CENTER for
BIOLOGICAL
DIVERSITY
Because life is good.

January 17, 2017

Via Internet Upload **(http://www.arb.ca.gov/lispub/comm/bclist.php)**

Clerk of the Board
Air Resources Board
1001 I Street
Sacramento, CA 95814

Re: *Revised Proposed* Short-Lived Climate Pollutant Reduction Strategy

To the California Air Resources Board:

The Center for Biological Diversity (the "Center") submits the following comments on the *Revised Proposed* Short-Lived Climate Pollutant Strategy (the "Revised Strategy") and accompanying Draft Environmental Analysis posted by the California Air Resources Board in November 2016.

The Center is a non-profit organization with more than one million members and online activists and offices throughout the United States, including in Oakland, Los Angeles, and Joshua Tree, California. The Center's mission is to ensure the preservation, protection and restoration of biodiversity, native species, ecosystems, public lands and waters and public health. In furtherance of these goals, the Center's Climate Law Institute seeks to reduce U.S. greenhouse gas emissions and other air pollution to protect biological diversity, the environment, and human health and welfare. Specific objectives include securing protections for species threatened by global warming, ensuring compliance with applicable law in order to reduce greenhouse gas emissions and other air pollution, and educating and mobilizing the public on global warming and air quality issues.

The Center greatly appreciates ARB's attention to the critical task of reducing short-lived climate super-pollutants like methane, black carbon, and HFCs (collectively "SLCPs"). The Center strongly supports the goal of seeking substantial reductions in anthropogenic SLCP emissions, and urges ARB to consider all options within the Strategy to increase the depth of reductions in each source and accelerate the rate of reduction or elimination of SLCP emissions.

The Center strongly supports the methane reduction measures detailed in the Revised Strategy and encourages ARB to pursue the greatest possible reductions for methane, especially from the oil and gas sector. The Center does not agree with ARB that using the outdated GWP estimate for methane is the only or best way to comply with UNFCCC reporting requirements.

Alaska . Arizona . California . Florida . Minnesota . Nevada . New Mexico . New York . Oregon . Vermont . Washington, DC

1212 Broadway, Suite 800 . Oakland, CA 94612 . *Phone:* 510-844-7100 . *Fax:* 510-844-7150

Revised Strategy at 42. However, the Center acknowledges that the use of the outdated AR4 GWP for methane does not necessarily have to undermine methane reduction efforts in California so long as the resulting understatement of the climatic impact of these emissions is broadly acknowledged and does not take away from the urgency to fully address anthropogenic methane emissions, and the accounting is rectified for purposes of the statewide emissions inventory.

The Center strongly supports ARB's decision to include only non-forest sources of black carbon in the Revised Strategy. The decision to remove forest management policies from the Revised Strategy obviates many of our previous comments on the Draft EA. However, the Revised Strategy includes several problematic statements and conclusions regarding forests and fire that raise concerns about ARB's proposed approach to forest ecosystems. The following comments relate to these points in the Revised Strategy.

I. The Revised Strategy mischaracterizes the state of the science regarding forest fire.

The Revised Strategy, like the previous draft, makes overly broad statements on the character of forests and fire with a level of certainty that is not supported by the scientific literature. Specifically, the Revised Strategy, at 7 and 46, asserts that "[in] general, forests are burning at increasing rates and at increasing levels of severity."

As explained in our previous comments, a key issue is whether and to what extent fire risk in California's forests is at unnatural or unusual levels and therefore should be reduced. The Revised Strategy provides only one citation for the assertion that forests are burning at increasing rates and increasing levels of severity: Hurteau et al. (2014). However, Hurteau et al. (2014) is a modeling study that projects how climate change, development, and population growth may affect wildfire emissions in the future; this study does not provide evidence that wildfire rates and severity have increased. As we demonstrated in detail in our previous comments, an extensive body of studies examining current effects of climate change on wildfire activity indicates that fire severity and amount have not increased in California's forests and that climate change effects on fire probability and area burned are very uncertain.

In fact, the best available science detailed below demonstrates that (1) wildfire is a natural and necessary component of California forests; California's mixed-conifer and ponderosa pine forests have been historically characterized by mixed-severity fire including significant amounts of high-severity fire; and high-severity fire creates biodiverse, ecologically important, and unique habitat; (2) California's forests are not burning at higher severity or amount, nor are the most fire-suppressed forests burning at higher severity; and (3) the projected effects of climate change on fire activity in California forests are highly uncertain.

Because the statement in the Revised Strategy does not encapsulate the best available science, fails to represent the full breadth, complexity, and uncertainty associated with this issue, and is largely out of place, we recommend striking these sentences from the Revised Strategy where they appear at 7 and 46: "In general, forests are burning at increasing rates and at increasing levels of severity. This trend raises concern over the long-term health of these forests and ability to sequester carbon and provide resource amenities."

A. Wildfire, including high-severity fire, is a natural and necessary component of California's forested landscapes.

Numerous studies and multiple lines of evidence demonstrate that California's mixed-conifer and ponderosa pine forests are characterized by mixed-severity fire that includes ecologically significant amounts of high-severity fire. Mixed-severity fire creates complex successional diversity, high biological diversity, and diverse stand structure across California's forested landscapes.

Baker 2014: A reconstruction of historical forest structure and fire across 330,000 ha of Sierra Nevada mixed-conifer forests using data from 1865-1885 demonstrates that these historical forests experienced mixed-severity fire over 43-48% of the land area, with high-severity fire over 31-39% and low-severity fire over just 13-26%. Historical forests were generally dense with abundant large trees, but numerically dominated by smaller pines and oaks. Smaller trees, understory seedlings, saplings and shrubs created abundant ladder fuels. The high-severity fire rotation was 281 years in the northern and 354 years in the southern Sierra, which contributed to high levels of heterogeneity, including abundant areas and large patches (up to 9,400 ha) of early successional forest and montane chaparral, as well as old-growth forest over large land areas. The author concludes that "[p]roposals to reduce fuels and fire severity would actually reduce, not restore, historical forest heterogeneity important to wildlife and resiliency."[1]

Beaty and Taylor 2001: On the western slope of the southern Cascades in California, historical fire intensity in mixed-conifer forests was predominantly moderate- and high-intensity, except in mesic canyon bottoms, where moderate- and high-intensity fire comprised 40.4% of fire effects [Table 7].)[2]

Bekker and Taylor 2001: On the western slope of the southern Cascades in California, in mixed-conifer forests, fire was predominantly high-intensity historically [Fig. 2F].[3]

Bekker and Taylor 2010: In mixed-conifer forests of the southern Cascades, reconstructed fire severity within the study area was dominated by high-severity fire effects, including high-severity fire patches over 2,000 acres in size [Tables I and II].[4]

---

[1] Baker, W.L. 2014. Historical forest structure and fire in Sierran mixed-conifer forests reconstructed from General Land Office survey data. Ecosphere 5(7): Article 79.
[2] Beaty, R.M. and A.H. Taylor. 2001. Spatial and temporal variation of fire regimes in a mixed conifer forest landscape, Southern Cascades, USA. Journal of Biogeography 28: 955–966.
[3] Bekker, M.F. and A.H. Taylor. 2001. Gradient analysis of fire regimes in montane forests of the southern Cascade Range, Thousand Lakes Wilderness, California, USA. Plant Ecology 155: 15-28.

Collins and Stephens 2010: In a modern "reference" forest condition within mixed-conifer/fir forests in Yosemite National Park, 15% of the area experienced high-intensity fire over a 33-year period—a high-intensity fire rotation interval of approximately 223 years.[5]

Halofsky et al. 2011: In the Klamath-Siskiyou Mountains of northwestern California and southwestern Oregon, a mixed-severity fire regime produces structurally diverse vegetation types with intimately mixed patches of varied age. The close mingling of early- and late-seral communities results in unique vegetation and wildlife responses, including high resilience of plant and wildlife species to mixed-severity fire.[6]

Hanson and Odion 2016: An assessment of US Forest Service forest survey data from 1910 and 1911 for central and southern Sierra Nevada ponderosa pine and mixed-conifer forests indicates that these historical forests had a mixed-severity fire regime, with an average of 26% high-severity fire effects. This study's findings are contrary to those of several other reports that use a very small subset of the available data from the 1910 and 1911 surveys, demonstrating the importance of analyzing data from sufficiently large spatial scales when drawing inferences about historical conditions.[7]

Nagel and Taylor 2005: The authors found that large high-severity fire patches were a natural part of 19th century fire regimes in mixed-conifer and eastside pine forests of the Lake Tahoe Basin, and montane chaparral created by high-severity fire has declined by 62% since the 19th century due to reduced high-severity fire occurrence. The authors expressed concern about harm to biodiversity due to loss of ecologically rich montane chaparral.[8]

Odion et al. 2014: In the largest and most comprehensive analysis conducted to date regarding the historical occurrence of high-intensity fire, the authors found that ponderosa pine and mixed-conifer forests in every region of western North America had mixed-intensity fire regimes, which included substantial occurrence of high-intensity fire. The authors also found, using multiple lines of evidence, including over a hundred historical sources and fire history reconstructions, and an extensive forest age-class analysis, that we now have unnaturally low

---

[4] Bekker, M.F. and A.H. Taylor. 2010. Fire disturbance, forest structure, and stand dynamics in montane forest of the southern Cascades, Thousand Lakes Wilderness, California, USA. Ecoscience 17: 59-72.

[5] Collins, B.M. and S.L. Stephens. 2010. Stand-replacing patches within a mixed severity fire regime: quantitative characterization using recent fires in a long-established natural fire area. Landscape Ecology 25: 927939.

[6] Halofsky, J. E., D.C. Donato, D.E. Hibbs, J.L. Campbell, M. Donaghy Cannon, J.B. Fontaine, J.R. Thompson, R.G. Anthony, B.T. Bormann, L.J. Kayes, B.E. Law, D.L. Peterson, and T.A. Spies. 2011. Mixed-severity fire regimes: lessons and hypotheses from the Klamath-Siskiyou Ecoregion. Ecosphere 2(4): art40.

