OREGON WILD

Cumulative Impacts of GHG Emissions Must not be Minimized

The NEPA analysis must avoid minimizing this project's contribution to carbon emissions and global warming by saying the effects of this project would be negligible on a global scale. This is not an appropriate framework. Global climate change and ocean acidification are the result of the **cumulative** effects on the **global** carbon cycle which is spatially distributed. There is no single culprit, nor is there a silver bullet solution. All emissions are part of the problem, and all land management decisions must be part of the solution. Since the global carbon cycle is spatially distributed, carbon storage and carbon emissions will always we spread out around the globe, and the carbon flux at any given place and time may appear small, but *cumulatively* they help determine the temperature of our climate and the pH of our oceans. Given the current carbon overload in the atmosphere and oceans, the carbon consequences of every project must be carefully considered (rather than dismissed as negligible).

The agency may argue that logging a few small patches of forest won't make a difference in the global scheme of the climate problem, but as Voltaire said, "No snowflake in an avalanche ever feels responsible." The NEPA analysis must recognize that global warming will not be solved by one miraculous technological fix or by changing one behavior or one economic activity. The whole global carbon cycle must be managed to reduce carbon emissions and increase carbon uptake. Recent evidence supports the conclusions that all net emissions of greenhouse gases are adverse to the climate. None can be considered *de minimus*. "We show first that a single pulse of carbon released into the atmosphere increases globally averaged surface temperature by an amount that remains approximately constant for several centuries, even in the absence of additional emissions. We then show that to hold climate constant at a given global temperature requires near- zero future carbon emissions. Our results suggest that future anthropogenic emissions would need to be eliminated in order to stabilize global-mean temperatures. As a consequence, any future anthropogenic emissions will commit the climate system to warming that is essentially irreversible on centennial timescales." H. Damon Matthews and Ken Caldeira. 2009. Stabilizing climate requires near-zero emissions. Nature Vol 455 | 18 September 2008 | doi:10.1038/nature07296.

Former D.C. Circuit Judge Wald wrote in a 1990 dissenting opinion, which was recently quoted with unanimous approval by the Ninth Circuit in Center *for Biological Diversity v. NHTSA*:

> [W]e cannot afford to ignore even modest contributions to global warming. If global warming is the result of the cumulative contributions of myriad sources, any one modest in itself, is there not a danger of losing the forest by closing our eyes to the felling of the individual trees?

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538 F.3d at 1217. Similarly, the U.S. Supreme Court's decision in *Massachusetts v. EPA* noted that one cannot avoid responsibility to reduce and mitigate the climate problem by attempting to minimize the scale of one's contribution to the problem. ("While it may be true that regulating motor-vehicle emissions will not by itself reverse global warming, it by no means follows that we lack jurisdiction to decide whether EPA has a duty to take steps to slow or reduce it.... In sum, … [t]he risk of catastrophic harm, though remote, is nevertheless real. That risk would be reduced to some extent if petitioners received the relief they seek." 127 S.Ct. 1438, 1455 (2007) http://web.archive.org/web/20080610172128/http://www.supremecourtus.gov/opinions/06pdf/05-1120.pdf)

> [The Prime Minister] claims that we [Australians] are responsible for just 1.3% of global carbon dioxide emissions, as if we are irrelevant. ...
>
> ...
>
> Even though Scott Morrison's logic for climate inaction has been debunked many times, let's do it again, ...
>
> ...
>
> The "too small to matter" argument is logically absurd, but it is also morally bankrupt and economically reckless.
>
> We all know that throwing one piece of litter out the window wouldn't ruin the environment, but if all did we'd soon be surrounded by rubbish.
>
> How about voting? It is a foundation of our democracy that nobody's voice is so small as to be meaningless.
>
> Likewise, if any one taxpayer stopped paying tax we all know it wouldn't make a measurable difference to the government's bottom line, but if everyone stopped paying tax it would smash consolidated revenue.

Simon Holmes à Court 2020. When it comes to emissions, the 'too small to matter' argument is absurd, reckless and morally bankrupt. The UK Guardian 8 Jan 2020. https://www.theguardian.com/australia-news/2020/jan/09/when-it-comes-to-emissions-the-too-small-to-matter-argument-is-absurd-reckless-and-morally-bankrupt?CMP=twt_a-environment_b-gdneco.

