direct and indirect 17 damages attributed to fire’. What do you mean by this?
- Page 1.1-Section 1.1, Line 23/24- ‘Fire has been used as a land management tool to return nutrients to the soil and remove detritus 23 and excess fuels to reduce wildfire risk and effects.’- Think you need to use a different word for “Fire” at the start of the sentence, or add in the term prescribed fire, or add the word extreme (or something similar) to wildfire risk latter in the sentence. Fire along seems too vague.
- Page 1-2 Section 1-2, Lines 15/17. Is this the right wording? with the rapid expansion of the WUI, wildfires are 15 increasingly encroaching on American communities, posing threats to lives, critical infrastructure, and 16 property (Lewis et al., 2018). It seems like American communities are encroaching on wildland fires. The way it is currently worded, it makes wildland fire the “bad person”, is it really?
- Page 1-4 Section 1-3 Line 1- What are “positive resource benefits”
- Page 1-8 Section 1-3 Lines 19/20- What about local economic conditions? Large fires close down business. That can be a large driver politically.

Chapter 2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed from the framework? How well does the text support the overall framework? Please explain.

- Page 2-3 Section 2-1 Line 9/10. You state “framework that gives 9 primary consideration to public and firefighter safety”, can you have both or does one need to take priority over the other? Someone has to take the risk?
- Page 206 Section 2-3 Line 27- You talk about “Effects are expected to vary based on characteristics “ but do not reference fuel model, you kinda do as biomass burned, but might want to clarify with a reference to fuel model. A lodgepole stand fire is a stand replacement vs a ponderosa pine stand is typically undergrowth. The fuel model typically dictates the fire conditions.
- Page 2-08 Lines 30/31- You state: It is only implemented when conditions meet preplanned elements”. I would reword to state that it is only implemented when the resource benefit as outlined in the burn plan is meet.
- Page 2-13, Section 2.3.5 -Lines 4/5: You state “using 4 N95 facemasks when outdoors to mitigate exposures” is this recommended across the country? Many public health agencies do not recommend masks.

Chapter 3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

- Not an expert in this area. Not appropriate to comment

Chapter 4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information

on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

- Page 4-7, Section 4.2.3, Lines 5, you state “focus of fire management” is it really or is it just a part of the risk management? It seems like smoke is not really the focus.

Chapter 5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?

- Page 5.2 Section 5.11. Lines 1 /2- What about ignition pattern as a factor for combustion intensity?
- Page 5-10, Section 5.1.5, Lines 5-7, Might want to try and get a copy of the burn plan to attach as a reference.

Chapter 6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

6a. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health impacts in BenMAP – CE. Have any U.S.- based studies been excluded from the discussion that should be included?

6b. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.

6c. Please comment on the ecological impacts highlighted and whether additional studies/citationssould be considered within this section.

Chapter 7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations

or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

- Section 7.2.1, Page 7-2, Lines 17/18: Do you have data to support this statement: “The main 17 inhalation hazards for wildland firefighters and other personnel at fire camp”. Most data collection has been on the fire line, not at camp.
- Would also be good to state in section 7.2.1 that OSHA standard is PM4, not PM2.5 like the general public.
- Section 7.2.2.1, Page 7-3, Lines 26-28: Do you have a source for this? “For example, if the Air Quality Index (AQI) during off-duty 26 exceeds 100 (i.e., orange: unhealthy for sensitive groups) due to PM in the fire camp, this can result in 27 firefighters experiencing continuous exposure to high PM concentrations.” Some camps are smokey, but most crews try not to sleep in them if that are smoked in.
- Section 7.3.2.5, Page 7-13, Line 30: Do they specify wildland “which include arson”, would a majority be structure fire arson arrests?

Chapter 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

- Did not have anything to add in this chapter

Chapter 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

- I enjoyed this final discussion in the paper. Really will help lay out options for additional discussion on both human and forest health.

Reviewer 4

Overarching Charge Question

Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

This report develops a conceptual framework for understanding, and potentially quantifying, the tradeoffs between prescribed burning and wildfire. The key strengths of the report include a strong background discussion and literature review of the many facets of the problem and a well thought out conceptual framework. Some chapters are excellent, and the final synthesis chapter presents the key findings and limitations well.

A weakness of the report is its very narrow quantitative focus. Though the conceptual framework is holistic, and the various aspects are discussed, only a small portion of the framework is quantified with a specific modeling case study. The findings of the case study are quite limited because they may not be broadly applicable to other locations or even times. To bolster the case studies, I would suggest a statistical approach, where a large number of hypothetical fires are modeled across many different locations and weather conditions to better explore the range of impacts.

Another important weakness of the report is its structure. The chapter progression does not make sense to me. Text switches back and forth between the broader qualitative discussion and details of the case study analysis. I would prefer the document broken into two major parts: one with the conceptual framework and background information that applies to that framework in all cases, and one on the case study, including info on the specific forests, land management, air quality modeling details, results, etc. Finally, the report could use a high-level editor. There is much repetition and significant style differences between the chapters.

Chapter Specific Charge Questions

Chapter 1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

Specific comments on chapter 1.

- Page 30, sentence beginning on line 8 is not a sentence.

- The descriptions of the scenarios in section 1.4 are confusing.

Chapter 2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed from the framework? How well does the text support the overall framework? Please explain.

The overall conceptual framework is appropriate, understandable, and comprehensive. However, while the framework itself is comprehensive, the study is not, being narrowly focused on public health impacts from smoke. The authors acknowledge this, and the framework will hopefully be useful for future work. This study just scratches the surface.

Specific comments on chapter 2.

- Page 41, line 3. Aren't there multiple possible goals for prescribed burning? Not just reducing wildfire?
- Section 2.3.5 paragraph 1. This paragraph asserts that more public actions can be taken to mitigate smoke impacts from prescribed fires than wildfires because of the potential to plan health messaging campaigns, but is that borne out? My experience is that the public takes more mitigation measures during wildfires. Also, why can't these communication and public awareness activities take place during wildfires?

Chapter 3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

This is not my area of expertise, but the chapter seems to provide an adequate introduction. Like other chapters in the report, it is confusing that some of the content is general overview, while some is specific to the case studies, and these are somewhat jumbled. For example, 3.1.1 is specific information that applies to the case studies.

Chapter 4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with

smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

For the most part, this chapter covers the subject of air quality monitoring in more than enough detail. In fact, I think that it has too many details that contribute to the unnecessary length of the document overall. For example, is Table 4-1 necessary? Why does this document tell me all the things I can learn from the EPA trends report visualization tools?

One type of air quality monitoring that is not really discussed is PM speciation, such as from the Chemical Speciation Network. This data is useful for apportioning PM to different sources, including wildland fire, and should be discussed.

Specific comments on chapter 4.

Page 85, line 33. The statement is true that there are no existing national monitoring programs specifically designed to evaluate smoke impacts from fires. However, this is true of most all emissions sectors. To my knowledge, there is no national-scale monitoring program designed to capture any one specific source.

Chapter 5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?

The modeling approach is mostly reasonable, as are the inputs developed for fuel loading and emissions. Fire emissions modeling, and chemical transport modeling are only briefly explained here. This is OK, but it is jarringly different from the sometimes excruciating detail of other chapters (3 and 4, for example). It would be good to at least include the equation used to calculate emissions.

One troubling point is the last line in section 5.2.5, which states that “fuel moisture is a global parameter that only varies by fire type (wildfire or prescribed).” Fuel moisture has a very significant impact on modeled consumption in the Consume model and thus will strongly affect the resulting emissions and downwind PM2.5 concentrations. What is the justification for using static fuel moistures, and how were they selected? This detail is important to include. The model validation statistics are important and should be in the main text instead of the appendix. They show that this model is only modestly successful at replicating observed PM2.5 and help the reader understand how to assess the results. The population exposure plots don’t make sense (the scaling of 1 ug or 1 ppb == 1 person is arbitrary) and should be removed. This topic is better addressed in Chapter 8. I don’t understand how the pile burn emissions exercise fits into the larger study.

Specific comments on chapter 5.

- Page 119, line 22. Fix link label.
- Figures 5-1, 5-2, 5-3. These maps need a scale bar. Also the grid is not explained.
- Figure 5-4. This map is at too large a scale to be useful and should be zoomed in. It also needs a scale bar.
- 5.2. How was plume injection height estimated?
- Page 126, line 3. This is not quite correct. The original BlueSky framework was written primarily in PERL, with some C and Java; however, the most widely used version of BlueSky prior to BlueSky Pipeline was BlueSky version 3, which was written in Python.
- Section 5.2.3. This paragraph is repetitive of information provided earlier in the chapter.
- Section 5.2.3.1 explains how the temporal profile for the TC6 case was developed. What about the Rough fire?
- Figure 5-8. The difference plots should have the same scales between the large and small cases so they can be compared.
- Figure 5-9. Same as 5-8.
- Figure 5-12. The units on the lower left plot are incorrect (although I think the population exposure plots should be removed). Why are the scales so large?
- Figure 5-12. It is unclear from the text how the pile burn estimates contribute to the case study. Are they included in the health effects portion (chapter 8)?