[7] Hanson, C.T. and D.C. Odion. 2016. Historical fire conditions within the range of the Pacific fishers and spotted owl in the central and southern Sierra Nevada, California, USA. Natural Areas Journal 36: 8-19.

[8] Nagel, T.A. and A. H. Taylor. 2005. Fire and persistence of montane chaparral in mixed conifer forest landscapes in the northern Sierra Nevada, Lake Tahoe Basin, California,USA. J. Torrey Bot. Soc.132: 442-457.

levels of high-intensity fire in these forest types in all regions, since the beginning of fire suppression policies in the early 20th century.[9]

High-severity fire creates biodiverse, ecologically important, and unique habitat (often called "snag forest habitat"), which often has higher species richness and diversity than unburned old forest. Plant and animal species in the forest evolved with fire, and many of these species (such as the black-backed woodpecker[10]) depend on wildfires, and particularly high-severity fires, to reproduce and grow. Fire helps to return nutrients from plant matter back to soil, the heat from fire is necessary to the germination of certain types of seeds, and the snags (dead trees) and early successional forests created by high-severity fire create habitat conditions that are beneficial to wildlife. Early successional forests created by high-severity fire support some of the highest levels of native biodiversity found in temperate conifer forests.

Bond et al. 2009: In a radio-telemetry study, California spotted owls preferentially selected high-intensity fire areas, which had not been salvage logged, for foraging, while selecting low- and moderate-intensity areas for nesting and roosting.[11]

Buchalski et al. 2013: In mixed-conifer forests of the southern Sierra Nevada, rare myotis bats were found at greater levels in unmanaged high-severity fire areas of the McNally fire than in lower fire severity areas or unburned forest.[12]

Burnett et al. 2010: Bird species richness was approximately the same between high-severity fire areas and unburned mature/old forest at 8 years post-fire in the Storrie fire, and total bird abundance was greatest in the high-severity fire areas of the Storrie fire [Figure 4]. Nest

---

[9] Odion, D.C., C.T. Hanson, A. Arsenault, W.L. Baker, D.A. DellaSala, R.L. Hutto, W. Klenner, M.A. Moritz, R.L. Sherriff, T.T. Veblen, and M.A. Williams. 2014. Examining historical and current mixed-severity fire regimes in Ponderosa pine and mixed-conifer forests of western North America. Plos One 9(2): e87852. *See also* response and rebuttal: Odion D.C., C.T. Hanson, W.L. Baker, D.A. DellaSala, and M.A. Williams. 2016. Areas of agreement and disagreement regarding ponderosa pine and mixed conifer forest fire regimes: a dialogue with Stevens et al. PLoS ONE 11(5): e0154579; Stevens J.T. et al. 2016. Average stand age from forest inventory plots does not describe historical fire regimes in ponderosa pine and mixed-conifer forests of western North America. PLoS ONE 11(5): e0147688.

[10] Seavy, N.E., R.D. Burnett, and P.J. Taille. 2012. Black-backed woodpecker nest tree preference in the burned forests of the Sierra Nevada, California. Wildlife Society Bulletin 36: 722-728; Tingely, M.W., R.L. Wilkerson, M.L. Bond, C.A. Howell, and R.B. Siegel. 2014. Variation in home-range size of black-backed woodpeckers. The Condor 116: 325-340.

[11] Bond, M.L., D.E. Lee, R.B. Siegel, and J.P. Ward, Jr. 2009. Habitat use and selection by California Spotted Owls in a postfire landscape. Journal of Wildlife Management 73: 1116-1124.

[12] Buchalski, M.R., J.B. Fontaine, P.A. Heady III, J.P. Hayes, and W.F. Frick. 2013. Bat response to differing fire severity in mixed-conifer forest, California, USA. PLOS ONE 8: e57884.

density of cavity-nesting species increased with higher proportions of high-severity fire, and was highest at 100% [Figure 8].[13]

Cocking et al. 2014: High-intensity fire areas are vitally important to maintain and restore black oaks in mixed-conifer forests.[14]

DellaSala et al. 2014: Complex early seral forests in the Sierra Nevada of California, which are produced by mixed-severity fire including large high severity patches, support diverse plant and wildlife communities that are essential to the region's ecological integrity. Fire suppression and biomass removal after fire reduce structural complexity, diversity, and resilience in the face of climate change.[15]

Donato et al. 2009: The high-severity re-burn [high-severity fire occurring 15 years after a previous high-severity fire] had the highest plant species richness and total plant cover, relative to high-severity fire alone [no re-burn] and unburned mature/old forest; and the high-severity fire re-burn area had over 1,000 seedlings/saplings per hectare of natural conifer regeneration.[16]

Franklin et al. 2000: The authors found that stable or increasing populations of spotted owls resulted from a mix of dense old forest and complex early seral habitat, and less than approximately 25% complex early seral habitat in the home range was associated with declining populations [Fig. 10]; the authors emphasized that the complex early seral habitat was consistent with high-intensity fire effects, and inconsistent with clearcut logging.[17]

Hanson and North 2008: Black-backed woodpeckers depend upon dense, mature/old forest that has recently experienced higher-intensity fire, and has not been salvage logged.[18]

Hanson 2013: Pacific fishers use pre-fire mature/old forest that experienced moderate/high-intensity fire more than expected based upon availability, just as fishers are selecting dense, mature/old forest in its unburned state. When fishers are near fire perimeters, they strongly

---

[13] Burnett, R.D., P. Taillie, and N. Seavy. 2010. Plumas Lassen Study 2009 Annual Report. U.S. Forest Service, Pacific Southwest Region, Vallejo, CA.

[14] Cocking M.I., J.M. Varner JM, and E.E. Knapp. 2014. Long-term effects of fire severity on oak-conifer dynamics in the southern Cascades. Ecological Applications 24: 94-107.

[15] DellaSala, D., M.L. Bond, C.T. Hanson, R.L. Hutto, and D.C. Odion. 2014. Complex early seral forests of the Sierra Nevada: what are they and how can they be managed for ecological integrity? Natural Areas Journal 34: 310-324.

[16] Donato, D.C., J.B. Fontaine, W.D. Robinson, J.B. Kauffman, and B.E. Law. 2009. Vegetation response to a short interval between high-severity wildfires in a mixed-evergreen forest. Journal of Ecology 97:142-154.

[17] Franklin, A.B., D.R. Anderson, R.J. Gutierrez, and K.P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California.Ecological Monographs 70: 539-590.

[18] Hanson, C. T. and M. P. North. 2008. Postfire woodpecker foraging in salvage-logged and unlogged forests of the Sierra Nevada. Condor 110: 777–782.

select the burned side of the fire edge. Both males and female fishers are using large mixed-intensity fire areas, such as the McNally fire, including several kilometers into the fire area.[19]

Hanson 2015: Pacific fisher females in the Sierra Nevada use unlogged higher severity fire areas, including very large high-severity patches. In the McNally fire area at 10 to 11 years postfire, female fishers used the large, intense fire area significantly more than unburned forest, and females were detected at multiple locations >250m into the interior of a very large (>5,000 ha), unlogged higher severity fire patch. The author concludes that these results "suggest a need to revisit current management direction, which emphasizes extensive commercial thinning and postfire logging to reduce fuels and control fire."[20]

Hutto 1995: A study in the northern Rocky Mountain region found that 15 bird species are generally more abundant in early post-fire communities than in any other major cover type occurring in the northern Rockies. Standing, fire-killed trees provided nest sites for nearly two-thirds of 31 species that were found nesting in the burned sites.[21]

Hutto 2008: Severely burned forest conditions have occurred naturally across a broad range of forest types for millennia and provide an important ecological backdrop for fire specialists like the black-backed woodpecker.[22]

Hutto et al. 2016: This review highlights that high severity fire was historically common in western conifer forests and is ecologically essential. Many animal and plant species depend on severely burned forests for persistence. The researchers recommend a "more ecologically informed view" of severe forest fire, including changes in management and education to maintain ecologically necessary levels of severe fire and the complex early-seral forest conditions it creates.[23]

Lee and Bond 2015: California spotted owls exhibited high site occupancy in post-fire landscapes during the breeding season following the 2013 Rim Fire, even where large areas burned at high severity; the complex early seral forests created by high-severity fire appear to provide important habitat for the small mammal prey of the owl.[24]

---

[19] Hanson, C.T. 2013. Pacific fisher habitat use of a heterogeneous post-fire and unburned landscape in the southern Sierra Nevada, California, USA. The Open Forest Science Journal 6: 24-30.
[20] Hanson, C.T. 2015. Uses of higher severity fire areas by female Pacific fishers on the Kern Plateau, Sierra Nevada, California, USA. Wildlife Society Bulletin 39: 497-502.
[21] Hutto, R. L. 1995. Composition of bird communities following stand-replacement fires in Northern Rocky Mountain (U.S.A.) conifer forests. Conservation Biology 9: 1041–1058.
[22] Hutto, R. L. 2008. The ecological importance of severe wildfires: Some like it hot. Ecological Applications 18: 1827–1834.
[23] Hutto, R.L., R.E. Keane, R.L. Sherriff, C.T. Rota, L.A. Eby, and V.A. Saab. 2016. Toward a more ecologically informed view of severe forest fires. Ecosphere 7(2):e01255.
[24] Lee, D.E. and M.L. Bond. 2015. Occupancy of California spotted owl sites following a large fire in the Sierra Nevada, California. The Condor 117: 228-236.