The responsibility to reduce emissions no matter how small is recognized in international law such as the European Convention on Human Rights.

> The fact that the amount of the Dutch emissions is small compared to other countries does not affect the obligation to take precautionary measures in view of the State's obligation to exercise care. After all, it has been established that any anthropogenic

> greenhouse gas emission, no matter how minor, contributes to an increase of CO_2 levels in the atmosphere and therefore to hazardous climate change.

Urgenda Foundation v. The State of the Netherlands. Hague Court of Appeal. October 9, 2018. https://uitspraken.rechtspraak.nl/inziendocument?id=ECLI:NL:RBDHA:2015:7196.

CEQ draft guidance on NEPA and climate change recognizes that disclosure of the incremental nature of GHG emissions attributable to any given project is merely a restatement of the nature of the climate problem itself and NEPA does not allow agencies to avoid disclosure and consideration of alternatives and mitigation.

> CEQ recognizes that many agency NEPA analyses to date have concluded that GHG emissions from an individual agency action will have small, if any climate change effects. Government action occurs incrementally, program-by-program and step-by-step, and climate impacts are not attributable to any single action, but are exacerbated by a series of smaller decisions, including decisions made by the government. Therefore, the statement that emissions from a government action or approval represent only a small fraction of global emissions is more a statement about the nature of the climate change challenge, and is not an appropriate basis for deciding whether to consider climate impacts under NEPA.
>
> Moreover, these comparisons are not an appropriate method for characterizing the potential impacts associated with a proposed action and its alternatives and mitigations. This approach does not reveal anything beyond the nature of the climate change challenge itself: The fact that diverse individual sources of emissions each make relatively small additions to global atmospheric GHG concentrations that collectively have huge impact.

77 Fed. Reg. 77802, 77825. (Dec. 24, 2014).

Agency NEPA analyses often say that the "Literature, however, has not yet defined any specifics on the nature or magnitude of any cause and effect relationship between greenhouse gases and climate change. [and] it is currently beyond the scope of existing science to identify a specific source of greenhouse gas emissions or sequestration and designate it as the cause of specific climate impacts at a specific location." The agency should stop saying this. Such statements are obviously part of the agency's dismissive boilerplate about climate change but they add nothing to the analysis, but they imply that things are far more uncertain than they are, and that logging-related GHG emissions can't be connected to the crime of global climate change, which is nonsense. What we know is that climate change is caused by cumulative effects. All GHG emissions become globally distributed in our well-mixed atmosphere, so all emissions are related to all harms and effects of global climate change. These effects are set forth in great detail in the scientific literature and IPCC reports. So, GHG emissions are bad and CO_2 uptake by forests is good, and the agency's logging program increases GHG emissions and reduces CO_2 uptake.

Because individual contributions to climate change are so small, but the cumulative problem is so large, meaningfully disclosing the impact of greenhouse gas emissions requires some tool beyond merely identifying physical changes in the environment attributable to an individual project's emissions.

Climate change is the quintessential cumulative impact problem, and a good way to disclose the incremental effects of individual contributions to the cumulative problems is to monetize the effects using tools that quantify the social cost of carbon dioxide emissions. Social Cost of Carbon 2010, https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/foragencies/Social-Cost-of-Carbon-for-RIA.pdf.

Individual physical changes that will result from any particular action will inevitably appear insignificant. Just as the public and decisionmakers "cannot be expected to convert curies or mrems into such costs as cancer deaths," the EIS's readership cannot be expected to understand whether an individual project's miniscule marginal increase contribution to increased temperature, sea levels, etc. is cause for concern. *Natural Res. Def. Council, Inc. v. U. S. Nuclear Regulatory Comm'n*, 685 F.2d 459, 487 n.149 (D.C. Cir. 1982) rev'd on other grounds sub nom. *Baltimore Gas & Elec. Co. v. Natural Res. Def. Council, Inc.*, 462 U.S. 87, 106-107 (1983).