- Figure 5-13. Caption does not match the figures (there is no middle row).
- Figure 5-16. The meteorological pattern and resulting population impacts are quite different from some other events (e.g., 2020). This highlights the limitations to the conclusions one can draw from this study.

Chapter 6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

6a. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health impacts in BenMAP – CE. Have any U.S.- based studies been excluded from the discussion that should be included?

6b. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.

6c. Please comment on the ecological impacts highlighted and whether additional studies/citationssould be considered within this section.

I'm not sure why this is all in the same chapter. These three sections seem quite different. The first section is very well researched, written, and organized, and I enjoyed reading it. I do not know the literature well enough to comment on if it included every relevant study. The section on actions to reduce wildfire smoke was also well presented, though the evidence there is much more tenuous. The section on ecological impacts was interesting, but outside my knowledge and I have no specific comments.

Chapter 7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

Though it is outside my area of expertise, this chapter seems disorganized and rough. The two main sections seem quite unrelated. Figure 7-2 is not well explained (and too low resolution).

Specific comments on chapter 7.

- Page 210, line 13. This is not a sentence.

Chapter 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

The approach for the main BenMAP analysis is appropriate, but the results are limited in applicability. The case studies are quite narrow. Not only can they not be broadly applied to cases in other locations and ecosystems, they can't really be applied to the same locations for different dates. A more statistical approach, looking at a wide range of fire locations and weather patterns would provide a more useful quantification of the differences between prescribed burns and wildfires. The resulting costs are highly dependent on wind direction and meteorology generally. Perhaps this is the biggest takeaway from the study for me. The air quality benefit of simply being able to select the meteorological conditions for prescribed burning can be huge, and I think is not stressed enough in the study.

It is very difficult to compare the results of the sensitivity analysis (section 8.3.2) from those of the “main results” because they are presented so differently. It would be very helpful for those to be parallel or, even better, on the same graphic or table. I am personally better able to understand the graphical presentation, such as in Figure 8-1, than the tabular presentation of Table 8-2.

Specific comments on chapter 8.

- Page 236, line 14. Fix broken link label.

Chapter 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

The synthesis is well written and does a good job of highlighting the strengths and limitations of the assessment.

Reviewer 5

Overarching Charge Question

Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

The organization made the report difficult to follow. Some of the questions and confusion I had reading through the document weren't addressed until the final chapter. The chapters addressing the actual case study analyses are broken up and should be consecutive. There are also varying levels of detail given to factors part of the conceptual framework, but not addressed in the case study analysis, with some chapters providing in depth syntheses and others providing a brief overview. The scope of the discussion should be more consistent throughout. Overall, I found the conceptual framework hard to follow. There needs to be a better description of its intent and flow, and how it relates to the case study, early in the report.

Chapter Specific Charge Questions

If a question is beyond your technical expertise, please skip it.

Chapter 1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

The authors correctly indicate that use of wildfire for resource benefit is also a critical fire management strategy on page 1-2 (lines 31-35). This concept should be carried through in the rest of the chapter. I recognize that the terminology can be confusing, as the term 'wildfire' can have a negative or positive connotation in this framework, but I strongly encourage the authors to adopt a terminology throughout the document that acknowledges that wildfire, more than being at times beneficial, is actually a critical fire management strategy. Some examples of where this can be more strongly incorporated:

- Page 1-3 line 1: "To ensure the effective use of prescribed fires **and wildfire** to reduce the risk of catastrophic fire" (or use agreed upon terminology to describe the beneficial use of wildfire.

- Page 1-3 line 13 ‘including prescribed fire **and wildfire**’

Since this is the primary portion of the report where the scenarios are discussed, it would be useful to have more detail. How much prescribed fire is in each scenario, what are the sizes of wildfire in each scenario, etc. A table highlighting the details of the different scenarios would be useful and provide a quick reference the reader could refer back to throughout the report. There also needs to be more discussion of linking these scenarios to pieces in the conceptual and expected value framework.

Other comments on chapter 1

- Page 1-1 line 17: ‘incident **management**’
- Page 1-1 line 20: delete **the**
- Page 1-1 lines 21-22: ‘linkages needed **to address identified research gaps**’
- Page 1-1 lines 8-12: Important to note that spread of invasive species has also changed fire regimes, by increasing fuel continuity, not necessarily fuel loading.
- Page 1-1 line 24: The goal of fuel treatments is not always to reduce wildfire size, more often it is to reduce fire intensity and severity
- Page 1-3 lines 9-10: and wildland firefighter health impacts?
- Page 1-4 line 2: consider using ‘periodic’ instead of ‘episodic’
- Page 1-4 line 15: **was** compared
- Page 1-4 lines 20-27: what do these different scenarios mean for fire intensity? Instead of indicating less or more fuel, wouldn’t less or more **fuel consumption** be a better descriptor?
- Figures 1-1, 1-2, and 1-3: It would be better if these figures were consistent across the two fire case studies. Figure 1-1 is repetitive and doesn’t add much value. Would it be possible to show prescribed fire areas in figure 1-2? In addition, figure 1-1 includes a baseline scenario, which is not described in the text.
- Pages 1-4 and 1-5: Descriptions of the different fires and their scenarios read as if they were written by different authors. It would be helpful to the reader if there was more consistency in language and structure of the descriptions of the different modeling scenarios.

- Page 1-8: Lines 21-28: Consider introducing the goals of the report prior to the ‘novel approach’ section, especially the first paragraph of this section. The second paragraph (lines 29-34) is more appropriate for the end of this chapter.

Chapter 2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed from the framework? How well does the text support the overall framework? Please explain.

Several things make the graphical representation of the conceptual framework difficult to understand and follow. For one, the authors go straight to a detailed description of the expected value framework to a graphical representation of the conceptual framework, without a clear description of how these relate. There is also no description of what the graphical representation is meant to convey, other than a long section defining and describing terms, some of which are inconsistent with what is shown in the graphic. Is the graphic meant to convey the expected value framework in the context of smoke and air quality? If so, that is not clear and the terminology between the expected value framework and the conceptual diagram is inconsistent. In addition, there are many aspects of the conceptual diagram are confusing. For example, why is there not a relationship between baseline conditions and wildfire, as is described in the text? What does the ‘ability to mitigate’ box connected to wildfire refer to? Why are ash, GHG emissions, and smoke emissions considered non-fire impacts? Why doesn’t prescribed fire have the ability to mitigate non-smoke fire impacts? I suggest greater thought and attention to detail put into a revised conceptual diagram, that is more clearly linked to the expected value framework (if indeed that is the intent), is consistent in terminology, and perhaps a simpler design. A simpler design could be achieved by omitting examples from the diagram itself (e.g., GHG, ash) and leaving those in the descriptions of broader terms (e.g., direct and indirect impacts or effects).

In general, I’m not convinced that there is value in adding a detailed description of the expected value framework, when it does not appear to have been used in this case study analysis. The discussion of this should either be minimized, or somewhere in this report there needs to be a

discussion of how the case study analysis links to pieces of this expected value framework and what pieces are missing and would need to be included in order to complete the framework.

Specific comments:

- Page 2-2 lines 18-19: Instead of ‘reduction or increase in fuel loads’, consider **change in fuel characteristics**, since some changes in fire behavior and effects are due to changes in fuel continuity, or other characteristic, and not always due to increases or decreases in fuel loading.
- Page 2-2 lines 18-22: The example of maintenance burns in the Southeast as an example of the previous statement is confusing, as the previous statement refers to wildfires, not prescribed fire. This in addition to the sentence starting with “the range of periodicity...”, while correct, seems misplaced and disrupts the flow the paragraph. I suggest deleting these sentences and start again with “the management of wildland fire”
- Page 2-2 line 23-24: Delete “Fire management strategies such as”. You’ve already separated wildfire in the previous sentence, and established that it has positive and negative effects.
- Page 2-2 line 24: change “fire” to “wildfire”
- Page 2-3 lines 3-4: pick impacts or effects, don’t include both
- Page 2-3 line 13: By management do you mean the opportunity to manage wildfire? This is unclear.
- Page 2-3 equation 2-1: Should F be WF? The equation already has prescribed fire related effects, shouldn’t the last part refer to wildfire related effects?
- Page 2-3 line 25 and 26: specify that F is referring to **wildfire** -related effects once a **wildfire** is ignited
- Page 2-3 line 27: positive and negative effects associated with fire management strategy and wildfire?
- Page 2-8 line 12: this is the first mention of P(control), it is not listed in the EV equation or the conceptual framework diagram
- Page 2-9 lines 12-16: There is lots of data on the degree to which mechanical thinning, alone or in conjunction with prescribed fire changes the probability of ignition or intensity and severity of wildfires and many studies published since Agee and Skinner 2005.