Malison and Baxter 2010: In ponderosa pine and Douglas-fir forests of Idaho at 5-10 years post-fire, levels of aquatic insects emerging from streams were two and a half times greater in high-intensity fire areas than in unburned mature/old forest, and bats were nearly 5 times more abundant in riparian areas with high-intensity fire than in unburned mature/old forest.[25]

Ponisio et al. 2016: A study of plant–pollinator communities in mixed-conifer forest in Yosemite National Park found that pyrodiversity (the diversity of fires within a region) increases the richness of the pollinators, flowering plants, and plant-pollinator interactions, and buffers pollinator communities against the effects of drought-induced floral resource scarcity. The authors conclude that lower fire diversity is likely to negatively affect the richness of plant–pollinator communities across large spatial scales. [26]

Raphael et al. 1987: At 25 years after high-intensity fire, total bird abundance was slightly higher in snag forest than in unburned old forest in eastside mixed-conifer forest of the northern Sierra Nevada; and bird species richness was 40% higher in snag forest habitat. In earlier post- fire years, woodpeckers were more abundant in snag forest, but were similar to unburned by 25 years post-fire, while flycatchers and species associated with shrubs continued to increase to 25 years post-fire.[27]

Sestrich et al. 2011: Native bull and cutthroat trout tended to increase with higher fire intensity, particularly where debris flows occurred. Nonnative brook trout did not increase.[28]

Siegel et al. 2011: Many more species occur at high burn severity sites starting several years post-fire, and these include the majority of ground and shrub nesters as well as many cavity nesters. Secondary cavity nesters, such as swallows, bluebirds, and wrens, are particularly associated with severe burns, but only after nest cavities have been created, presumably by the pioneering cavity excavating species such as the black-backed woodpecker. As a result, fires that create preferred conditions for black-backed woodpeckers in the early post-fire years will likely result in increased nesting sites for secondary cavity nesters in successive years.[29]

---

[25] Malison, R.L. and C.V. Baxter. 2010. The fire pulse: wildfire stimulates flux of aquatic prey to terrestrial habitats driving increases in riparian consumers. Canadian Journal of Fisheries and Aquatic Sciences 67: 570-579.

[26] Ponisio, L.C., K. Wilken, L.M. Gonigle, K. Kulhanek, L. Cook, R. Thorp, T. Griswold, and C. Kremen. 2016. Pyrodiversity begets plant-pollinator community diversity. Global Change Biology 22: 1794-1808.

[27] Raphael, M.G., M.L. Morrison, and M.P. Yoder-Williams. 1987. Breeding bird populations during twenty-five years of postfire succession in the Sierra Nevada. The Condor 89: 614-626.

[28] Sestrich, C.M., T.E. McMahon, and M.K. Young. 2011. Influence of fire on native and nonnative salmonid populations and habitat in a western Montana basin. Transactions of the American Fisheries Society 140: 136-146.

[29] Siegel, R.B., M.W. Tingley, and R.L. Wilkerson. 2011. Black-backed Woodpecker MIS surveys on Sierra Nevada national forests: 2010 Annual Report. A report in fulfillment of U.S. Forest Service Agreement No. 08-CS-11052005-201, Modification #2; U.S. Forest Service Pacific Southwest Region, Vallejo, CA.

Swanson et al. 2010: A literature review concluding that some of the highest levels of native biodiversity found in temperate conifer forest types occur in complex early successional habitat created by stand-initiating [high severity] fire.[30]

B. Scientific studies are finding no significant trends in wildfire risk.

Scientific evidence does not indicate that wildfire risk is at unnatural levels in California's forests and therefore must be reduced. Notably, the majority of studies that have analyzed recent trends in fire severity and area burned in California forests have found no significant trends in these metrics. Studies have also consistently found that forest areas in California that have missed the largest number of fire return intervals are not burning at higher fire severity.

1. California forests are not experiencing an increase in fire severity or burned area.

Eleven studies have analyzed recent trends in fire severity in California's forests in terms of proportion, area, and/or patch size. Nine of eleven studies found no significant trend in fire severity, including: Baker 2015 (California dry pine and mixed conifer forests), Collins et al. 2009 (central Sierra Nevada), Dillon et al. 2011 (Northwest California), Hanson et al. 2009 (Klamath, southern Cascades), Hanson and Odion 2014 (Sierra Nevada, southern Cascades), Miller et al. 2012 (four Northwest CA forests), Odion et al. 2014 (eastern and western Sierra Nevada, eastern Cascades), Picotte et al. 2016 (California forest and woodland), and Schwind 2008 (California forests).[31] The two studies that report an increasing trend in fire severity—

[30] Swanson, M.E., J.F. Franklin, R.L. Beschta, C.M. Crisafulli, D.A. DellaSala, R.L. Hutto, D. Lindenmayer, and F.J. Swanson. 2010. The forgotten stage of forest succession: early- successional ecosystems on forest sites. Frontiers Ecology & Environment 9: 117-125.

[31] Baker, W.L. 2015. Are high-severity fires burning at much higher rates recently than historically in dry-forest landscapes of the Western USA? PLoS ONE 10(9): e0136147; Collins, B.M., J.D. Miller, A.E. Thode, M. Kelly, J.W. van Wagtendonk, and S.L. Stephens. 2009. Interactions among wildland fires in a long-established Sierra Nevada natural fire area. Ecosystems 12:114–128; Dillon, G.K., et al. 2011. Both topography and climate affected forest and woodland burn severity in two regions of the western US, 1984 to 2006. Ecosphere 2: Article 130; Hanson, C.T., D.C. Odion, D.A. DellaSala, and W.L. Baker. 2009. Overestimation of fire risk in the Northern Spotted Owl Recovery Plan. Conservation Biology 23:1314–1319; Hanson, C.T., and D.C. Odion. 2014. Is fire severity increasing in the Sierra Nevada mountains, California, USA? International Journal of Wildland Fire 23: 1-8; Miller, J.D., C.N. Skinner, H.D. Safford, E.E. Knapp, and C.M. Ramirez. 2012. Trends and causes of severity, size, and number of fires in northwestern California, USA. Ecological Applications 22: 184-203; Odion, D.C. et al. 2014; Picotte, J.J., B. Peterson, G. Meier, and S.M. Howard. 2016. 1984-2010 trends in fire burn severity and area for the coterminous US. International Journal of Wildland Fire 25: 413-420; Schwind, B. 2008. Monitoring trends in burn severity: report on the Pacific Northwest and Pacific Southwest fires (1984 to 2005). USGS.

Miller et al. 2009 and Miller and Safford 2012 (Sierra Nevada, southern Cascades)[32]—were refuted by Hanson and Odion (2014) using a larger dataset.

Of note, Baker (2015) found that the rate of recent (1984–2012) high-severity fire in dry pine and mixed conifer forests in California is within the range of historical rates, or is too low. There were no significant upward trends from 1984–2012 for area burned and fraction burned at high severity. The author concluded that "[p]rograms to generally reduce fire severity in dry forests are not supported and have significant adverse ecological impacts, including reducing habitat for native species dependent on early-successional burned patches and decreasing landscape heterogeneity that confers resilience to climatic change."

Hanson and Odion (2014) conducted the first comprehensive assessment of fire intensity since 1984 in the Sierra Nevada using 100% of available fire intensity data, and found no increasing trend in terms of high-intensity fire proportion, area, mean patch size, or maximum patch size. Hanson and Odion (2014) reviewed the approach of Miller et al. (2009) and Miller and Safford (2012) for bias, due to the use of vegetation layers that post-date the fires being analyzed in those studies. Hanson and Odion (2014) found that there is a statistically significant bias in both studies ($p = 0.025$ and $p = 0.021$, respectively), the effect of which is to exclude relatively more conifer forest experiencing high-intensity fire in the earlier years of the time series, thus creating the erroneous appearance of an increasing trend in fire severity. Hanson and Odion (2014) also found that the regional fire severity data set used by Miller et al. (2009) and Miller and Safford (2012) disproportionately excluded fires in the earlier years of the time series, relative to the standard national fire severity data set (www.mtbs.gov) used in other fire severity trend studies, resulting in an additional bias which created, once again, the inaccurate appearance of relatively less high-severity fire in the earlier years, and relatively more in more recent years.

In studies of area burned, Dennison et al. (2014) found no significant increase in annual fire area in the Sierra Nevada/Klamath/Cascades forest ecoregion in California during the 1984-2011 study period, nor a significant trend toward an earlier fire season in this or any other western ecoregion.[33] Similarly, Dillon et al. (2011) detected no trends in annual area burned in the two ecoregions that occurred in part in northern California (Pacific, Inland Northwest) during the 1984-2006 study period.[34]

---

[32] Miller, J.D., H.D. Safford, M.A. Crimmins, and A.E. Thode. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. Ecosystems 12:16–32; Miller, J.D. and H. Safford. 2012. Trends in wildfire severity: 1984-2010 in the Sierra Nevada, Modoc Plateau, and southern Cascades, California, USA. Fire Ecology 8(2): 41-57.
[33] Dennison, P.E., Brewer, S.C., Arnold, J.D., and M.A. Moritz. 2014. Large wildfire trends in the western United States, 1984-2011. Geophysical Research Letters 41: 2928–2933.
[34] Dillon, G.K., et al. 2011.

2. The most fire-suppressed forests are not burning at higher fire severity.

Studies empirically investigating the assumption that the most fire-suppressed forests are burning predominantly at high severity have consistently found that forest areas in California that have missed the largest number of fire return intervals are not burning at higher fire severity. Specifically, six empirical studies that have investigated this question found that the most long-unburned (most fire-suppressed) forests burned mostly at low/moderate-severity, and did not have higher proportions of high-severity fire than less fire-suppressed forests. Forests that were not fire suppressed (those that had not missed fire cycles, i.e., Condition Class 1, or "Fire Return Interval Departure" class 1) generally had levels of high-severity fire similar to, or higher than, those in the most fire-suppressed forests, as found by Odion et al. 2004, Odion and Hanson 2006, Odion and Hanson 2008, Odion et al. 2010, Miller et al. 2012, and van Wagtendonk et al. 2012.[35]

C. The projected impacts of climate change on wildfire activity in California are uncertain.

While climate change will almost certainly alter fire activity in many California ecosystems, scientific research does not indicate that climate change will increase fire severity nor necessarily increase fire amount in California forests. As described above, the majority of studies that have analyzed recent wildfire trends in California forests have found no significant trends in these metrics. Studies that project trends in fire activity under climate change scenarios indicate that fire severity in California forests is likely to decrease or stay the same, and projection studies show no consensus on how climate change is likely to affect fire probability or area burned in California forests, as detailed below.