Estimates of the social cost of carbon dioxide emissions are based on reasonable forecasts of the actual physical effects that each incremental unit of greenhouse gas emissions will have on the environment, including temperature, sea level rise, ecosystem services, and other physical impacts, together with assessments of how these physical changes will impact agriculture, human health, etc. The social cost protocol identifies the social cost imposed by a ton of emissions' pro rata contribution to these environmental problems. This either amounts to an assessment of physical impacts or the best available generally accepted alternative to such an assessment; either way, the tool is appropriate for use under NEPA. 40 C.F.R. § 1502.22(b)(4).

Any assertion that it is impossible to discuss the impact or significance of the Project's greenhouse gas emissions is arbitrary. Agencies must use available generally accepted tools to address the impact of these emissions, 40 C.F.R. 1502.22, and employ reasonable forecasting in its analysis. The agency's refusal to use available modeling tools, such as the estimates of the social cost of carbon and other greenhouse gases, violates NEPA.

Forest Degradation just as bad as Deforestation

The agency often says "This project does not fall within any of these main contributors of greenhouse gas emissions. … The main activity in this [forestry] sector associated with GHG emissions is deforestation, which is defined as removal of all trees, most notably the conversion of forest and grassland into agricultural land or developed landscapes (IPCC 2000).” The agency is again minimizing the effects of its activities and avoiding its dual responsibilities to produce accurate NEPA analysis and help store carbon in forests. All emissions are a problem. Categories do not really matter. The atmosphere sees each molecule of CO2 and other GHG equally. Climate authorities recognize “forest degradation” is just as bad as deforestation. In fact, the urgency to maintain and enhance biogenic terrestrial carbon stores has long been recognized and is reflected in the inclusion of the land sector in the report of the United Nations Framework Convention on Climate Change (UNFCCC). The official title of UN program related to reducing GHG emissions from land use includes the words deforestation AND “forest degradation” i.e., Reducing Emissions from Deforestation and Forest Degradation (REDD). This clearly refutes the agency’s assertion that forest management activities that fall short of deforestation are not among the categories of concern regarding global GHG emissions.

The Copenhagen Accord recognizes the need to avoid dangerous climate change and the role of forests in climate mitigation.

> “…To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius … enhance our long-term cooperative action to combat climate change. We recognize the crucial role of reducing emission from deforestation **and forest degradation** and the need to enhance removals of greenhouse gas emission by forests and agree on the need to provide positive incentives to such actions”

http://www.climatesciencewatch.org/file-uploads/Copenhagen_Accord.pdf. This likely requires reducing atmospheric CO_2 concentrations below 350 ppm[1] and avoiding logging that would increase atmospheric carbon emissions. Boucher, D., and K. Belletti-Gallon, 2015. Halfway There? What the Land Sector Can Contribute to Closing the Emissions Gap. Union of Concerned Scientists. http://www.ucsusa.org/sites/default/files/attach/2015/01/ucs-halfway-there-2015-full-report.pdf (“Enormous amounts of carbon are released into the atmosphere when forests are cleared. “**Forest degradation” activities, such as selective logging, … are also significant emissions sources**.”)

> **Forest degradation should be defined from a climate change perspective to include any human land-use activity that reduces the carbon stocks of a forested landscape relative to its carbon carrying capacity**. The climate change imperative demands that

[1] Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. 2009. Planetary boundaries:exploring the safe operating space for humanity. *Ecology and Society* 14(2): 32. [online] URL: http://www.ecologyandsociety.org/vol14/iss2/art32/. http://www.stockholmresilience.org/download/18.1fe8f33123572b59ab800012568/pb_longversion_170909.pdf. http://www.ecologyandsociety.org/vol14/iss2/art32/figure6.html.

> we take a fresh look at our forest estate. The carbon impacts of all land uses, including commercial logging, must be brought explicitly into our calculations in terms of their direct and indirect effects on forest degradation.

Brendan G. Mackey, Heather Keith, Sandra L. Berry and David B. Lindenmayer. 2008. Green Carbon: The role of natural forests in carbon storage. Part 1. A green carbon account of Australia's south-eastern Eucalypt forests, and policy implications. Australian National University. http://epress.anu.edu.au/green_carbon/pdf/whole_book.pdf.

The agency must account for all forest carbon loses, not just from deforestation, but also degradation. Sophie Yeo 2015. Blog - **Forest degradation as bad for climate as deforestation**, says report. 08 Apr 2015, http://www.carbonbrief.org/blog/2015/04/forest-degradation-as-bad-for-climate-as-deforestation,-says-report/

A study by Erb et al (2017) shows that deforestation represents only about half of the cumulative carbon emissions from land use. Most of the other half is from forest degradation.