- Section 2.3.3.3 – I suggest deleting this section and adding a statement to the section above about the effectiveness of mechanical treatments. You could certainly still cite IFTDSS 2021, but I see no need to highlight this particular program in this report.
- Section 2.3.4 – should this be titled the effects of wildland fire?
- Page 2-10 line 33: Cheatgrass is not a good example of an invasive species that fire helps control. Yellow star thistle might be a better example.
- Section 2.3.4.1.2 – Why not call this ability to mitigate impacts, to be consistent with the conceptual diagram
- Page 2-11 line 28: Here and throughout, I would argue that fire effects do not depend on the type of fire (prescribed vs. wildfire), but on the burn conditions, because both types of fire can have a wide range of burn conditions.
- Page 2-14 Table 2-1: Loss of ecosystem services is listed as an example of effects on property. Is this correct? I'm not sure what this would entail outside of other listed economic effects – timber and grazing, municipal watersheds, aesthetics, tourism, natural and cultural resources. Should biodiversity be included under ecological?

Chapter 3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

Specific edits:

- Page 3-7 line 24: **European** settlement
- Section 3.1.5 – Since this is touched on in the next section, shouldn't there be a discussion in this section on the role of insect and disease outbreaks in changing fire regimes?
- Page 3-9 section 3.2: This paragraph seems misplaced. There instead should be a subsection on use of wildfire as a land management approach to reduce fire risk. The introduction to this section should introduce the various land management approaches to reducing fire risk – fuel treatments, prescribed fire, wildfire.
- Page 3-9 lines 18-21: This language is taken almost directly from Young et al. 2020 (Effects of policy change on wildland fire management strategies: evidence for a paradigm shift in western US?) without attribution. This would also be a good paper to cite here to show the growing use of strategies other than full suppression after the 2009 policy guidance.

- Young J.D. et al. 2020. Effects of policy change on wildland fire management strategies: evidence for a paradigm shift in the western US? International Journal of Wildland Fire 29: 857-877.
- Page 3-9 section 3.2.1: This subsection is not needed. Instead, parts of it could be incorporated in an introduction to the section on land management approaches to reducing fire risk.
- Section 3.2.2 – This is repetitive with section 3.1.5. Some of what is in this section could be included in section 3.1.5 (e.g., cultural burning). Otherwise, this section should focus on land management approaches to reducing fire risk.
- Section 3.2.2.4 – see comments related to page 3-9. I don't agree with the language stating this is mostly limited to wilderness areas and national parks. Young et al. 2020 shows that strategies beyond full suppression are becoming much more common in general. Consider calling this section “use of wildfire” rather than just natural ignitions, to be more consistent with the previous chapter.
- Page 3-16 lines 28-31: It would be so much more powerful if there was greater information on the fuel treatment activities. How many acres were treated and when? Can these be displayed on the map? This would be more informative than the modeling scenarios, since those are already shown elsewhere in this report.
- Page 3-21 lines 1-2: change to **where wildfires can be safely managed to achieve resource benefit.**

Chapter 4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

This is not my area of expertise. I provide a few suggested edits to improve readability, as the chapter is pretty jargon and acronym heavy. I wonder if this level of detail on this topic is really needed for this report.

Specific edits:

- Page 4-8 line 36 change contribute to **contributed**

- Page 4-10 lines 9-12: Consider changing to **EPA has established one or more FRMs, including specific measurement techniques and instruments, for measuring each of the six criteria pollutants (U.S. EPA, ...).**
- Page 4-10 line 13: consider deleting 40 CFR Part 53
- Page 4-10 lines 19-21: consider deleting “these FEM requirements are also detailed in 40 CFR Part 53 (U.S. EPA, 2019a), and. Begin next sentence with “A monitor”

Chapter 5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?

The modeling approach is reasonable and well described and the authors include an honest assessment of the limitations of this approach, especially as related to the different time horizons of prescribed fire and wildfire. Even with this limitation, given the attention paid to the expected value framework in chapter 2, I was expecting the scenarios with wildfire and prescribed fire to have results presented as a cumulative effects. For example, hypothetical smaller TC6 fire is assumed to be smaller because of implemented prescribed fires. To evaluate expected value of this scenario, wouldn't you need to examine the emissions of the wildfire as well as all the prescribed fires combined, even if they occur over different time periods? Here or elsewhere in the report, I'm seeking some explanation for why each of these scenarios display outputs from individual fires, when there are basic assumptions behind the scenarios that the prescribed fires and wildfires are not acting independently.

Specific edits:

- Page 5-2 line 18. Carbon should be capitalized
- Page 5-2 line 19: Should emission factor be defined?
- Page 5-4 line 21: suppression and **fuels management efforts.**
- Figure 5-3: Why isn't the 2019 Rx Fire on this map?

- Figure 5-4: It would be better if the scale of this figure could be more akin to that of figure 5-3.

Chapter 6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

6a. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health impacts in BenMAP – CE. Have any U.S.- based studies been excluded from the discussion that should be included?

This is not my area of expertise, but the section includes all the literature I am aware of.

6b. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.

This discussion is adequate

6c. Please comment on the ecological impacts highlighted and whether additional studies/citationssould be considered within this section.

I'm not sure why ash impacts are singled out and included in this section and in the conceptual framework. It seems like this should be included in the broader discussion of ecological fire effects.

Chapter 7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

Specific edits:

- Table 7-1: Disaster resilience – should this be disaster assistance?
- Page 7-11 lines 11-26: This paragraph omits the argument, which some studies support, that fuels treatments can lead to increasing suppression costs because it provides opportunities for more aggressive and expensive fire suppression response. Other studies to consider:

Bevel, E.J., C.D. O'Connor, M.P. Thompson, and M.S. Hand. 2019. The role of previous fires in the management and expenditures of subsequent large wildfires. *Fire* 2 doi.org/10.3390/fire2040057.

Loomis, J., J.J. Sánchez, A. González-Cabán, D. Rideout, and R. Reich. 2019. Do fuel treatments reduce wildfire suppression costs and property damages? Analysis of suppression costs and property damages in U.S. National Forests. USDA Forest Service Pacific Southwest Research Station Gen. Tech. Rep. PSW-GTR-261. Albany, CA.

Rideout, D.B. and P.S. Ziesler. 2004. Three great myths of wildland fire management. In: González-Cabán, A. (technical coordinator) Proceedings of the II International symposium on fire economics, planning, and policy: A world view, April 19-22, 2004 Córdoba, Spain. USDA Forest Service Pacific Southwest Research Station Gen. Tech. Rep. PSW-GTR-208, Albany, CA.

Thompson, M.P. and N.M. Anderson. 2015. Modeling fuel treatment impacts on fire suppression cost savings: A review. *California Agriculture* 69: 164-170.

- Section 7.3.2.4 – Either here or somewhere in the report, there should be a brief discussion of what types of activities are included under these costs.
- Page 7-13 line 28: “In 2019, there were 785,500 prisoners in local prisons” – What is this referring to, the number in prison for arson?
- Page 7-15 line 15: change ‘mudslide’ to ‘flooding and debris flow’
- Section 7.3.3.1.4 – Also the costs of dredging reservoirs that experience reduced water capacity from increased sediment transport due to fire.

Chapter 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

My comments for this chapter are very similar to that of chapter 5. While the modeling approach seems appropriate, it don't understand why the effects of the smaller wildfires and prescribed fires are not assessed in a cumulative manner, to be more consistent with the expected value framework. It would also make more sense to me if this chapter were to follow chapter 5, as it is an extension of the modeling effort presented in that framework.

Chapter 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs

between the different fire management strategies adequately described? Does it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

- Page 9-1 lines 20-28: This is a good description of the intent of the report and I wish this had been articulated in this manner earlier in the report. I think the report overall however, fails to fully meet the goal of describing “the state of the science with respect to implementing this framework with the goal of employing the best available science and data to estimate many of those impacts and goals”. Many of the chapters do not explicitly address the framework. The authors should carefully review each chapter, especially those not pertaining to the novel modeling approach, with this larger goal in mind.
- Page 9-13 Line 20: This part of the conceptual diagram is very confusing. What is meant by the ability to mitigate the direct effects of wildfire? I’m assuming this is referring to the line that goes from wildfire to ability to mitigate impacts to non-smoke fire impacts. Is this referring to suppression actions, wildfire use for resource benefit. That flow in the diagram doesn’t make a lot of sense and I don’t recall seeing a good explanation for what it is referring to.
- Page 9-13 line 21: Why are these considered “nonfire effects”? They are certainly related to fire.
- Page 9-13 line 23: It seems strange to me to pull out ash deposition as such a prominent fire effect in the conceptual diagram.
- Page 9-15 middle of last paragraph: Consider this edit: “although prescribed fires may reduce both the ignition probabilities and severity of fires, they produce smoke that may, or may not, **mitigate the smoke output of a potential future wildfire**”