Notably, a recent study by Parks et al. (2016) projected that most areas of the western US, including California's forested areas, will experience decreases or no change in fire severity by mid-century (2040-2069) under the highest-emission RCP 8.5 scenario used in global climate

[35] Odion, D.C., E.J. Frost, J.R. Strittholt, H. Jiang, D.A. DellaSala, and M.A. Moritz. 2004. Patterns of fire severity and forest conditions in the Klamath Mountains, northwestern California. Conservation Biology 18: 927-936; Odion, D.C., and C.T. Hanson. 2006. Fire severity in conifer forests of the Sierra Nevada, California. Ecosystems 9: 1177-1189; Odion, D.C., and C.T. Hanson. 2008. Fire severity in the Sierra Nevada revisited: conclusions robust to further analysis. Ecosystems 11: 12-15; Odion, D. C., M. A. Moritz, and D. A. DellaSala. 2010. Alternative community states maintained by fire in the Klamath Mountains, USA. Journal of Ecology; Miller, J.D., C.N. Skinner, H.D. Safford, E.E. Knapp, and C.M. Ramirez. 2012. Trends and causes of severity, size, and number of fires in northwestern California, USA. Ecological Applications 22:184-203; van Wagtendonk, J.W., K.A. van Wagtendonk, and A.E. Thode. 2012. Factors associated with the severity of intersecting fires in Yosemite National Park, California, USA. Fire Ecology 8: 11-32.

models.[36] Three studies that have projected changes in the probability of burning or the probability of a large fire occurring show no consensus, with projections for no change, increases, or decreases in fire varying by region: Krawchuk and Moritz 2012, Moritz et al. 2012, and Westerling and Bryant 2008.[37]

Studies that have projected trends in area burned in California forests under climate change show no consensus. Four studies project both increases and decreases in total area burned depending on the region: Lenihan et al. 2003, Lenihan et al. 2008, Krawchuk et al. 2009, and Spracklen et al. 2009.[38] One study projected an overall decrease in area burned (McKenzie et al. 2004), while two studies projected increases (Fried et al. 2004 in a small region in the Amador-El Dorado Sierra foothills; Westerling et al. 2011).[39] The projected increases in Westerling et al. (2011) are relatively modest, with median increases in area burned of 21% and 23% by 2050, and 20% and 44% by 2085, relative to 1961-1990 under lower (B1) and higher (A2) emissions scenarios respectively. Given that the average annual burned area in California in the past several decades was many times lower than the burned area historically, these projected increases in fire activity in California would likely remain well within the historical range of the past several centuries.

As reviewed in Whitlock et al. (2015), wildfire projection studies involve numerous uncertainties which create significant variation in study results, including significant

---

[36] Parks, S.A., C. Miller, J.T. Abatzoglou, L.M. Holsinger, M-A. Parisien, and S. Dobrowski. 2016. How will climate change affect wildland fire severity in the western US? Environmental Research Letters 11: 035002.
[37] Krawchuk, M. A., and M. A. Moritz. 2012. Fire and Climate Change in California. California Energy Commission. Publication number: CEC-500-2012-026; Moritz, M., Parisien, M., Batllori, E., Krawchuk. M., Van Dorn, J., Ganz, D., & Hayhoe, K. 2012. Climate change and disruptions to global fire activity. Ecosphere 3 (6): 1-22; Westerling, A. and B. Bryant. 2008. Climate change and wildfire in California. Climate Change 87: S231– S249.
[38] Lenihan, J.M., Drapek, R.J., Bachelet, D., and Neilson, R.P. 2003. Climate change effects on vegetation distribution, carbon, and fire in California. Ecological Applications 13: 1667-1681;
Lenihan, J.M., D. Bachelet, R.P. Neilson, and R. Drapek. 2008. Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California. Climate Change 87(Suppl. 1): S215-S230; Krawchuk, M.A., M.A. Moritz, M. Parisien, J. Van Dorn, K. Hayhoe. 2009. Global pyrogeography: the current and future distribution of wildfire. PloS ONE 4: e5102; Spracklen, D.V., L.J. Mickley, J.A. Logan, R.C. Hudman, R. Yevich, M.D. Flannigan, A.L. Westerling. 2009. Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States. Journal of Geophysical Research 114: D20301.
[39] McKenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. Conservation Biology 18: 890-902; Fried, J. S., M. S. Torn, and E. Mills. 2004. The impact of climate change on wildfire severity: A regional forecast for northern California. Climatic Change 64 (1–2):169–191; Westerling, A.L., B. P. Bryant, H.K. Preisler, T.P. Holmes, H.G. Hidalgo, T. Das. And S.R. Shrestha. 2011. Climate change and growth scenarios for California wildfire. Climatic Change 109 (Suppl 1): S445-S463.

uncertainties in future changes in precipitation timing and amount in the western US, which are important factors affecting wildfire activity. According to Whitlock et al. (2015), observed and projected changes in wildfire activity must be understood in terms of (1) fire's ecological benefits, (2) the current fire deficit in most forested regions of North America, and (3) a sufficiently long baseline to capture the historical range of fire variability within the particular ecosystem. Detecting and interpreting the significance of climate-driven fire patterns requires information on the magnitude and direction of change in comparison to the long-term fire occurrence within the ecosystem as well as the relative influences of climatic and non-climatic drivers that affect fire activity (i.e., invasion of nonnative plants, introduction of nonnative grazers, land-use change, and changes in forest management practices).[40]

II. The Proposed Strategy understates the uncertainty and variation associated with black carbon emissions from forest fire.

The Revised Strategy rightfully acknowledges the uncertainties associated with estimating the climate impacts of emissions associated with forest fires. However, the proposed estimate of 86.7 $MMTCO_2e$ for black carbon emissions from wildfire (Revised Strategy at 46) provides a comparison to other emission sources, without providing a metric of either the uncertainty or the possible range of values.

Furthermore, the reference to the uncertainty and variation associated with emissions from forest fires (Revised Strategy at 46) fails to present the full depth of uncertainty associated with this emissions source.[41] If ARB feels it is necessary to provide an estimate for the GWP for black carbon emissions from forest fires, we recommend revising this table to present the estimate as a range of values based on annual variability, variations in emissions due to forest and fire characteristics, and the uncertainties associated with quantification of climate effects.

As noted in our previous comments, the estimation of black carbon from wildfires is notoriously difficult and fraught with uncertainty. Not only does the extent of wildfire vary widely from year to year, but also the factors influencing black carbon emissions are highly condition-dependent and time-variable.

Unlike other sources of black carbon, wildfire emissions are not amenable to reasonable estimation using current data and methods. ARB uses a "speciation" model to create its black carbon inventory. This means that black carbon emissions from each source are assumed to be a

---

[40] Whitlock, C., D.A. DellaSala, S. Wolf, and C.T. Hanson. 2015. Climate Change: Uncertainties, Shifting Baselines, and Fire Management. Pp. 265-289 in The Ecological Importance of Mixed Severity Fires: Nature's Phoenix. D.A. DellaSala and C.T. Hanson, eds. Elsevier, Amsterdam, Netherlands.

[41] "Emissions from fires in forests and other lands vary dramatically from year to year, and these inventories contain higher uncertainty than the anthropogenic sources in Figure 1." Revised Strategy at 46.

percentage of total PM2.5 emissions for that source, with the percentage of black carbon based on observational data. For wildfire, total PM2.5 is derived from a model that includes parameters such as the geographic extent of wildfire, fuel type and estimated moisture content, and fire phase (flaming or smoldering).[42]

Wildfire presents several challenges that undermine the accuracy of ARB's speciation approach. The first challenge is that the black carbon portion of PM2.5 can be difficult to estimate because estimates of emissions from biomass burning are highly uncertain. This is a result of the many factors that contribute to emissions, including but not limited to the mix of fuels, mass of fuel, moisture content, temperature of the fire, incline and wind direction, and duration of the fire. This results in estimates of black carbon in PM2.5 that range over two orders of magnitude, as noted by ARB.[43] Nonetheless, the ARB inventory assumes a single value for the proportion of black carbon in PM2.5 of 0.2 (20 percent).[44] Notably, this is more than double EPA's national speciation value for wildfire, which is 0.095 (9.5 percent).[45]

The Technical Support Document (TSD) for ARB's black carbon inventory indicates that the speciation value of 0.2 was selected as a median value from the literature, but the studies that ARB relies on for its speciation value indicate the highly variable nature of biomass black carbon emissions, even in the controlled conditions of a laboratory. Only a handful of burns are completed for each sample, and the variability between samples under the same conditions can be extremely high.[46]

Speciation values are typically derived by burning fuels in a laboratory and measuring resulting emissions, although lab conditions cannot "fully anticipate or reproduce the complex real-world fires."[47] Where downwind samples were taken from prescribed burns, the black

---

[42] Cal. Air Resources Board, California's Black Carbon Inventory: Technical Support Document 8 (2015) (hereinafter "TSD") *available at* http://www.arb.ca.gov/cc/inventory/slcp/doc/bc_inventory_tsd_20160411.pdf (visited May 25, 2016).

[43] TSD at 9.

[44] The TSD cites a number of studies that are presumed to reflect California's typical wildfire fuel mix, but at least one study by McMeeking et al. that included a similar fuel mix – and coincidentally observed much lower black carbon proportions – was omitted. *See* G.R. McMeeking et al., *Emissions of trace gases and aerosols during the open combustion of biomass in the laboratory*, 114 JOURNAL OF GEOPHYSICAL RESEARCH D19210 (2009)(average for Montane mix was 1.4% BC).

[45] EPA SPECIATE profile for wildfire, *available at* https://cfpub.epa.gov/si/speciate/ehpa_speciate_browse_details.cfm?ptype=PC&pnumber=91102.

[46] See L.-W.A. Chen et al., *Moisture effects on carbon and nitrogen emission from burning of wildland biomass*, 10 ATMOS. CHEM. PHYS. 1, Table 1 (2010).