> **Scientists just presented a sweeping new estimate of how much humans have transformed the planet**
>
> By Chris Mooney, Washington Post
> December 20 , 2017
> https://www.washingtonpost.com/news/energy-environment/wp/2017/12/20/scientists-present-a-sweeping-new-estimate-of-how-much-humans-have-altered-the-planet/
> ...
> Razing forests or plowing grasslands puts carbon in the atmosphere just like burning fossil fuels does.
> Now, new research provides a surprisingly large estimate of just how consequential our treatment of land surfaces and vegetation has been for the planet and its atmosphere.
> ...
> [T]he study also presented an even larger and perhaps more consequential number: 916 billion tons. That's the amount of carbon, the research calculated, that could reside in the world's vegetation — so not in the atmosphere — if humans somehow entirely ceased all uses of land and allowed it to return to its natural state. The inference is that current human use of land is responsible for roughly halving the potential storage of carbon by that land.
> ...
> The study found that there are two far-less-recognized components of how humans have subtracted from Earth's potential vegetation — and that in combination they are just as substantial as deforestation. Those are large-scale grazing and other uses of grasslands, as well as forest "management." With the latter, many trees and other types of vegetation are subtracted from forests — often the larger and older trees due to logging — but the forests as a whole don't disappear. They're just highly thinned out.

> "This effect is quite massive, more massive than we expected actually," Erb said.
> ...
> The research means that so-called degraded land — not fully deforested but not "natural" or whole, either — is a phenomenon to be reckoned with.
> "It suggests that the amount of carbon released to the atmosphere from land use is approximately equal to the amount still retained," said Tom Lovejoy, an ecologist at George Mason University who was not involved in the work. "That means the restoration agenda is even more important than previously thought and highlights the enormous amount of degraded land in the world."
> ...
> "Scenarios that limit global warming to 1.5 or 2 degrees [Celsius] require not only rapid cessation of greenhouse gas emissions but also removal of somewhere between about 100 and 300 billion tons of carbon from the atmosphere," Phil Duffy, president of the Woods Hole Research Center, said in an email.
> "This paper suggests that restoring vegetation around the world could in principle achieve that," Duffy continued, noting that if all the potential vegetation were restored it would offset some 50 years of global carbon emissions. While "the full theoretical potential will never be realized in practice … this paper indicates that restoring vegetation could make an extremely important contribution to controlling global climate change."

See Karl-Heinz Erb et al. 2017. Unexpectedly large impact of forest management and grazing on global vegetation biomass. Nature. Published online 20 Dec 2017. doi:10.1038/nature25138. https://www.nature.com/articles/nature25138.epdf

Arneth et al (2017) showed that global vegetation models often make unrealistic assumptions about forests (such as that areas maintained in forest cover suffer no decline in carbon storage) and therefore underestimate both the carbon flux from logging as well as the carbon benefits of forest conservation.

> … Dynamic global vegetation model simulations suggest that CO2 emissions from land-use change have been substantially underestimated because processes such as tree harvesting and land clearing from shifting cultivation have not been considered. As the overall terrestrial sink is constrained, a larger net flux as a result of land-use change implies that terrestrial uptake of CO2 is also larger, and that terrestrial ecosystems might have greater potential to sequester carbon in the future. Consequently, reforestation projects and efforts to avoid further deforestation could represent important mitigation pathways, with co-benefits for biodiversity. …
> …
> **Wood Harvesting**
> Until recently, global DGVM studies that accounted for LULCC concentrated on the representation of conversion of natural lands to croplands and pastures, whereas areas under forest cover were represented as natural forest, and hence by each model's

dynamics of establishment, growth and mortality. Two-thirds to three-quarters of global forests have been affected by human use, which is mainly due to timber harvest; but forests are also a source of firewood or secondary products; or used for recreational purposes13. Between 1700 and 2000 an estimated 86 PgC has been removed globally from forests due to wood harvesting (WH)14. WH leads to reduced carbon density on average in managed forests15 and can ultimately result in degradation in the absence of sustainable management strategies. Furthermore, the harvesting of wood can reduce litter input, which lowers soil pools13. Bringing a natural forest under any harvesting regime probably will lead to net-CO2 emissions to the atmosphere — with a magnitude and time-dependency conditional on harvest intensity and frequency, regrowth and the fate and residence time of the wood products.