Reviewer 6

Overarching Charge Question

Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

- Overall comment: This is an outstanding case study. It's interesting, and it is a useful contribution to science. I applaud the EPA scientists (as well as those from other collaborating governmental agencies) for this work.
- Major comment (perhaps not a “critical deficiency,” but something that I think should be addressed): I was surprised to see the list of concentration-response functions used in the “primary” analysis were from studies of urban air pollution. It's fine, but it feels out-of-whack with Chapter 6, which didn't really comments on these studies (at all), but instead focused on the studies of wildfire smoke. Also, when I read 8.2.3, I didn't understand why there were CR functions for long-term PM exposure being used in this analysis – I think better justification for this is warranted – scientifically, I don't understand the rational for applying CR functions for long-term PM exposure to a ~60 day fire event. Also, some of the CR functions (e.g., Katsouyanni et al. 2009) aren't from the US, which seems at odds with the focus on US studies in Chapter 6, since there are a lot of international studies of health effects of fires (e.g., from Australia) that could be relevant.
- Overall comment: Beyond the previous comment, I did not find any “critical deficiencies” in the report. However, I've provided several comments for the authors to consider.
- Section 1.2 gets to the main contribution of the report – “the overall air quality impacts of different fire management strategies, which consist of different land management practices, including prescribed fire, are not well characterized).” This is reiterated in Section 1.3, which elaborates on the “modelling component of the analysis, which is the main focus of this report” and takes us through the hypothetical scenarios. However, the Executive Summary seems to have more of an economic value focus rather than an air quality focus, which feels a bit misaligned with the rest of the report – having read the executive summary first I wasn't expecting such a heavy focus on the air quality modeling.
- The Executive Summary doesn't convey the uncertainty that is commented on extensively in Chapter 2 – perhaps one sentence to this affect could be added.
- There are some small grammar issues in the report – I assume these will get fixed once the scientists finalize the content and it gets routed for editing.

- Consider having Chapter 8 follow after Chapter 6. It seems like the logical next step (to me) in terms of organization. Or maybe consider having Chapter 7 come before Chapter 6.

Chapter Specific Charge Questions

If a question is beyond your technical expertise, please skip it.

Chapter 1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

- I think Chapter 1 is effective in introducing the assessment. I like the figures showing the hypothetical smaller/larger scenarios relative to the “baseline” scenario (perhaps a better description than “baseline” is “actual fire scenario” or something like that, although “baseline” was also clear to me).
- Section 1.3 is titled “Novel Approach.” It might be worth being explicit as to what exactly is novel (this is not a criticism that the work isn’t novel; I am asking for clarity in the authors articulating what specifically about the work is novel).
- Clearly, there are details that aren’t developed in Chapter 1. For example, there is virtually no discussion of how the public health impacts / effectiveness of public health messaging are modeled, where those estimates come from, and so on. But I think this is fine for Chapter 1 – saving these kinds of details for later chapters makes sense to me.

Chapter 2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed from the framework? How well does the text support the overall framework? Please explain.

- Chapter 2 covers a lot of the background that goes along with the conceptual framework. I am realizing that several of my comments are on the figures and tables, and I think the authors have done a good job with these. Sometimes reading a big report it’s hard to keep track of everything, and the figures and tables help a lot. Even something like Table 2-1 – which might seem unnecessary given what is in the text – I found it was very efficient at helping me understand what is going on.

- Equation 2-1 seems inconsistent with the written description as to whether certain terms are conditional on M_i – somethings are written in the equation as not being conditional whereas the description says they are conditional.
- Figure 2-1 is helpful, although some things are a little unclear (e.g., the difference between ecological impacts and ecosystem impacts). Also the two categories of “non-smoke impacts” and “non-fire impacts” is a little confusing...would it be more straightforward to call them “smoke impacts,” “fire impacts,” and “other” (if a third category is needed)?

Chapter 3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

It seems very complete. No comments.

Chapter 4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

- In my opinion, this section of the report contains plenty of detail.
- One comment – which the authors can consider and which is by no means essential for them to address right now – is the question of “how good of a measurement is good enough?” As a member of the general public living downwind of a fire, does it really matter if the true AQI is 400 and it gets misreported as 300 or 500? Either way it is a lot of PM, and some measurement error doesn’t really matter – the tools we currently have available might be perfectly adequate. Whereas for a scientific researcher, very accurate species concentrations measurements might be quite important, and we often don’t have those, and even when we do we know the aerosol composition of the plume changes with aging, etc. so one monitor isn’t enough. So different goals might necessitate different investments into the monitoring network, and this point could be made in section 4.5 or 4.6.
- Figure 4-1 – what are the colors? The shapes are explained in the figure description but not the colors.

Chapter 5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in a cohesive way to describe the exercise?

- The methodologic details of this chapter are outside my area of expertise

Chapter 6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

6a. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health impacts in BenMAP – CE. Have any U.S.-based studies been excluded from the discussion that should be included?

6b. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.

6c. Please comment on the ecological impacts highlighted and whether additional studies/citationssould be considered within this section.

Minor comment: My reading of the literature is that the short-term health effects of PM from smoke are a bit different from the short-term health effect of PM from typical urban sources – the systematic reviews suggests show that smoke is strongly associated with respiratory events (and the consistency across epidemiologic studies of wildfire smoke is remarkable), and that smoke is less strongly associated with cardiovascular events (compared to PM from traffic sources). This seems to be supported by the forest plots shown in the chapter as well. Whereas the intro of chapter 6 seems to suggest that the findings for smoke are similar to what we see for PM in general.

1. The review of the epidemiologic literature seems solid – the forest plots are good to show how the results from the different studies compare. One thought is that in earlier chapters the report makes a clear point to restrict focus & generalization to Ponderosa pine forests, but the CR functions are coming from U.S. studies where the fires

occurred in a variety of ecosystems – presumably because we don’t have enough restricted to Ponderosa pine forests, but perhaps it makes sense to justify this explicitly in the report given what is written in earlier chapters.

2. The section on the public health actions is good, but it’s hard to think about how to use this alongside the concentration-response functions described earlier in the chapter with BenMAP. One reason is that in the epidemiologic studies, these exposure reduction actions were already employed (to various unquantified extents) in the populations in which the epi studies were conducted. Perhaps this will be clearer to me how the authors use this once I get to the BenMAP chapters, but it is something I was thinking about while reading section 6-3. Another challenge is that Table 6-3 is about in-home exposures, whereas the CR functions are about ambient concentrations.

Chapter 7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

I don’t have comments on this chapter. While it’s undeniably true that these are real issues, they are separate from the air quality and health impacts work that comprise the new science that this report is contributing to the literature. I get that the authors are trying to be holistic and encompassing with this report, but in some ways it distracts from the new work that was actually done. I paged through it to get to Chapter 8, which is the chapter that (in my mind) should logically come after Chapter 6.

Some of the sections in Chapter 7 are terse (e.g., 7.3.3.1.3). Even so, I am not convinced that expanding Chapter 7 would meaningfully add to the value of the overall report.

Chapter 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

Major comment (repeated from earlier in the document): I was surprised to see the list of concentration-response functions used in the “primary” analysis were from studies of urban air pollution. It’s fine, but it feels out-of-whack with Chapter 6, which didn’t really comment on these studies (at all), but instead focused on the studies of wildfire smoke. Also, when I read 8.2.3, I didn’t understand why there were CR functions for long-term PM exposure being used in this analysis – I

think better justification for this is warranted – scientifically, I don’t understand the rationale for applying CR functions for long-term PM exposure to a ~60 day fire event. Also, some of the CR functions (e.g., Katsouyanni et al. 2009) aren’t from the US, which seems at odds with the focus on US studies in Chapter 6.

Table 8-6...are the authors assuming that the prevalence of these actions in the studies that provided the CR functions is 0%? If so, that assumption is wrong for the studies of wildfire smoke health associations...although I guess the authors could argue that by using the CR functions from the urban air pollution studies that it’s a reasonable assumption. But that sort of argument also highlights the disconnect between Table 8-6 and the health impact estimates that are ACTUALLY being generated vs. the ones that we wish we were in a position to generate...

I don’t want to be too critical about Chapter 8 – I think it’s great work, and there is value in understanding the relative magnitude of differences in impacts across the scenarios (getting the numbers right is scientifically interesting, but also a lot harder to do, and ultimately may not be necessary to inform forest management practices). Using the estimates from the epidemiologic studies of wildfire smoke won’t necessarily get better estimates, since the literature is smaller and also the random errors are larger owing to smaller sample size. But it does have the advantage of being a bit more logically connected to the science, particularly for some of the sensitivity analyses. The authors are upfront and transparent about this in the Summary, which is good.

Chapter 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

My feeling is that Chapter 9 is a nice summary of the information presented within this report. I really don’t have comments here – I think it is well-written and comprehensive. My understanding is that the datasets for prescribed fires are lacking and not systematically collected, and that this is really a big limitation for the air quality modelers. I appreciate that this is mentioned in Section 9.5 as well as in the Executive Summary.