[47] L.-W.A. Chen et al., *Emissions from Laboratory Combustion of Wildland Fuels: Emission Factors and Source Profiles*, 41 ENVIRON. SCI. TECHNOL. 4317, 4317 (2007); *see also* T.C. Bond et al., *Bounding the role of black carbon in the climate system: A scientific assessment*, 118 JOURNAL OF GEOPHYSICAL RESEARCH 5380, 5419 (2013).

carbon concentrations were significantly lower.[48] Moreover, Turn et al. expressly noted that their laboratory burns were in relatively windless conditions that would simulate prescribed burns, but not wildfire conditions.[49]

One of the determinants of the emission profile is combustion efficiency. A number of studies have analyzed combustion efficiency, including conditions in which it is increased or decreased. It appears that greater combustion efficiency (more carbon converted to CO_2) is associated with lower organic carbon and PM2.5 emissions, while black carbon may be slightly elevated at high combustion efficiency. There are a number of factors that contribute to combustion efficiency, many of which are difficult to predict for wildfire. Fuel type is one determinant of combustion efficiency.[50] Another influence is moisture content, which may naturally vary with conditions.[51] Generally, higher moisture burns are associated with increased PM2.5 and organic carbon emissions, reducing the relative contribution of black carbon.[52] The mass of fuel being combusted can also alter combustion efficiency,[53] which is particularly problematic when translating laboratory emission factors to large scale wildfire.

The second challenge is that PM2.5 and black carbon emissions have different dependencies on phase of burning. Several studies have found that there is an inverse relationship between the mass of PM2.5 and black carbon emissions at different phases of the fire. During the brief duration of the flaming phase, PM2.5 is relatively low while black carbon emissions are elevated. In contrast, smoldering is associated with much higher total PM2.5, but similar or lower black carbon emissions.[54] A similar disjunction between PM2.5 mass and black carbon mass was observed by Mazzoleni et al. 2007 when examining the effect of fuel type and incline (and consequently speed of the fire).[55] Depending on how PM2.5 emissions progress in ARB's model, spurious results may occur if a high percentage of black carbon is assumed for all phases rather than just the flaming phase, when total PM2.5 is actually low.[56]

In sum, the data needed to make accurate estimates of black carbon emissions from wildfire are sorely lacking. The current speciation value selected by ARB is not adequately

---

[48] See L.R. Mazzoleni et al., *Emissions of Levoglucosan, Methoxy Phenols, and Organic Acids from Prescribed Burns, Laboratory Combustion of Wildland Fuels, and Residential Wood Combustion*, 41 ENVIRON. SCI. TECHNOL. 2115, Table 1 (2007).
[49] S.Q. Turn et al., *Elemental characterization of particulate matter emitted from biomass burning: Wind tunnel derived source profiles for herbaceous and wood fuels*, 102 JOURNAL OF GEOPHYSICAL RESEARCH, 3683, 3687 (1997).
[50] McMeeking 2009 at 8.
[51] Chen 2010.
[52] *Id.* at Table 1.
[53] McMeeking 2009 at 8.
[54] Bond 2013 at 5419; *See also* Chen 2010; Chen 2007.
[55] Mazzoleni 2007 at 2117.
[56] Bond 2013 at 5408.

supportable as the basis for the emissions estimates and comparisons in the Revised Strategy, much less for a state-wide mitigation policy. Not only are the speciation values themselves in question, but the time dependence and inverse trends in black carbon as opposed to PM2.5 over fire phases further complicate matters to the point that ARB's estimates of wildfire black carbon are entirely unsupportable.

Furthermore, in contrast to fossil fuel soot, wildfire black carbon is a much lower proportion of total aerosol emissions. Therefore, mitigation policies must examine the potential climate impacts of the co-emitted particles that include, for instance, various elements, organic carbon, and nitrogen. Some of these co-emitted aerosols exert a cooling effect.[57] At one time it was assumed that all organic carbon exerted a cooling influence. It is now accepted that while black carbon is highly absorbing (hence warming), some portion of organic carbon (brown carbon) is also absorbing to a lesser degree.[58] Various studies have attempted to quantify the effects of absorption by brown carbon, and the current consensus appears to be that the direct cooling effects of non-carbon aerosols may approximately offset brown carbon forcings from biomass burning.[59] But this is an area of active investigation with a large number of remaining uncertainties.

It should be noted that the general conclusion that brown carbon may offset cooling impacts is largely related to agricultural burning and residential cooking and heating stoves. Thus, it is not clear what impact wildfire with its unique combustion qualities would have. A recent study that presented the most comprehensive global black carbon inventory to date noted that because the net forcing from *all* black carbon sources is slightly negative, or cooling, the "uniform elimination of all emissions from black-carbon-rich sources could lead to no change in climate warming."[60] That study indicated that the best potential targets were diesel emissions and potentially residential solid fuel.[61] With regard to wildfire, Bond and colleagues estimate that the total climate forcing for open biomass burning of forests is negative or near zero.[62] Thus, mitigation efforts related to wildfire are not guaranteed to have substantial, if any, net climate benefits.

---

[57] Some portion of organic carbon is light scattering and cooling. In addition, some reactive nitrogen species from combustion can be cooling. R.W. Pinder et al., *Climate change impacts of US reactive nitrogen*, 109 PROC. NATL. ACAD .SCI. 7671 (2012). See Chen 2010 for a discussion of nitrogen species in biomass burning smoke.
[58] *See, e.g.*, C.E. Chung et al., *Observationally constrained estimates of carbonaceous aerosol radiative forcing*, 109 PROC. NATL. ACAD .SCI. 11624 (2012).
[59] *Id.*
[60] Bond 2013 at 5388.
[61] *Id.*
[62] *Id.* at 5504. Although Bond et al. did not expressly include brown carbon, the method used to estimate black carbon emissions likely included brown carbon as a portion of the mass, such that brown carbon effects would be implicitly included. Bond et al. also considered cloud indirect effects in estimating total black carbon forcing.

One of the looming uncertainties related to climate impacts from black carbon relates to indirect cloud impacts. Bond and colleagues reviewed the literature on this topic and estimated that forest burning likely has a net negative climate forcing (cooling), although there is very large uncertainty. Jacobson also recently modeled climate impacts of black carbon using a model that incorporates detailed cloud interactions.[63] His results suggest a warming effect, but the results have not been replicated and he points to large uncertainties as well. Furthermore, Jacobson's recent cloud-interaction model estimates that only 7 percent of the biomass burning in his model was from natural sources such as wildfire.[64] Thus, those results may not be applicable to the specific emissions associated with wildfire. Finally, Kodros et al. recently reviewed the uncertainties in estimates of biofuel aerosol direct forcing and cloud-albedo indirect effects. Notably this study only looked at domestic biofuel combustion, and thus is not directly comparable to wildfire emissions. Nonetheless, the authors concluded that the uncertainties in effects and parameters were so large that it was not clear on a global scale whether the effects were positive (warming) or negative (cooling).[65] Furthermore, the authors pointed out that estimates of effects were highly dependent on background pollution levels for a given region.[66]

Taken together, it is clear that co-emitted aerosols can drastically alter the climate impacts of wildfire black carbon. The science is evolving rapidly, but at this point the uncertainties are too large to make any concrete predictions of overall climate impact. Given these uncertainties, black carbon mitigation strategies that rely on attempts to reduce wildfire emissions lack scientific support and may be counterproductive to climate goals.

III. Forest carbon policy must consider the climate effects of forest thinning projects.

The Revised Strategy cites a number of publications to support the statement that forest thinning projects have resulted in net benefits with respect to fuel loads and fire management objectives.[67] Revised Strategy at 46. However, this statement and these studies largely do not address the point most relevant to the Revised Strategy, as well as to the Forest Carbon Plan and the Target Scoping Plan, which is the net climate effects of such projects or the policies that would drive them.

The main purpose of "fuels reduction" to reduce wildfire risk and severity is to remove wood from the forest. Wood contains a great deal of carbon. Harvesting and processing of wood

---

[63] M.Z. Jacobson, *Effects of biomass burning on climate, accounting for heat and moisture fluxes, black and brown carbon, and cloud absorption effects*, 119 J. GEOPHYS. RES. 8980 (2014).
[64] *Id.* at 8984.
[65] J.K. Kodros et al., *Uncertainties in global aerosols and climate effects due to biofuel emissions*, 15 ATMOS. CHEM. PHYS. 8577, 8592 (2015).
[66] *Id.*
[67] "Many studies have demonstrated net benefits for fuel treatments and forest management activities designed to reduce both fire spread and fire severity at the experimental unit or stand level, both in modeled and real world scenarios." Revised Strategy at 46.

products result in substantial CO_2 emissions.[68] Several studies have demonstrated that thinning forests and burning the resulting materials for bioenergy can result in a loss of forest carbon stocks and a transfer of carbon to the atmosphere lasting many years. Because it is impossible to know in advance that wildfire will occur in a thinned stand, thinning operations may remove carbon that never would have been released in a wildfire; one recent study concluded, for this and other reasons, that thinning operations tend to remove about three times as much carbon from the forest as would be avoided in wildfire emissions.[69] Another report from Oregon found that thinning operations resulted in a net loss of forest carbon stocks for up to 50 years.[70] Another published study found that even light-touch thinning operations in several Oregon and California forest ecosystems incurred carbon debts lasting longer than 20 years.[71] Other recent studies have shown that intensive harvest of logging residues that otherwise would be left to decompose on site can deplete soil nutrients and retard forest regrowth as well as reduce soil carbon sequestration.[72]

Combustion of wood for energy instantaneously releases virtually all of the carbon in the wood to the atmosphere as CO_2. Burning wood for energy is typically less efficient, and thus far more carbon-intensive per unit of energy produced, than burning fossil fuels. Measured at the stack, biomass combustion produces significantly more CO_2 per megawatt-hour than fossil fuel combustion; a large biomass-fueled boiler may have an emissions rate far in excess of 3,000 lbs CO_2 per MWh.[73] Smaller-scale facilities using gasification technology are similarly carbon-