Impacts of land-management processes on the carbon cycle
The few published DGVM studies that account for the management of land more realistically16,19–21 consistently suggest a systematically larger FLULCC over the historical period compared to estimates that ignored these processes, with important implications for our understanding of the terrestrial carbon cycle and its role for historical (and future) climate change. …

…

Implications for the future land carbon mitigation potential
Our calculated increases in FLULCC, in absence of a clear understanding of the processes underlying FRL, notably strengthen the existing arguments to avoid further deforestation (and all ecosystem degradation) — an important aspect of climate change mitigation, with considerable co-benefits to biodiversity and a broad range of ecosystem service supply.

Arneth, A., Sitch, S., Pongratz, J. et al (2017) Historical carbon dioxide emissions caused by land-use changes are possibly larger than assumed. NATURE GEOSCIENCE | VOL 10 | FEBRUARY 2017. http://bstocker.net/wp-content/uploads/2016/09/arneth17natgeo.pdf.

When forest carbon accounting looks only at forest clearing, significant forgone carbon sequestration caused by forest degradation are overlooked. "[N]ew research shows that we should be taking much better care of our last great intact forests because doing so has remarkable climate benefits. ... A single episode of serious damage can lead to decades of 'lost earnings' in the carbon accounts." Tom Evans, Sean Maxwell 2019. The Carbon Bomb - A new report shows that deforestation released a shocking 626 percent more CO2 between 2000 and 2013 than previously thought. Scientific American. November 8, 2019. https://blogs.scientificamerican.com/observations/the-carbon-bomb/ *citing* Sean L. Maxwell, Tom Evans, James E. M. Watson et al 2019. Degradation and forgone removals increase the carbon impact of intact forest loss by 626%. Science Advances 30 Oct 2019: Vol. 5, no. 10, eaax2546. DOI: 10.1126/sciadv.aax2546.

https://advances.sciencemag.org/content/5/10/eaax2546. ("[W]e encourage national governments to better account for the full carbon impact of intact forest retention. For example, emission baselines that account for selective logging and other more cryptic degradation processes would reduce the disproportionate emphasis on recent forest clearance").

Logging Does Not Increase Capacity for Growing Trees

The NEPA analysis suggests that logging will increase forest productivity, but there is no evidence that this is true. The agency often says "Projects like the proposed action that create forests or improve forest conditions and capacity to grow trees are positive factors in carbon sequestration."

> "I am unaware of a single study, or plausible mechanism, by which tree removal increases stand-level productivity (and by extension carbon stocks). For instance, the CFCP fairly cites Battles et al. (2015) as empirical evidence that thinned forests can "within a decade or two" regain the carbon lost due to the removal of smaller trees, but fails to acknowledge that the un-thinned control forests in this same study continued to grow over this period and, at all times, contained more carbon that the thinned ones. Even when one considers the protection thinning affords forests from carbon losses in high-severity fire, thinned forests contain less carbon over space and time than do fire suppressed ones (provided conditions afford timely post-fire regeneration). Such is well-established in several reviews of the subject, all of which are notable missing from the CFCP citations (Campbell et al., 2012; Restaino and Peterson 2013; Young, 2015; Kalies and Kent 2016)."

Campbell, J.L. 2017, Comments on the Jan 2017 draft California Forest Carbon Plan. http://www.fire.ca.gov/fcat/downloads/FCAT_PublicComment/Campbell_CFCP_Review_Final-2nd.pdf. The "capacity to grow trees" (i.e., net ecosystem productivity) on this landscape will actually be adversely affected by the proposed action to the extent the FS builds roads, compacts soil, removes biomass, etc.

In the context of carbon and climate change, the agency cannot define "improve forest conditions" in way that justifies logging that increases GHG emissions at the expense of maintaining forest carbon storage.