Reviewer 7

Overarching Charge Question

Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

This report is best when it plays to the strength of the US EPA and covers topics such as air quality monitoring and chemistry, human health effects, and water quality. When covering these subjects, this report is excellent. Where the report ventures into forest ecology, land management, and ecological effects, the text is good overall, but needs revision to correct instances where framing is incomplete or important details are lacking.

Organizing a report of this scope is difficult. I found the organization challenging sometimes because information about the modeling exercise was scattered across a number of chapters. EPA might consider if there is a way to reorganize the report to have the information about the wildfire modeling centralized to within a single chapter. I see that different aspects of the modeling are imbedded within chapters that provide context, but that makes it challenging to understand the full scope of the model.

The overall approach of focusing on two different western fires and then devising alternate scenarios for these fires to understand the potential influence of fuels management practices on public health is interesting, but of limited veracity and breadth. Rather than attempt to understand more holistically the potential costs and benefits of different fuel management strategies by integrating probabilistic estimates of fire activity and behavior, the alternate scenarios were simply created by opaque “expert judgement”. The limitations of this approach are identified in Chapter 9 and elsewhere in the text, but these limitations are significant. While the approach here is insightful, I was disappointed it was not more robust given the large number of scientists involved and the overall breadth of this report.

One small but important issue that I see with this report is that it repeatedly frames contemporary issues with wildland fire in the U.S. as a problem of wildfires increasingly “encroaching” on human populations. In fact, and as acknowledged in the report, humans are increasingly living within wildlands that have regularly experienced fires for millennia and these humans are also a tremendous

source of ignitions. The problem is not necessarily that wildfires are burning, it is that humans are now in the way of the fires. More specifically, our collective problem is that our priorities for the services that should be provided by wildlands have changed faster than our ability to manage those lands in a way that will provide these services in our contemporary ecological context. That puzzle of managing our (fire-prone) lands to provide our collective desired environmental outcomes is the foundational question of this report.

The executive summary was very clearly written and did a good job of synthesizing the information about the effects of the two studied wildfires and hypothetical alternatives. However, some of the most important findings of this report are the identification of knowledge gaps around monitoring, fully understanding health impacts, and quantifying environmental effects, but these topics were not covered by the executive summary. I urge you to include those items so that policymakers and others who may not read all the way through this lengthy report will also receive these key conclusions.

Please, more commas! I've commented on a few instances where the lack of a comma forced me to reread sentences, but there are numerous other spots that would have benefitted from the addition of a comma.

Chapter Specific Charge Questions

If a question is beyond your technical expertise, please skip it.

Chapter 1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

I think Chapter 1 is successful in providing the rationale, approach, and goals for the report. I have some comments about how this work and contemporary issues are framed, which are detailed below. I don't see need for fundamental changes to this chapter, only changes in language.

- P1-1 L24: Not just wildlife habitat, but also habitat for plants and other organisms.
- P1-2 L2-7: Fire suppression isn't an ignition source and climate change isn't an ignition source, except for possible changes in lightning frequency. However, all of these things

influence the occurrence of wildfire. Also, this sentence implies that the occurrence of wildfires has increased, but that contradicts line 10 in the next paragraph. I realize the two statements have different time frames, but it is still a contradiction.

- P1-2 L13: Animal and plant habitats
- P1-2 L15-17: I disagree with the framing that fires are encroaching on communities. Communities are encroaching on natural systems that have burned for millennia. I would suggest deleting “encroaching on American communities” and simply say that wildfires are increasingly posing threats to lives, etc.
- P1-2 L21-22: This is a good and important sentence, but I think there is an equal need to recognize that the accumulation of wildfire fuels is also inevitable and that without extensive intervention, wildfires themselves are inevitable. This is a crucial point that needs to be made prominently in this report.
- P1-6 L1: Every fire will increase some ecosystem process/function/service that has a value to someone, so it is a bit imprecise to say a fire “resulted in resource benefits”. It would be more appropriate to say the fire was “managed for resource benefits”. Some organisms, like the black-backed woodpecker, like extensive stands of dead trees killed by wildfire. High-severity fires would also likely increase streamflow, a benefit to downstream water users.

Chapter 2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed from the framework? How well does the text support the overall framework? Please explain.

Although there are issues with some of the text framing wildfires, the chapter is successful in providing context for subsequent chapters. Figure 2-1 matches the structure of the chapter, but it also does not fully describe interactions between prescribed fire, “resource benefits”, non-smoke fire impacts, and risk of wildfire. As currently constructed, figure 2-1 is bit confusing. For instance, the “Management Decision” box has a number of arrows coming out of it. All of the green arrows and the orange arrow appear to be coming out of only “Prescribed fire”, while “probability of wildfire ignition” seems to be flowing from the “Management Decision” box as a whole. In reality, there would be some benefits also from mechanical thinning or even from “no action” (lower implementation costs). I would suggest either making this diagram more complete to show those

benefits/costs or removing “mechanical thinning” from the list. I would also remove “ash” and “GHG emissions”, or at least make them a different color than the smoke boxes. Ash and GHG emissions are both certainly components of smoke plumes, but GHG emissions have no direct human health effects, while ash has a number of negative (contributes to smoke, decreases water quality, etc) and positive (soil nutrient cycling) effects. Ash and GHGs are also components of smoke emissions, which makes unclear why they are distinct from the smoke emissions box. (Though arguably, ecosystems will remain a net GHG source to the atmosphere for some time following a severe wildfire.)

- P2-3 L11: Intensity is energy output, but over a defined space and time. It is possible for fires to release a lot of energy over a long period of time in a low intensity fire. For the text, I would suggest providing example units of W m^{-2} to better convey the nature of fire intensity.
- P2-4 Footnote: Some of these effects, such as air pollutant emissions from heavy equipment, chainsaws, and trucks could be quite easy to quantify; others have quantified these emissions.
- P2-6 L11: The word legacy is unnecessary and should be struck; contaminants are problematic no matter their age or source.
- P2-6 L26: I realize this is an existing definition, but this is problematic given human influence on virtually every part of the natural world. Is a fire sparked by a car on the side of a highway in eastern Oregon, which burns non-native cheatgrass in a sagebrush ecosystem that would otherwise not frequently have fire, a “natural event”?
- P2-7 L12-15: This sentence should be rearranged to simplify its construction.
- P2-8 L17-19: This understates the evidence and implies uncertainty that prescribed fire can achieve these objectives. Suggest changing to “There are decades of evidence that...”
- 2.3.3.2: It should be noted that in many arid forests in the western US, forest management practice regulations require that residues from harvest or thinning be treated in reduce fire danger. In many areas, that treatment is achieved through pile burning or (less frequently) broadcast burning. Thinning is often done in combination with prescribed burning, often as a first step.
- P2-10 L24: This sentence is somewhat awkward because “pine” is not a species, but a genus (*Pinus*) and a family of trees (*Pinaceae*). Not all pines depend on fire for reproduction.

- P2-10 L27-29: This can be true, but fires can also lead the loss of nutrients from ecosystems, particularly nitrogen. The supply of nitrogen is often the nutrient most limiting to growth in temperate ecosystems. However, in some cases this loss of nutrients could be helpful for plants and other organisms favored by nutrient-poor conditions.
- P2-10 L33: Under the right circumstance this is true, but fires can also increase the dominance of cheatgrass. Also, provide a scientific name (*Bromus tectorum*).
- P2-12 L30: It is also recognized that fuels treatments can decrease carbon sequestration, but increase the stability (decrease the vulnerability) of the remaining forest carbon.
https://ww3.arb.ca.gov/cc/inventory/pubs/wildfire_emissions_faq.pdf

Chapter 3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e., Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

This chapter provides a broad background that is important context for the understanding the Rough and TC-6 fires. I think this chapter is well-written and complete except that while the “historic” conditions here are well described, there is no time period identified for when these conditions occurred. I have a number of comments, but these are minor remarks.

- P3-1 Line 10-13 notes that climate is a key driver of fire regimes, but should have also mentioned that fire regimes are also strongly influenced by human actions, including those of indigenous people.
- P3-3 L2: Rather than visual or measured, I think you mean qualitative and quantitative. If you count something you see with your eyes, that is both visual and measured.
- P3-3 L8-9: I disagree with this statement. It is relatively easy to estimate flame length, which is a proxy for fireline intensity. However, estimation of duration and actual intensity are of similar difficulty.
- P3-4 L8: Scientific name should be provided at first use in the report.
- Figure 3-2: It feels somewhat misleading to show a large map extent and show WUI area across all of that map, but only show ponderosa pine distribution across part of that map.
- P3-6 L4: Here and throughout the report, Douglas-fir should be spelled with a hyphen to denote that it is not a true fir (it is not member of the genus *Abies*).