---

[68] Mark E. Harmon, et al., *Modeling Carbon Stores in Oregon and Washington Forest Products: 1900-1992*, 33 CLIMATIC CHANGE 521, 546 (1996) (concluding that 40-60% of carbon in harvested wood is "lost to the atmosphere . . . within a few years of harvest" during wood products manufacturing process).
[69] John L. Campbell, et al., *Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions?* FRONT. ECOL. ENV'T (2011), doi:10.1890/110057.
[70] Joshua Clark, et al., *Impacts of Thinning on Carbon Stores in the PNW: A Plot Level Analysis*, Final Report (Ore. State Univ. College of Forestry May 25, 2011).
[71] Tara Hudiburg, et al., *Regional carbon dioxide implications of forest bioenergy production*, 1 NATURE CLIMATE CHANGE 419 (2011), doi:10.1038/NCLIMATE1264.
[72] David L. Achat, et al., *Forest soil carbon is threatened by intensive biomass harvesting*, SCIENTIFIC REPORTS 5:15991 (2015), doi:10.1038/srep15991; D.L. Achat, et al., *Quantifying consequences of removing harvesting residues on forest soils and tree growth – A meta-analysis*, 348 FOREST ECOLOGY & MGMT. 124 (2015).
[73] The Central Power and Lime facility in Florida, for example, is a former coal-fired facility recently permitted to convert to a 70-80 MW biomass-fueled power plant. According to permit application materials, the converted facility would consume the equivalent of 11,381,200 MMBtu of wood fuel per year. *See* Golder Assoc., Air Construction Permit Application: Florida Crushed Stone Company Brooksville South Cement Plant's Steam Electric Generating Plant, Hernando County Table 4-1 (Sept. 2011). Using the default emissions factor of 93.8 kg/MMBtu CO_2 found in 40 C.F.R. Part 98, and conservatively assuming both 8,760 hours per year of operation and electrical output at the maximum 80 MW nameplate capacity, the facility would produce about 3,350 lbs/MWh CO_2. If the plant were to produce only 70 MW of electricity, the CO_2 emissions rate would exceed 3,800 lbs/MWh. If such a facility were dispatched to replace one MWh of fossil-fuel fired generation with one MWh of biomass

intensive; the Cabin Creek bioenergy project recently approved by Placer County would have an emissions rate of more than 3,300 lbs CO_2/MWh.[74] By way of comparison, California's 2012 baseline emissions rate from the electric power sector was 954 lbs CO_2 per MWh.[75] As one recent scientific article noted, "[t]he fact that combustion of biomass generally generates more CO_2 emissions to produce a unit of energy than the combustion of fossil fuels increases the difficulty of achieving the goal of reducing GHG emissions by using woody biomass in the short term."[76] Put more directly, replacing California grid electricity with biomass electricity likely more than *triples* smokestack CO_2 emissions.

Biomass and fossil CO_2 are indistinguishable in terms of their atmospheric forcing effects.[77] Claims about the purported climate benefits of biomass energy thus turn entirely on "net" carbon cycle effects, particularly the possibility that new growth will resequester carbon emitted from combustion, and/or the possibility that biomass combustion might "avoid" emissions that would otherwise occur. But even if these net carbon cycle effects are taken into account, emissions from biomass power plants can increase atmospheric CO_2 concentrations for decades to centuries depending on feedstocks, biomass harvest practices, and other factors. Multiple studies have shown that it can take a very long time to discharge the "carbon debt" associated with bioenergy production, even where fossil fuel displacement is assumed, and even where "waste" materials like timber harvest residuals are used for fuel.[78] One study, using

---

generation, the facility's elevated emissions rate would also result in proportionately higher emissions on a mass basis.

[74] Ascent Environmental, Cabin Creek Biomass Facility Project Draft Environmental Impact Report, App. D (July 27, 2012) (describing 2 MW gasification plant with estimated combustion emissions of 26,526 tonnes CO_2e/yr and generating 17,520 MWh/yr of electricity, resulting in an emissions rate of 3,338 lbs CO2e/MWh).

[75] See Energy and Environment Daily, Clean Power Plan Hub, at http://www.eenews.net/interactive/clean_power_plan/states/california (visited May 18, 2016).

[76] David Neil Bird, et al., *Zero, one, or in between: evaluation of alternative national and entity-level accounting for bioenergy*, 4 GLOBAL CHANGE BIOLOGY BIOENERGY 576, 584 (2012), doi:10.1111/j.1757-1707.2011.01137.x.

[77] U.S. EPA Science Advisory Board, *Science Advisory Board Review of EPA's Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources* 7 (Sept. 28, 2012) (hereafter "SAB Panel Report"); *see also Center for Biological Diversity, et al. v. EPA*, 722 F.3d 401, 406 (D.C. Cir. 2013) ("In layman's terms, the atmosphere makes no distinction between carbon dioxide emitted by biogenic and fossil-fuel sources").

[78] *See, e.g.*, Stephen R. Mitchell, et al., *Carbon Debt and Carbon Sequestration Parity in Forest Bioenergy Production*, GLOBAL CHANGE BIOLOGY BIOENERGY (2012) ("Mitchell 2012"), doi: 10.1111/j.1757-1707.2012.01173.x (attached); Ernst-Detlef Schulze, et al., *Large-scale Bioenergy from Additional Harvest of Forest Biomass is Neither Sustainable nor Greenhouse Gas Neutral*, GLOBAL CHANGE BIOLOGY BIOENERGY (2012), doi: 10.1111/j.1757-1707.2012.01169.x at 1-2 (attached); Jon McKechnie, et al., *Forest Bioenergy or Forest Carbon? Assessing Trade-Offs in Greenhouse Gas Mitigation with Wood-Based Fuels*, 45 ENVIRON. SCI. TECHNOL. 789 (2011) (attached); Anna Repo, et al., *Indirect Carbon Dioxide Emissions from Producing Bioenergy from Forest Harvest Residues*,

realistic assumptions about initially increased and subsequently repeated bioenergy harvests of woody biomass, concluded that the resulting atmospheric emissions increase may even be permanent.[79]

It has been argued that if logging residues otherwise would be burned in the open, using those same materials for bioenergy might result in a very short carbon payback period. However, unlike combustion in a bioenergy facility, broadcast and pile burning of logging slash does not tend to consume all of the material; a significant portion may remain uncombusted on site. According to Forest Service research, fuel consumption in slash piles can range as low as 75%.[80] Combustion factors for broadcast understory burning of coarse woody debris can be as low as 60%.[81] Moreover, open burning of slash is not a universal practice, nor is it universally permissible; rather, it depends on local conditions, including weather and relevant air quality regulations.[82]

ARB thus cannot assume that biomass CO_2 emissions have no effect on the climate. As EPA's Science Advisory Board panel on biogenic CO_2 emissions concluded, biomass cannot be considered a priori "carbon neutral."[83] Rather, a full and scrupulously accurate life-cycle analysis is essential to understanding the atmospheric implications of burning biomass for energy.[84] In particular, biomass emissions must be compared with emissions that would otherwise occur if

---

GLOBAL CHANGE BIOLOGY BIOENERGY (2010) ("Repo 2010"), doi: 10.1111/j.1757-1707.2010.01065.x (attached); John Gunn, et al., Manomet Center for Conservation Sciences, Massachusetts Biomass Sustainability and Carbon Policy Study (2010), *available at* https://www.manomet.org/sites/manomet.org/files/Manomet_Biomass_Report_Full_LoRez.pdf (visited May 24, 2016).

[79] Bjart Holtsmark, *The Outcome Is in the Assumptions: Analyzing the Effects on Atmospheric CO_2 Levels of Increased Use of Bioenergy From Forest Biomass*, GLOBAL CHANGE BIOLOGY BIOENERGY (2012), doi: 10.1111/gcbb.12015.

[80] Colin C. Hardy, *Guidelines for Estimating Volume, Biomass, and Smoke Production for Piled Slash*, U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, Gen. Tech. Rep. PNW-GTR-364 (1996).

[81] *See* Eric E. Knapp et al., *Fuel Reduction and Coarse Woody Debris Dynamics with Early Season and Late Season Prescribed Fire in a Sierra Nevada Mixed Conifer Forest,* 208 FOREST ECOLOGY & MGMT. 383 (2005).

[82] *See, e.g.*, North Coast Unified Air Quality Management District (California), Regulation II , *available at* http://www.ncuaqmd.org/index.php?page=rules.regulations; Placer County (California) Air Pollution Control District, Regulation 3, *available at* http://www.placer.ca.gov/departments/air/rules.

[83] SAB Panel Report at 18.

[84] *See id.*; *see also generally* Timothy D. Searchinger, et al., *Fixing a Critical Climate Accounting Error*, 326 SCIENCE 527 (2009) (attached); see also Mitchell 2012 at 9 (concluding that management of forests for maximum carbon sequestration provides straightforward and predictable benefits, while managing forests for bioenergy production requires careful consideration to avoid a net release of carbon to the atmosphere).

the materials were not used for bioenergy.[85] Such a comparison requires careful attention not only to the quantity of emissions, but also to the timeframe on which the emissions occur; bioenergy emissions occur almost instantaneously, while future resequestration or avoided decomposition may take years, decades, or even centuries to achieve atmospheric parity.

Conclusion

The Center recognizes that steep and immediate reductions in short-lived climate pollutants will help to minimize adverse near-term impacts of climate change. As discussed above, the Center strongly supports ARB's proposals to reduce emissions of these super pollutants from anthropogenic sources, and we support ARB's decision to include only non-forest sources of black carbon in the Revised Strategy. Furthermore, we look forward to working with ARB, in their work on the Scoping Plan and Forest Carbon Plan, on developing an ecologically sound and science-based approach to the highly complex issue of forest carbon.

Sincerely,

Shaye Wolf, Ph.D.
Climate Science Director

Kevin P. Bundy
Senior Attorney

Brian Nowicki
California Climate Policy Director

[85] *See* SAB Panel Report at 18; *see also* Michael T. Ter-Mikaelian, et al., *The Burning Question: Does Forest Bioenergy Reduce Carbon Emissions? A Review of Common Misconceptions about Forest Carbon Accounting*, 113 J. FORESTRY 57 (2015).

Cited References

Achat, D.L., C. Deleuze, G. Landmann, N. Pousse, J. Ranger, and L. Augusto. 2015. Quantifying consequences of removing harvesting residues on forest soils and tree growth – A meta-analysis. Forest Ecology and Management 348: 124-141.