Also, this project will cause far more tree mortality by logging than would be avoided via natural mortality. See discussion in DeCicco J.M. 2013. Biofuel's carbon balance: doubts, certainties and implications. Climatic Change (2013) 121:801–814. DOI 10.1007/s10584-013-0927-9 http://download.springer.com/static/pdf/522/art%253A10.1007%252Fs10584-013-0927-9.pdf?auth66=1398528430_ad123a71083ade45750f8bec9a091a43&ext=.pdf ("A first-order model shows that biofuels are beneficial only to the extent that their production effectively enhances net ecosystem production.").

> Where clear-cutting of long-established virgin forest is followed by the establishment of commercial plantation forests or agroforestry systems, it is doubtful that the C released to the atmosphere will ever be fully recovered within the ecosystem.

Matthews R.W. et al. (1996) WG3 Summary: Evaluating the role of forest management and forest products in the carbon cycle. In: Apps M.J., Price D.T. (eds) Forest Ecosystems, Forest Management and the Global Carbon Cycle. NATO ASI Series (Series I: Global Environmental Change), vol 40. Springer, Berlin, Heidelberg. http://www.sysecol2.ethz.ch/pdfs/Ma121-lq.pdf

William R. Moomaw, Susan A. Masino, and Edward K. Faison. 2019. Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good Front. For. Glob. Change, 11 June 2019 | https://doi.org/10.3389/ffgc.2019.00027; https://www.frontiersin.org/articles/10.3389/ffgc.2019.00027/full ("ABSTRACT: Climate change and loss of biodiversity are widely recognized as the foremost environmental challenges of our time. Forests annually sequester large quantities of atmospheric carbon dioxide (CO2), and store carbon above and below ground for long periods of time. Intact forests—largely free from human intervention except primarily for trails and hazard removals—are the most carbon-dense and biodiverse terrestrial ecosystems, with additional benefits to society and the economy. Internationally, focus has been on preventing loss of tropical forests, yet U.S. temperate and boreal forests remove sufficient atmospheric CO2 to reduce national annual net emissions by 11%. U.S. forests have the potential for much more rapid atmospheric CO2 removal rates and biological carbon sequestration by intact and/or older forests. The recent 1.5 Degree Warming Report by the Intergovernmental Panel on Climate Change identifies reforestationand afforestation as important strategies to increase negative emissions, but they face significant challenges: afforestation requires an enormous amount of additional land, and neither strategy can remove sufficient carbon by growing young trees during the critical next decade(s). In contrast, growing existing forests intact to their ecological potential—termed proforestation—is a more effective, immediate, and low-cost approach that could be mobilized across suitable forests of all types. Proforestation serves the greatest public good by maximizing co-benefits such as nature-based biological carbon sequestration and unparalleled ecosystem services such as biodiversity enhancement, water and air quality, flood and erosion control, public health benefits, low impact recreation, and scenic beauty. ... Proforestation produces natural forests as maximal carbon sinks of diverse species (while supporting and accruing additional benefits of intact forests) and can reduce significantly and immediately the amount of forest carbon lost to nonessential management. Because existing trees are already growing, storing carbon, and sequestering more carbon more rapidly than newly planted and young trees (Harmon et al., 1990; Stephenson et al., 2014; Law et al., 2018; Leverett and Moomaw, in preparation), proforestation is a near-term approach to sequestering additional atmospheric carbon: a significant increase in "negative emissions" is urgently needed to meet temperature limitation goals. The carbon significance of proforestation is demonstrated in multiple ways in larger trees and older forests. For example, a study of 48 undisturbed primary or mature secondary forest plots worldwide found, on average, that the largest 1% of trees [considering all stems ≥1 cm in diameter at breast height (DBH)] accounted for half of above ground living biomass (The largest 1% accounted for ~30% of the biomass in U.S. forests due to larger average size and fewer stems compared to the tropics) (Lutz et al., 2018). Each year a single tree that is 100 cm in diameter adds the equivalent biomass of an entire 10–20 cm diameter tree, further underscoring the role of large trees (Stephenson et al., 2014). Intact forests also may sequester half or more of their carbon as organic soil carbon or in standing and fallen trees that eventually decay and add to soil carbon (Keith et al., 2009). Some older forests continue to sequester additional soil organic carbon (Zhou et al., 2006) and older forests bind soil organic matter more tightly than younger ones (Lacroix et al., 2016).") See also, How to fight climate change? Save existing forests. Guest column by William R. Moomaw, Bob Leverett, Robert A. Jonas and Monica Jakuc Leverett. 7-24-2019. https://www.gazettenet.com/Guest-column-by-William-R-Moomaw-Bob-Leverett-Robert-A-Jonas-and-Monica-Jakuc-Leverett-27110056.