- P3-6 L7-8: This is not true for the ponderosa pine forests that would have been part of the Rough Fire. The lower elevation boundary of ponderosa pine forests in that area abuts forests and savannahs composed to oaks (*Quercus* spp.) and grey pine (*Pinus sabiniana*).
- Figure 3-3: This is an odd choice of photos. (1) These do not appear to be the same locations, making it difficult to make a direction comparison. Photo pairs of the same locations are available. (2) This contemporary ponderosa pine stand 10-15 years after a fire does represent some portion of the landscape, but arguably larger portions of the landscape have not experienced recent fire or have experienced recent fires of greater severity. In short, the contemporary image is not indicative of current conditions.
- P3-7 L24: change “settlement” to “widespread Euro-American settlement”. Indigenous people had lived in these regions for millennia; European settlers arrived in the 1700s and 1800s.
- P3-8 L18-20: Relative to grasslands and deserts, the spread of invasive species has been lower. However, I would not describe the abundance of invasive plants within ponderosa pine forests as “minimal”. There are numerous published reports of invasive annual grasses in ponderosa pine forests in Oregon and California. Keeley and McGinnis (2007) specifically note cheatgrass invasions were considered problematic in the vicinity of the Rough Fire as far back as the late 1990s. I would also refer you to Kern et al. *Forest Ecology and Management* 463 (2020) 117985
- 3.1.5.2: Some mention of the role of humans in igniting fires should be added here.
- P3-10 L12-15: I’m confused. An effect of prescribed fire is the lack of advanced fire suppression?
- P3-10 L15: Lightning
- P3-16 L24: I’m confused by “the montane chaparral shrub”. Is that a descriptor of bitterbrush? If so, I suggest reconstructing the sentence to improve clarity.
- P3-17 L6: Fire should be capitalized.
- P3-18 L9-10: The units here are way off. I think Mg is what is intended. It’d be hard to carry much fire with a couple of grams of fuel per km²!
- P3-18 L13 & L17: These dates do not align and it seems likely that the 2011-2014 should be changed to 2012-2015. However, there is no direct citation given for the tree mortality in the Rough Fire area.

Chapter 4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses

current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

Although I have some experience with air monitoring research, I am not an expert in this field. I found this chapter to be an interesting read and a comprehensive and honest assessment of the strengths and limitations of current monitoring capabilities. The information in this chapter helps inform some of the subsequent approaches and analyses. I thought this chapter was perhaps too detailed, particularly in the discussion of some of the remote sensing techniques that have less direct relevance to public health. However, this information is useful if the purpose of this chapter is to provide a comprehensive assessment of monitoring capabilities.

Chapter 5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?

I think the modeling approaches that were used were sound. In general, the assumptions and the source data driving the modeling is clearly described. However, while I see where the meteorological data driving the atmospheric transport is described and I see where the fuel load and type data are described, I do not see any description of the meteorological inputs to the fire modeling (no description of fire weather) and I do not see a description of fuel moisture. Presumably, these are handled in the BlueSky Pipeline/Consume because it is producing estimates of fuel consumption and emissions. While presumably the modeling reflected the conditions of the actual burns, conditions would have to be assumed for the other burns. Some description of these assumptions would be insightful.

- P5-18 L8: All land is managed and all USFS and NPS lands should have management plans. Even wilderness lands are managed!

- Figure 5-14 needs better labeling, particularly the panels on the left side that all have the same heading.
- Figures 5-15 and 5-16: The color ramps are similar for the absolute concentrations (left panels) and the differenced concentrations (middle and right panels), which is unintuitive given that the scales are quite different. I think it would be easier to understand that the middle panels are lower and right panels are higher if a different color scheme was used.
- P5-31, L 9-14: It is good to note this limitation because a 12-km grid size does seem like it would be too coarse to accurately model and quantify the impacts of fire emissions on downwind communities.
- P5-33, L3: This sentence desperately needs a comma after “population”
- P5-37: Given that there are large population centers near the Rough Fire and that a higher resolution (finer scale) model may be much more accurate, why not also do a finer scale model run instead of only relying on the coarse 12 km grid?

Chapter 6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

6a. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the studies that could be used to estimate health impacts in BenMAP – CE. Have any U.S.- based studies been excluded from the discussion that should be included?

6b. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.

6c. Please comment on the ecological impacts highlighted and whether additional studies/citations should be considered within this section.

Sections 6.2 and 6.3 are great. I am not a researcher of the health effects of smoke, but I am familiar with the literature and I think these sections are really excellent syntheses. Section 6.2 is a good concise survey of the available evidence for wildland fire smoke health effects that I think produced a very balanced assessment of the state of the science on this topic. Section 6.3 is the best synthesis of mitigation measures that I’ve seen. Section 6.4 was well written, but missed some important context and neglected a couple of important environmental effects of smoke. In particular, section

6.4 is missing two components: (1) The ability of smoke to create diffuse radiation, which can increase photosynthesis (2) The effect of smoke on air temperature and vapor pressure deficit.

- P6-1 L2: “ecological benefits” would be better phrased as “environmental benefits”, particularly given the potential positive impacts on streamflow. Watershed yield is a critical environmental parameter in the water-limited western US.
- P6-3 L8: Comma needed after “exposure”
- P6-28 L29-30: I’m confused by the redundancy of “particulate matter” in this sentence.
- P6-29 L1: “It is”
- 6.4.2: The effects of ozone on plants tends to be a result of cumulative exposure and uptake, which is relevant here for two reasons. (1) Smoke from wildland fires is highly episodic. (2) Wildland fires tend to burn during episodes of especially dry conditions and during periods of the year in dry (western) ecosystems when growth and carbon assimilation are limited and many plants have senesced; both of these would limit plant ozone uptake. Therefore, although this section does provide a concise review of the effects of ozone on plants, it should be caveated with the fact that wildland fire smoke itself is unlikely to produce the cumulative ozone exposures necessary to create these effects. However, there is potential for wildland fire smoke to exacerbate ozone effects in environments already suffering from ozone pollution.

Chapter 7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

This chapter discusses numerous aspects of fire-related damage. The coverage of these topics is broad and often brief. However, I don’t disagree with this strategy and I think the text provides sufficient depth. I observed only a few concepts that had been omitted or described insufficiently. First, there should be some discussion of structure hardening as a mitigation measure. While the focus of this chapter seems to mitigation of fires on wildlands, inclusion of structure hardening would seem appropriate given the inclusion of defensible space because both are about limiting ignition to build infrastructure. Second, the description of hydrologic impacts of fire could be expanded to be more robust, as detailed below.

In late 2020, the California Council on Science & Technology produced a report on the costs of wildfire that would be a very relevant contribution to many aspects of this chapter.

- 7.3.3.1.5: In areas experiencing extensive wildfire, the sudden surge in timber availability from salvage logging can saturate local markets (mill capacity). This has two effects (1) It decreases the immediate value of timber from unburned areas and (2) It can limit opportunities and financial incentives to conduct salvage harvests.
- P7-16, L12: Spelling: Hayman, not Haymen
- P7-19 L30: This section neglects to mention the decrease in precipitation interception created by the loss of vegetation and plant litter material. Interception of precipitation can have a tremendous effect on both the quantity and timing of water delivery to the soil surface and subsequent run-off.
- 7.3.3.2.5 The section on Water Resources neglects to mention that low and moderate severity wildfires can have a positive impact on downstream water users because water quality impacts may be low, but the decrease in vegetation can increase the supply of water (stream flow).

Chapter 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

The technical details of BenMAP are beyond my area of expertise, so I have few substantive comments on this chapter.

- P8-4 L31-34: It is true that the Rough Fire lasted for multiple months, but most of the population exposure (Figure 5-17) was limited to a few distinct episodes. Would combining the short-term exposure effects of these episodes have resulted in stronger or weaker effects relative to modeling the effects of long-term exposure?
- Figure 8-1 and Figure 8-2: Some of the symbols are empty and some filled, but I don't see any text explaining the significance of this. Please explain or change.

Chapter 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does

it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

Chapter 9 is an effective synthesis, though the length and breadth of the report makes it difficult to provide much substantive information about the individual chapters. I think the emphasis on (1) the main conclusions regarding the smoke produced in these fires and the subsequent public health effects (2) the limitations of this work (3) research gaps, was appropriate.

I'm not sure the Introduction section (9.1) adds much value because it restates what was previously written and then simply outlines the rest of the chapter.

- Figure 9-1: What are the error bars? Standard error? 95% CI? Other?
- Figure 9-2: What are the white portions of the bars?
- Page 9-15: This text is excellent, important, and should be elevated to more prominence within this analysis.
- P9-19 L1-3: Rephrase to “As human development extends further into fire-prone wildlands, it can lead to a change in the composition...” The wildfires have (essentially) always been there. Humans and their stuff are now in the way of those fires.
- P9-19 L33: I think “can” should be deleted from this sentence.

Reviewer 8

Review of “Comparative Assessment of the Impacts of Prescribed Fire Versus Wildfire (CAIF): A Case Study in the Western U.S.”

Overarching Charge Question

Please comment on the overall organization and clarity of the report. Please identify its overall strengths and weaknesses.