Achat, D.L., M. Fortin, G. Landmann, B. Ringeval, and L. Augusto. 2015. Forest soil carbon is threatened by intensive biomass harvesting. Scientific Reports 5: Art. 15991.

Ascent Environmental, Cabin Creek Biomass Facility Project Draft Environmental Impact Report, App. D (July 27, 2012).

Baker, W.L. 2014. Historical forest structure and fire in Sierran mixed-conifer forests reconstructed from General Land Office survey data. Ecosphere 5(7): Article 79.

Baker, W.L. 2015. Are high-severity fires burning at much higher rates recently than historically in dry-forest landscapes of the Western USA? PLoS ONE 10(9): e0136147.

Beaty, R.M. and A.H. Taylor. 2001. Spatial and temporal variation of fire regimes in a mixed conifer forest landscape, Southern Cascades, USA. Journal of Biogeography 28: 955–966.

Bekker, M. F. and A.H. Taylor. 2001. Gradient analysis of fire regimes in montane forests of the southern Cascade Range, Thousand Lakes Wilderness, California, USA. Plant Ecology 155: 15-28.

Bekker, M. F. and A.H. Taylor. 2010. Fire disturbance, forest structure, and stand dynamics in montane forest of the southern Cascades, Thousand Lakes Wilderness, California, USA. Ecoscience 17: 59-72.

Bird, D.N., N. Pena, and G. Zanichi. 2011. Zero, one, or in between: evaluation of alternative national and entity-level accounting for bioenergy. Global Change Biology Bioenergy 4: 576-587.

Bond, M.L., D.E. Lee, C.M. Bradley, and C.T. Hanson. 2009. Influence of pre-fire tree mortality on fire severity in conifer forests of the San Bernardino Mountains, California. The Open Forest Science Journal 2: 41-47.

Bond, M.L., D.E. Lee, R.B. Siegel, and J.P. Ward, Jr. 2009. Habitat use and selection by California Spotted Owls in a postfire landscape. Journal of Wildlife Management 73: 1116-1124.

Bond, T.C., et al. 2013. Bounding the role of black carbon in the climate system: A scientific assessment. Journal of Geophysical Research 118: 53805552.

Buchalski, M.R., J.B. Fontaine, P.A. Heady III, J.P. Hayes, and W.F. Frick. 2013. Bat response to differing fire severity in mixed-conifer forest, California, USA. PLOS ONE 8: e57884.

Burnett, R.D., P. Taillie, and N. Seavy. 2010. Plumas Lassen Study 2009 Annual Report. U.S. Forest Service, Pacific Southwest Region, Vallejo, CA.

California Air Resources Board. 2015 Edition California's Black Carbon Emission Inventory Technical Support Document (2016)

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

Chen, L.-W.A. et al. 2007. Emissions from laboratory combustion of wildland fuels: emission factors and source profiles. Environmental Science and Technology 41: 4317-4325.

Chen, L.-W.A., P. Verburg, A. Shackelford, D. Zhu, R. Susfalk, J.C. Chow, and J.G. Watson. 2010. Moisture effects on carbon and nitrogen emission from burning of wildland biomass. Atmospheric Chemistry and Physics 10: 6617-6625.

Chung, C.E., V. Ramanathan, and D. Decremer. 2012. Observationally constrained estimates of carbonaceous aerosol radiative forcing. PNAS 109: 11624-11629.

Clark, J. et al. 2011. Impacts of Thinning on Carbon Stores in the PNW: A Plot Level Analysis, Final Report (Ore. State Univ. College of Forestry May 25, 2011).

Cocking MI, Varner JM, and E.E. Knapp. 2014. Long-term effects of fire severity on oak-conifer dynamics in the southern Cascades. Ecological Applications 24: 94-107.

Collins, B.M. and S.L. Stephens. 2010. Stand-replacing patches within a mixed severity fire regime: quantitative characterization using recent fires in a long-established natural fire area. Landscape Ecology 25: 927939.

Collins, B.M., J.D. Miller, A.E. Thode, M. Kelly, J.W. van Wagtendonk, and S.L. Stephens. 2009. Interactions among wildland fires in a long-established Sierra Nevada natural fire area. Ecosystems 12: 114–128.

DellaSala, D., M.L. Bond, C.T. Hanson, R.L. Hutto, and D.C. Odion. 2014. Complex early seral forests of the Sierra Nevada: what are they and how can they be managed for ecological integrity? Natural Areas Journal 34: 310-324.

DellaSala, D.A. 2016. Do mountain pine beetle outbreaks increase the risk of high-severity fires in western forests? A summary of recent field studies. GEOS Institute

Dennison, P.E., Brewer, S.C., Arnold, J.D., and M.A. Moritz. 2014. Large wildfire trends in the western United States, 1984-2011. Geophysical Research Letters 41: 2928–2933.

Dillon, G.K. et al. 2011. Both topography and climate affected forest and woodland burn severity in two regions of the western US, 1984 to 2006. Ecosphere 2: Article 130.

Donato, D.C., J.B. Fontaine, W.D. Robinson, J.B. Kauffman, and B.E. Law. 2009. Vegetation response to a short interval between high-severity wildfires in a mixed-evergreen forest. Journal of Ecology 97: 142-154.

Franklin, A.B., D.R. Anderson, R.J. Gutierrez, and K.P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs 70: 539-590.

Fried, J. S., M. S. Torn, and E. Mills. 2004. The impact of climate change on wildfire severity: A regional forecast for northern California. Climatic Change 64 (1–2): 169–191.

Golder Assoc. 2011. Air Construction Permit Application: Florida Crushed Stone Company Brooksville South Cement Plant's Steam Electric Generating Plant, Hernando County Table 4-1 (Sept. 2011).

Gunn, J., et al., Manomet Center for Conservation Sciences. 2010. Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources.

Halofsky, J. E., D.C. Donato, D.E. Hibbs, J.L. Campbell, M. Donaghy Cannon, J.B. Fontaine, J.R. Thompson, R.G. Anthony, B.T. Bormann, L.J. Kayes, B.E. Law, D.L. Peterson, and T.A. Spies. 2011. Mixed-severity fire regimes: lessons and hypotheses from the Klamath-Siskiyou Ecoregion. Ecosphere 2(4): art40.

Hanson, C. T. and M. P. North. 2008. Postfire woodpecker foraging in salvage-logged and unlogged forests of the Sierra Nevada. Condor 110: 777–782.

Hanson, C.T. 2013. Pacific fisher habitat use of a heterogeneous post-fire and unburned landscape in the southern Sierra Nevada, California, USA. The Open Forest Science

Journal 6: 24-30.

Hanson, C.T. 2015. Uses of higher severity fire areas by female Pacific fishers on the Kern Plateau, Sierra Nevada, California, USA. Wildlife Society Bulletin 39: 497-502.

Hanson, C.T. and D.C. Odion. 2016. Historical fire conditions within the range of the Pacific fishers and spotted owl in the central and southern Sierra Nevada, California, USA. Natural Areas Journal 36: 8-19.

Hanson, C.T., and D.C. Odion. 2014. Is fire severity increasing in the Sierra Nevada mountains, California, USA? International Journal of Wildland Fire 23: 1-8.

Hanson, C.T., D.C. Odion, D.A. DellaSala, and W.L. Baker. 2009. Overestimation of fire risk in the Northern Spotted Owl Recovery Plan. Conservation Biology 23:1314–1319.

Hardy, C.C. 1996. Guidelines for Estimating Volume, Biomass, and Smoke Production for Piled Slash. U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, Gen. Tech. Rep. PNW-GTR-364 (1996).

Harmon, M.E. et al. 1996. Modeling carbon stores in Oregon and Washington forest products: 1900-1992. Climatic Change 33: 521-550.

Holtsmark, B. 2013. The outcome is in the assumptions: analyzing the effects on atmospheric CO_2 levels of increased use of bioenergy from forest biomass. Global Change Biology Bioenergy 5: 467-473.

Hudiburg, T.W., B.E. Law, C. Wirth, and S. Luyssaert. 2011. Regional carbon dioxide implications of forest bioenergy production. Nature Climate Change 1: 419-423.

Hutto, R. L. 2008. The ecological importance of severe wildfires: Some like it hot. Ecological Applications 18: 1827–1834.

Hutto, R. L. 1995. Composition of bird communities following stand-replacement fires in Northern Rocky Mountain (U.S.A.) conifer forests. Conservation Biology 9: 1041–1058.

Hutto, R.L., R.E. Keane, R.L. Sherriff, C.T. Rota, L.A. Eby, and V.A. Saab. 2016. Toward a more ecologically informed view of severe forest fires. Ecosphere 7(2): e01255.

Jacobson, M.Z. 2014. Effects of biomass burning on climate, accounting for heat and moisture fluxes, black and brown carbon, and cloud absorption effects. Journal of Geophysical Research 119: 8980-9002.

Johnson, E.A. 2003. Towards a sounder fire ecology. Frontiers in Ecology and the

Environment 1: 271-276.

Knapp, E.E. et al. 2005. Fuel reduction and coarse woody debris dynamics with early season and late season prescribed fire in a Sierra Nevada mixed conifer forest. Forest Ecology and Management 208: 383-397.

Kodros, J.K., C.E. Scott, S.C. Farina, Y.H. Lee, C. L'Orange, J. Volckens, and J.R. Pierce. 2015. Uncertainties in global aerosols and climate effects due to biofuel emissions. Atmospheric Chemistry and Physics 15: 8577-8596.

Krawchuk, M. A., and M. A. Moritz. 2012. Fire and Climate Change in California. California Energy Commission. Publication number: CEC-500-2012-026.

Krawchuk, M.A., M.A. Moritz, M. Parisien, J. Van Dorn, K. Hayhoe. 2009. Global pyrogeography: the current and future distribution of wildfire. PloS ONE 4: e5102.

Lee, D.E. and M.L. Bond. 2015. Occupancy of California spotted owl sites following a large fire in the Sierra Nevada, California. The Condor 117: 228-236.