FEN MONTAIGNE 2019. Why Keeping Mature Forests Intact Is Key to the Climate Fight. Yale e360 OCTOBER 15, 2019. https://e360.yale.edu/features/why-keeping-mature-forests-intact-is-key-to-the-climate-fight ("... [P]reserving existing mature forests will have an even more profound effect on slowing global warming in the coming decades, since immature trees sequester far less CO2 than older ones. ... 'The most effective thing that we can do is to allow trees that are already planted, that are already growing, to continue growing to reach their full ecological potential, to store carbon, and develop a forest that has its full complement of environmental services,' said Moomaw. ... [I]n order to meet our climate goals, we have to have greater sequestration by natural systems now. So that entails protecting the carbon stocks that we already have in forests. ... We've seen a lot of interest lately in planting more trees. And planting trees is great and it makes us all feel good and it's a wonderful thing to do ... but they will not make much of a difference in the next two or three decades because little trees just don't store much carbon. Letting existing natural forests grow is essential to any climate goal we have.")

As climate stress increases, maintaining forest productivity will require conserving fungal diversity, which in turn requires conserving the trees and dead wood that support fungal diversity. As explained by Peter et al (2013) –

> New emerging techniques allow to study the functional diversity of mycorrhizal fungi under natural conditions in forests (Courty et al. 2010). One of the most important functions of these fungi is the enhanced nutrient uptake of forest trees. Therefore, the functional abilities of nutrient mobilisation from organic material were tested in several forest ecosystems and under diverse environmental conditions (Pritsch and Garbaye 2011). These studies show that species do have different functional abilities in enzymatic activities, e.g. for nitrogen acquisition by degrading proteins in the soil or in lignin degradation (see Figure 57, Hutter et al. in prep). Whereas some mycorrhizal species complement each other, some are redundant in these functions but are sometimes adapted

to other soil conditions and might be complementary in additional functions such as water uptake (Buée et al. 2007, Jones et al. 2010, Rineau and Courty 2011). Therefore, on the one hand, high diversity in the mycorrhizal fungal community is of great importance for forest trees to optimally exploit soil resources through the different functional abilities of single species. On the other hand, a high diversity allows the mycorrhizal community to respond to changing environmental conditions and disturbances by modifying the community towards better-adapted species that maintain important ecosystem functions. ... With climate warming, it is expected that the severity and duration of drought will increase, and therefore the maintenance of intact mycorrhizal networks will become more critical to the stability of forest ecosystems (Simard and Austin 2010). ... Several factors, such as natural disturbances, forest management, and anthropogenic pollution, impact this diversity and structure, in most cases by changing the competitiveness and dominance of the species present. Under severe disturbances, species richness is impacted, lowering the potential resistance to additional stresses or even reducing ecological function. ... Although the effect of climate change factors and their interaction on mycorrhizal communities is complex and difficult to predict, it is likely that these communities will help stabilize forest ecosystems under the predicted climatic scenarios (Simard and Austin 2010). Management practices should therefore consider the functional importance of mycorrhizal fungi and their networks in the natural regeneration and resilience of forests.

Martina Peter, Marc Buée and Simon Egli 2013. Biodiversity of mycorrhizal fungi as a crucial player in forest ecosystem functioning. *In* Daniel Kraus and Frank Krumm (eds.) 2013. Integrative approaches as an opportunity for the conservation of forest biodiversity. European Forest Institute. 284 pp.
http://www.integrateplus.org/uploads/images/Mediacenter/integrate_book_2013.pdf.

A literature review by Tomao et al (2020) explains that the adverse effects of logging on fungi populations has at least three causes: (i) loss of ectomycorrhizal-hosts and the associated reduction in carbohydrate production and carbohydrate transfer from living trees to the fungal symbionts, (ii) reduction in quantity and diversity of dead wood substrate, and (iii) adverse modification of the microclimate, e.g., rapid wetting and drying, soil compaction, reduced water retention, reduced gas exchange, etc.