Overall the report does an excellent job introducing the reader to the issues involved in prescribed fires, fire management, and public health concerns. Air quality managers, especially in the western US, need to weigh the benefits and costs of prescribed fires, and to convince the public of the value of such fires as a tool to limit the potentially catastrophic impacts of large wildfires. These issues have acute importance, especially as climate change and accumulated fuel load make such large fires more likely.

The executive summary is well-written and convincing. This review outlines strengths and weaknesses by chapter.

Chapter Specific Charge Questions

If a question is beyond your technical expertise, please skip it.

Chapter 1. Chapter 1 introduces this assessment including the rationale, approach, and goals of the report, along with the appropriate context in which to view the results. Please comment on the completeness of the introductory information. Are there any areas that are unclear, or would benefit from additional information to set the basis of the assessment? Please explain.

Chapter 1 does a good job laying out the rationale, approach, and goals of the report, and this reader was impressed by the intra-agency effort to address the issue of prescribed fires in the western United States.

- Section 1.3. A table or bullet list of the different scenarios for each fire would be helpful. Such bullet lists appear in Chapters 8 and 9. Also, the text states that the scenarios “equate to” specific conditions, but “represent” would be the better word choice.

- Page 1-7. Describing more exactly the “resource benefits” of the Sheep Complex Fire would be helpful.

Chapter 2. The structure of this assessment is described in the form of a conceptual framework in Chapter 2. The chapter is intended to set the stage for the remaining chapters and demonstrate how the individual components of the assessment fit together to inform the key questions regarding the air quality, health, and ecological effects of different fire management strategies. Please comment on whether the conceptual framework fully captures the components of different fire management strategies and the corresponding health impacts and damages. Are there specific components that should be added or removed from the framework? How well does the text support the overall framework? Please explain.

Overall, Chapter 2 does a good job “setting the stage” for subsequent chapters. Comments are as follows.

- Page 2.3. It would be helpful to know earlier in the chapter whether or not the fire-related effects include health impacts.
- Page 2.9. The reader is puzzled why over 14,000 assessments have not sufficed to characterize the effectiveness of fuel treatments. The text reports that these assessments have suffered from an “under sampling of fuel treatment effectiveness monitoring, mostly on the smaller fires (less than 1,000 acres).”
- Page 2-12, Section 2.3.4.2.3, Effects on greenhouse gas (GHG) emissions. The text should acknowledge that in a natural fire regime, the CO₂ emitted through biomass burning is taken up again by the subsequent regrowth of vegetation, with a net impact on CO₂ concentrations of zero. Only when a forest is replaced by less dense vegetation – e.g., savannah – are fires a source of greenhouse gases. Indeed, the forests in the western US are likely functioning as unnatural CO₂ reservoirs, sequestering carbon due to the decades-long fire deficit in this region.
- Figure 2.1. See comment above on greenhouse gas emissions from fires.

Chapter 3. Chapter 3 outlines baseline forest conditions, defines different fire management strategies, and discusses the role of fire in ecosystems, specifically focusing on the ecosystem of the case study fire locations (i.e.,

Ponderosa Pine Ecosystems). Please comment on the completeness of this discussion and whether it forms an adequate introduction of the topics.

This chapter presents an excellent overview of fire regimes and the vulnerabilities of forests to wildfire after decades of fire suppression. This reader, whose expertise is air quality, learned a lot. The recent fire history of the Rough Fire area was especially enlightening.

Authors might consider specifying whether the fire regimes described in Table 1 are all natural, or a mix of natural and unnatural regimes. Given the caption to Figure 3-1, it sounds like these are natural regimes.

Chapter 4. Current air quality monitoring capabilities, as they pertain to wildfire smoke, are a key resource for understanding the specific health effects associated with smoke exposures and are critical to evaluate the performance of air quality models in predicting air quality impacts from wildfires. Chapter 4 discusses current air quality monitoring capabilities for wildfire smoke and associated challenges. Are all relevant capabilities discussed, or is there anything that should be added? Are the strengths and weaknesses of the individual capabilities covered in sufficient detail? Does the presentation of information on monitoring capabilities help to characterize the confidence in the air quality and health and ecological impacts provided in the assessment? Please explain.

Chapter 4 does a good job describing current efforts to monitor smoke air quality with in situ sensors, ground-based measurements such as AERONET, and satellite observations. In particular, the challenge of translating aerosol optical depths (AOD) as viewed by satellites into surface concentrations of smoke PM_{2.5} was well described.

- Figure 4.2. The colors in this figure do not match those of Table 4.1.
- Page 4-17. The text describes current efforts to combine satellite measurements of AOD with results from chemical transport models (e.g., GEOS-Chem) to derive surface values of smoke PM_{2.5}. Figure 4.3 shows of such an effort for one day in 2020. The reader is curious if efforts are being made to validate such maps of daily surface PM_{2.5}. As the text makes clear, most (successful) efforts to combine satellite AOD and GEOS-Chem results have led to estimates of annual or seasonal mean PM_{2.5} at the surface, not daily concentrations.
- Section 4.5. A key challenge not mentioned in this section is the difficulty of attributing PM_{2.5} measurements to smoke or to some other species. Even if sensors were placed close to wildfire-prone regions, the challenge of distinguishing smoke from other kinds of PM_{2.5} would remain. Aguilera et al. (2021) used a combination of surface EPA-AQS measurements with HMS smoke plumes to attribute surface PM_{2.5} to smoke or not-

smoke in southern California. But the HMS smoke product, as the CAIF report rightly mentions, may not reflect surface concentrations.

One way to resolve this issue would be for EPA/AQS to routinely measure tracers of biomass burning such as levoglucosan. Other species currently measured – including black carbon and organic carbon – are emitted by both wildfires and other anthropogenic and/or biogenic sources.

Aguilera, R., T. Corringham, A. Gershunov, and T. Benmarhnia, Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California, *Nature Commun.* 12, 1493, 2021.

Chapter 5. The main component of this assessment is a novel air quality modeling approach that allows for a comparison of the health impacts between different fire management strategies, discussed in Chapter 6. Chapter 5 outlines the modeling approach employed and the various assumptions and decisions made in the process of modeling both hypothetical fire management strategies as well as prescribed fire. Please comment on the overall modeling approach, specifically the characterization of fuel loads, emissions, and the application of the air quality models, and whether there are inherent limitations that have not been adequately captured within the chapter. Is the chapter clearly written in cohesive way to describe the exercise?

Chapter 5 lays out the design of the model simulations and presents results in terms of the PM_{2.5} and ozone enhancements from the different kinds of fires – wildfire vs. prescribed, actual vs. hypothetical. Overall the modeling approach is sound, and the authors seem very aware of both the strengths and the limitations of this approach. For example, the chapter mentions how the interannual variability of meteorology is not captured by this approach, and how the spatial resolution of the model may fail to capture steep gradients in both topography and in concentrations. The chapter is also very clearly written, with a nice introduction to the challenges of modeling fires – e.g., the limited knowledge of emission factors, especially from smoldering vs. flaming fires.

- Section 5.1.3. As mentioned for a previous chapter, it might be helpful to include a table describing the characteristics of the different scenarios and the timeframes of these scenarios.
- Sections 5.2.1 and 5.2.2. There seems to be some overlap between the two sections. For example, FCCS is introduced to the reader twice. Perhaps some effort could be made to better harmonize this text.

- Section 5.2.3.1. This section presents the temporal profile for the Timber Crater Fire. I didn't see a similar description of the profile for the Rough Fire.
- Page 5.18. This reader is surprised that modeled fuel moisture is not a function of meteorological variables like relative humidity or recent precipitation. Is this typical for fire models?
- Table 5.2. The authors might consider adding a footnote to explain that the 1978 and 2001 TimberCrater fires and the 2007 Cornerstone fires are actual fires, occurring in the past. Also the designation of "Timber Crater 1/2" is confusing. The reader thinks "1/2" means one-half.
- Figures 5.8 and others. A note explaining that the colorbars differ among panels would be helpful.
- Figure 5.10. Again a note explaining the different extents of the y-axes would be helpful.
- Page 5.25. The text states that the daily impacts of MDA8 ozone from prescribed fire were sometimes comparable or even larger than that in the wildfire scenarios. The first reason given for this increase – that the model burned all the fuel in one day – seems unconvincing, as the same phenomenon is not seen for the PM_{2.5} results. Perhaps this reviewer is missing something.
- Figure 5.13. The caption seems not to match the Figure.
- Page 5.35. The text points out that the model sometimes overestimates PM_{2.5} compared to that measured by the sensors. A potential reason given for this overestimate is that the model does not take into account the volatilization of primary organic aerosol (POA). That could be true, although Palm et al. (2020) found that much of the volatilized POA actually re-condenses to produce an equivalent mass of secondary organic aerosol. A more likely reason for the mismatch could be the coarse model resolution, as the authors also note.
- Palm, B.B. Quantification of organic aerosol and brown carbon evolution in fresh wildfire plumes,
- *PNAS*, 117 (47), 29469-29477, 2020.
- Section 5.4. This section nicely summarizes the approaches and limitations of the study.