Lenihan, J.M., D. Bachelet, R.P. Neilson, and R. Drapek. 2008. Response of vegetation distribution, ecosystem productivity, and fire to climate change scenarios for California. Climate Change 87 (Suppl. 1): S215-S230.

Lenihan, J.M., R.J. Drapek, D. Bachelet, and R.P. Neilson. 2003. Climate change effects on vegetation distribution, carbon, and fire in California. Ecological Applications 13: 1667-1681.

Malison, R.L. and C.V. Baxter. 2010. The fire pulse: wildfire stimulates flux of aquatic prey to terrestrial habitats driving increases in riparian consumers. Canadian Journal of Fisheries and Aquatic Sciences 67: 570-579.

Mazzoleni, L.R., B. Zielinska, and H. Moosmüller. 2007. Emissions of levoglucosan, methoxy phenols, and organic acids from prescribed burns, laboratory combustion of wildland fuels, and residential wood combustion. Environmental Science and Technology 41: 2115-2122.

McKechnie, J. et al. 2011. Forest bioenergy or forest carbon? Assessing trade-offs in greenhouse gas mitigation with wood-based fuels. Environ. Sci. Technol. 45: 789-795.

McKenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climatic change, wildfire, and conservation. Conservation Biology 18: 890-902.

McMeeking, G.R. et al. 2009. Emissions of trace gases and aerosols during the open combustion of biomass in the laboratory. Journal of Geophysical Research 114:

D19210.

Miller, J.D. and H. Safford. 2012. Trends in wildfire severity: 1984-2010 in the Sierra Nevada, Modoc Plateau, and southern Cascades, California, USA. Fire Ecology 8(2): 41-57.

Miller, J.D., C.N. Skinner, H.D. Safford, E.E. Knapp, and C.M. Ramirez. 2012. Trends and causes of severity, size, and number of fires in northwestern California, USA. Ecological Applications 22: 184-203.

Miller, J.D., H.D. Safford, M.A. Crimmins, A.E. Thode. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. Ecosystems 12: 16–32.

Mitchell, S.R. et al. 2012. Carbon debt and carbon sequestration parity in forest bioenergy production. Global Change Biology Bioenergy 4: 818-827.

Moritz, M., Parisien, M., Batllori, E., Krawchuk. M., Van Dorn, J., Ganz, D., & Hayhoe, K. 2012. Climate change and disruptions to global fire activity. Ecosphere 3(6): 1-22.

Myhre, G., D. Shindell et al. 2013. Anthropogenic and Natural Radiative Forcing. Pp 659-740 in Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change IPCC. Stocker, T.F. et al., eds. Cambridge University Press, Cambridge UK and New York USA.

Nagel, T.A. and A. H. Taylor. 2005. Fire and persistence of montane chaparral in mixed conifer forest landscapes in the northern Sierra Nevada, Lake Tahoe Basin, California, USA. J. Torrey Bot. Soc.132: 442-457.

North Coast Unified Air Quality Management District (California), Regulation II , available at http://www.ncuaqmd.org/index.php?page=rules.regulations

Odion D.C., C.T. Hanson, W.L. Baker, D.A. DellaSala, and M.A. Williams. 2016. Areas of agreement and disagreement regarding ponderosa pine and mixed conifer forest fire regimes: a dialogue with Stevens et al. PLoS ONE 11(5): e0154579.

Odion, D. C., M. A. Moritz, and D. A. DellaSala. 2010. Alternative community states maintained by fire in the Klamath Mountains, USA. Journal of Ecology.

Odion, D.C. and C.T. Hanson. 2006. Fire severity in conifer forests of the Sierra Nevada, California. Ecosystems 9: 1177-1189.

Odion, D.C. and C.T. Hanson. 2008. Fire severity in the Sierra Nevada revisited:

conclusions robust to further analysis. Ecosystems 11: 12-15.

Odion, D.C., C.T. Hanson, A. Arsenault, W.L. Baker, D.A. DellaSala, R.L. Hutto, W. Klenner, M.A. Moritz, R.L. Sherriff, T.T. Veblen, and M.A. Williams. 2014. Examining historical and current mixed-severity fire regimes in Ponderosa pine and mixed-conifer forests of western North America. PLoS ONE 9(2): e87852.

Odion, D.C., E.J. Frost, J.R. Strittholt, H. Jiang, D.A. DellaSala, and M.A. Moritz. 2004. Patterns of fire severity and forest conditions in the Klamath Mountains, northwestern California. Conservation Biology 18: 927-936.

Parks, S.A., C. Miller, J.T. Abatzoglou, L.M. Holsinger, M-A. Parisien, and S. Dobrowski. 2016. How will climate change affect wildland fire severity in the western US? Environmental Research Letters 11: 035002.

Picotte, J.J., B. Peterson, G. Meier, and S.M. Howard. 2016. 1984-2010 trends in fire burn severity and area for the coterminous US. International Journal of Wildland Fire 25: 413-420.

Pinder, R.W., E.A. Davidson, C.L. Goodale, T.L. Greaver, J.D. Herrick, and L. Liu. 2012. Climate change impacts of US reactive nitrogen. PNAS 109: 7671-7675.

Placer County (California) Air Pollution Control District, Regulation 3, http://www.placer.ca.gov/departments/air/rules

Ponisio, L.C., K. Wilken, L.M. Gonigle, K. Kulhanek, L. Cook, R. Thorp, T. Griswold, and C. Kremen. 2016. Pyrodiversity begets plant-pollinator community diversity. Global Change Biology 22: 1794-1808.

Raphael, M.G., M.L. Morrison, and M.P. Yoder-Williams. 1987. Breeding bird populations during twenty-five years of postfire succession in the Sierra Nevada. The Condor 89: 614-626.

Repo, A. et al. 2010. Indirect carbon dioxide emissions from producing bioenergy from forest harvest residues. Global Change Biology Bioenergy 3: 107-115.

Schulze, E.-D. et al. 2012. Large-scale bioenergy from additional harvest of forest biomass is neither sustainable nor greenhouse gas neutral. Global Change Biology Bioenergy 4: 611-616.

Schwind, B. 2008. Monitoring trends in burn severity: report on the Pacific Northwest and Pacific Southwest fires (1984 to 2005). U.S. Geological Survey. Online at: http://www.mtbs.gov/reports/projectreports.html.

Searchinger, T.D. et al. 2009. Fixing a critical climate accounting error. Science 326: 527-528.

Seavy, N.E., R.D. Burnett, and P.J. Taille. 2012. Black-backed woodpecker nest tree preference in the burned forests of the Sierra Nevada, California. Wildlife Society Bulletin 36: 722-728.

Sestrich, C.M., T.E. McMahon, and M.K. Young. 2011. Influence of fire on native and nonnative salmonid populations and habitat in a western Montana basin. Transactions of the American Fisheries Society 140: 136-146.

Siegel, R.B., M.W. Tingley, and R.L. Wilkerson. 2012. Black-backed Woodpecker MIS surveys on Sierra Nevada national forests: 2011 Annual Report. A report in fulfillment of U.S. Forest Service Agreement No. 08-CS-11052005-201, Modification #4; U.S. Forest Service Pacific Southwest Region, Vallejo, CA.

Spracklen, D.V., L.J. Mickley, J.A. Logan, R.C. Hudman, R. Yevich, M.D. Flannigan, A.L. Westerling. 2009. Impacts of climate change from 2000 to 2050 on wildfire activity and carbonaceous aerosol concentrations in the western United States. Journal of Geophysical Research 114: D20301.

Stevens J.T. et al. 2016. Average stand age from forest inventory plots does not describe historical fire regimes in ponderosa pine and mixed-conifer forests of western North America. PLoS ONE 11(5): e0147688.

Swanson, M.E., J.F. Franklin, R.L. Beschta, C.M. Crisafulli, D.A. DellaSala, R.L. Hutto, D. Lindenmayer, and F.J. Swanson. 2010. The forgotten stage of forest succession: early- successional ecosystems on forest sites. Frontiers in Ecology and Environment 9: 117-125.

Ter-Mikaelian, M.T., S. Colombo, and J. Chen. 2015. The burning question: does forest bioenergy reduce carbon emissions? A review of common misconceptions about forest carbon accounting. Journal of Forestry 113: 57-68.

Tingely, M.W., R.L. Wilkerson, M.L. Bond, C.A. Howell, and R.B. Siegel. 2014. Variation in home-range size of black-backed woodpeckers. The Condor 116: 325-340.

Turn, S.Q., B.M. Jenkins, J.C. Chow, L.C. Pritchett, D. Campbell, T. Cahill, and S.A. Whalen. 1997. Elemental characterization of particulate matter emitted from biomass burning: Wind tunnel derived source profiles for herbaceous and wood fuels. Journal of Geophysical Research 102: 3683-3699.

U.S. Environmental Protection Agency, SPECIATE Data Browser, Profile 91102 (Wildfires – Composite), https://cfpub.epa.gov/si/speciate/ehpa_speciate_browse_details.cfm?ptype=PC&pnumber=91102

U.S. EPA Science Advisory Board. 2012. Science Advisory Board Review of EPA's Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources 7 (Sept. 28, 2012).

van Wagtendonk, J.W., K.A. van Wagtendonk, and A.E. Thode. 2012. Factors associated with the severity of intersecting fires in Yosemite National Park, California, USA. Fire Ecology 8: 11-32.

Westerling, A. and B. Bryant. 2008. Climate change and wildfire in California. Climate Change 87: S231– S249.

Westerling, A.L., B. P. Bryant, H.K. Preisler, T.P. Holmes, H.G. Hidalgo, T. Das. And S.R. Shrestha. 2011. Climate change and growth scenarios for California wildfire. Climatic Change 109 (Suppl 1): S445-S463.

Whitlock, C., D.A. DellaSala, S. Wolf, and C.T. Hanson. 2015. Climate Change: Uncertainties, Shifting Baselines, and Fire Management. Pp. 265-289 in The Ecological Importance of Mixed Severity Fires: Nature's Phoenix. D.A. DellaSala and C.T. Hanson, eds. Elsevier, Amsterdam, Netherlands.