Chapter 6. Chapter 6 encompasses two components of this report: (1) a discussion of the health effects attributed to wildfire smoke and potential actions that can be taken to reduce exposures to wildfire smoke; and (2) a discussion of the ecological effects of wildfire smoke. Please comment on the following:

6a. Please comment on whether the discussion on the health effects evidence, including the corresponding appendix table, adequately inform decisions on the

studies that could be used to estimate health impacts in BenMAP – CE. Have any U.S.- based studies been excluded from the discussion that should be included?

Yes, this section does a good job providing an overview of the health impacts of smoke exposure. The summary of different metric of smoke exposure was helpful.

One recent study examining the health impacts of smoke is Aguilera et al. (2021). Also, Liu et al. (2017a) is cited but not Liu et al. (2017b), which investigated the health impacts of smoke on different populations. References listed below. The authors might consider including all three references in the Figures showing odds ratios.

- Page 6-5. The authors might consider mentioning the modeling approach of Liu et al. (2017a), in which the modeled PM_{2.5} was calibrated with observations.
- Figures 6-1, 6-2, 6-3. The tiny text is difficult to read.
- Page 6-14. The text states that “current evidence does not indicate a difference in the health effects between ambient PM_{2.5} exposure and other source-based exposures, such as wildfire smoke...” However both Liu et al. (2017a) and especially Aguilera et al. (2021) suggest that wildfire smoke may be more deleterious than anthropogenic PM_{2.5}.

Aguilera, R., T. Corringham, A. Gershunov, and T. Benmarhnia, Wildfire smoke impacts respiratory health more than fine particles from other sources: observational evidence from Southern California, *Nature Commun.* 12, 1493, 2021.

Liu, J.C., A. Wilson, L.J. Mickley, F. Dominici, K. Ebisu, Y. Wang, M.P. Sulprizio, R.D. Peng,

X. Yue, J.Y. Son, G.B. Anderson, and M.L. Bell, Wildfire-specific fine particulate matter and risk of hospital admissions in urban and rural counties, *Epidemiology*, 28, 77-85, 2017a.

Liu, J.C., A. Wilson, L.J. Mickley, K. Ebisu, M.P. Sulprizio, Y. Wang, R.D. Peng, X. Yue, F. Dominici, and M.L. Bell, Who among the elderly is most vulnerable to exposure and health risk of PM_{2.5} from wildfire smoke? *American Journal of Epidemiology*, 186, 730-735, 2017b.

6b. Please comment on the adequacy of this discussion, the exposure reduction options characterized, and the overall conclusions of the section.

This reviewer does not have the expertise to evaluate this section.

6c. Please comment on the ecological impacts highlighted and whether additional studies/citations should be considered within this section.

The reviewer also does not have the expertise to judge this section. However, a discussion of the differences between ash and black carbon particles would have been helpful.

Chapter 7. In fully characterizing the tradeoffs between prescribed fires and wildfires it is necessary to also characterize the non-smoke related damages associated with fire, including impacts on fire fighter health and safety, as well as some additional direct and indirect damages attributed to wildfire smoke. Please comment on the adequacy of these discussions. Are there additional citations or information needed to strengthen this summary? Are there other damages that should be included in this Chapter?

The reviewer has little expertise in the topics discussed in this chapter. However, the descriptions of the costs and benefits of fires seemed relatively clear. For example, the authors point out that low-intensity prescribed fires coupled with mechanical thinning can reduce the risk of catastrophic fire, and thus lead to a net benefit. The chapter also makes clear the resistance that some landowners have toward prescribed fire.

- Figure 7-1. Axis labels are too small to read.
- Section 7.3.1. This section was hard to follow. The notion of prefire suppression is introduced but not defined until later in the chapter. It wasn't clear what the difference is between C+L and C+NVC. How do prescribed fires fit into Figure 7-2?
- Section 7.3.2.3. Do suppression efforts include prescribed fires?
- Page 7-15. The text mentions that trees sequester carbon, and that this carbon can be released during burning, implying that forest fires can affect CO₂ concentrations. The text should acknowledge that the regrowth of forests can draw CO₂ levels back down, with a net zero impact of fires on CO₂.
- Page 7-19. Two more recent papers that predict increasing fire under a climate change regime include Ford et al. (2018) and Li et al. (2020)

Ford, B., M. Val Martin, S. Zelasky, E. Fischer, S. Anenberg, C. Heald, and J. Pierce, Future fire impacts on smoke concentrations, visibility, and health in the contiguous United States, *GeoHealth*, 2, 229–247, 2018.

Li, Y., L.J. Mickley, and J. O. Kaplan, Response of dust emissions in southwestern North America to 21st century trends in climate, CO₂ fertilization, and land use: Implications for air quality, *Atmos. Chem. Phys.*, 21, 57-68, 2021.

Chapter 8. Chapter 8 conducts a BenMAP – CE analysis building off the information presented in the air quality modeling chapter (Chapter 5) and the health effects and exposure reduction sections of Chapter 6. Please comment on (1) the approach used to compare results between the different fire management strategies (2) the sensitivity analyses conducted, and (3) the presentation of results.

The authors take a very reasonable approach to estimate the health effects of the Rough and Timber Crater Fires and possible scenarios for both these fires. Writing was very clear, and the bullet list of the different fires and scenarios was helpful. This reader was glad to see a distinction made between the long- and short-term health effects of fires.

- Table 8-1 and Section 8.3.2. The text states that concentration response (CR) functions for wildfire-specific PM_{2.5} were applied in the sensitivity studies, and the discussion of such functions in Chapter 6 is referenced. But there exist many such wildfire-specific CR functions, as Chapter 6 reports. The reader wonders which of these many CR functions were applied here.
- Section 8.2.6. This section introduces the concept of Value of a Statistical Life (VSL), and more information is provided in Section 8.3.1. Perhaps the authors would consider consolidating this text. Not all readers are familiar with VSL. Does VSL vary with age?
- Figure 8-1. A note about the meaning of the filled and open circles would be helpful.
- Table 8-6. The caption should make clear what is meant by “impacts.” It took this reader some time to realize that “impacts” referred to the sum of ER visits, hospital admissions, and deaths for each scenario – i.e., the sum of counts going across Table 8-2 for the actual fires and scenarios.
- Section 8.4. The impacts of the actual Rough Fire are large – 80 deaths due to long-term effects and \$3 billion in costs. The summary may want to quote these values in an effort to emphasize the huge cost of wildfires to human health and welfare.

Chapter 9. Chapter 9 consists of an integrated synthesis of the information presented within this report. Please comment on how well this chapter fully captures the breadth of this report. Are the various factors to consider in examining tradeoffs between the different fire management strategies adequately described? Does it appropriately highlight the strengths and limitations of the assessment, as well as key insights? Please explain.

Chapter 9 does a good job synthesizing information in this document, including a description of the approach taken and the results obtained. The rationale for the modeling approach is clearly laid out, and the background information on prescribed fires in the Timber Crater area is detailed. There is also

a nice summary of fire reduction efforts around Timber Crater. The limitations of the study and data gaps are well described.

The authors might consider including here a more quantitative description of the various impacts of the two fires. Those readers who cannot peruse every section will expect the summary to quantify some of the public health impacts reported in Chapter 8. For example, the public would likely be astonished to learn that the Rough fire may have led to as many as 80 deaths and \$3 billion in damages. The take home message that prescribed fires can substantially reduce morbidity and mortality from fires, especially in populated areas, should be more strongly emphasized.

- Section 9.2.2. As stated above, more quantitative information on the impacts of the Rough fire would be appreciated by readers. Page 9-9 states that the hypothetical scenario yields a 40% reduction in fire “impacts,” but these impacts are not defined. Is this meant as the sum of emergency visits, hospital admissions, and deaths? Also effective would be a statement of the number of lives saved in the smaller-fire scenario.
- Section 9.2.2. This section seems wordy and hastily written and so could be more carefully written.
- Page 9-9. The text states that fires occurred more frequently in the Sierra Nevada in the past relative to today. It would be helpful to know just how frequently such fires occurred.
- Page 9-10. The text states: “Impacts to air quality from these fires...” What is meant by “these fires”? Fires prior to 1900? In any event, the text further states that these fires would have been similar to the prescribed fires because they spread more slowly *and* because less fuel was available to burn. But isn’t the spread related to the fuel availability? Or is there another reason for the slow spread? Further down the page, the text states “...daily emissions were much lower compared to those during the Rim fire...” Again, are these daily emissions from the pre-1900 fires?
- Page 9-11. The text states: “In summary, in dry forest ecosystems, such as in the area of the Rough Fire, these landscapes will experience some combination of prescribed fire and wildfire.” This seems to be a weak conclusion, and the authors might consider strengthening the concluding remarks. The health impact of the Rough Fire is probably much larger than the public expects, and an emphasis on the benefits of prescribed fires for public health seems warranted.