Highlights –

• We review the effect of forest management practices on fungal diversity.

• Fungal diversity is positively related with canopy cover, basal area and tree species diversity.

• Diversity of deadwood size and decomposition stage is positively related to richness of wood-inhabiting fungi.

• The higher is the forest management intensity the lower is the diversity of fungal species. ...

> If no management practices are performed for a long time, stands may gradually evolve into so-called "old-growth forests". In the absence of anthropogenic disturbances, forests may slowly recover the natural disturbance dynamics (forest fires and windstorms, parasite outbreaks, fungal decay, gap creation due to insects) and develop those stand structural features (large living trees, large amount of deadwood, canopy gaps of various size, coexistence of senescent, mature and initial stages) typical of primary forests (Burrascano et al., 2013). ... Old-growth forests are recognized as an important reserve of fungal diversity for several fungal functional guilds. Indeed, a very large number of ectomycorrhizal species can be hosted in old growth stands (Richard et al., 2004; Zhang et al., 2017).

Antonio Tomao, José Antonio Bonet, Carles Castaño, Sergiode-Miguel, 2020. How does forest management affect fungal diversity and community composition? Current knowledge and future perspectives for the conservation of forest fungi. Forest Ecology and Management, Volume 457, 1 February 2020, 117678, https://doi.org/10.1016/j.foreco.2019.117678.

Risk reduction logging does not help store carbon.

Forest Service NEPA analyses often include the following assertion - "The release of carbon associated with this project is justified given the overall change in condition increases forest resistance to release of much greater quantities of carbon from wildfire, drought, insects/disease, or a combination of these disturbance types (Millar 2007)" This is inaccurate and misleading.

Logging proponents often claim that logging will increase carbon storage in the forest by limiting carbon emissions caused by natural processes such as fire and insect-induced mortality. This is simply counter-factual. In most cases, managing forests in an effort to control natural processes that release carbon will only make things worse by releasing MORE carbon. This is mostly because no one can predict where fire or insects will occur, so the treatments must be applied to broad landscapes, yet the probability of fire or insects at any given location remains low, and only a small fraction of the treated areas will actually experience fire or insects. As a result, many acres will be treated "unnecessarily" and therefore the cumulative carbon emissions from logging to control fire and insects (plus the carbon emissions from fire and insects that occur in spite of control efforts) are greater than emissions from fire and insects alone. A careful analysis shows that logging to control fire and expecting to increase carbon storage is analogous to rolling a die and expecting to roll a six every time.

This is an example of the "base rate fallacy" or "neglecting priors" from Bayesian statistics. The probability of a forest stand NOT burning are far greater than the probability of a forest stand burning. Attempts to address a problem that is unlikely to occur, such as by thinning a forest that is unlikely to burn, runs a high risk that unintended negatives effects will overwhelm beneficial effects. https://en.wikipedia.org/wiki/Base_rate_fallacy

The 2018 US Forest Service Northwest Forest Plan Science Synthesis concluded that fuel reduction is unlikely to be an effective climate mitigation strategy.

> Some studies from other regions in the Western United States (i.e., the Southwest and Sierra Nevada) suggest that thinning and fuel reduction can mitigate carbon loss from fire. Fuel reduction may reduce losses of carbon at stand levels compared with the consequences of high-severity wildfire burning in stands with high fuel loads (Finkral and Evans 2008; Hurteau and North 2009; Hurteau et al. 2008, 2011, 2016; North and Hurteau 2011; North et al. 2009, Stephens et al. 2009). However, because the probability of treated areas burning is generally low (Barnett et al. 2016), and most biomass is not consumed by fire, slight differences in losses resulting from combustion in fire compared with losses from fuel reduction are unlikely to make fuel reduction a viable mitigation strategy (Ager et al. 2010, Campbell et al. 2012, Kline et al. 2016, Mitchell et al. 2009, Restaino and Peterson 2013, Spies et al. 2017).

USDA 2018. Synthesis of Science to Inform Land Management Within the Northwest Forest Plan Area. General Technical Report. PNW-GTR-966 Vol. 1. June 2018. https://www.fs.fed.us/pnw/pubs/pnw_gtr966_vol1.pdf.

Let's start with a simple truism of risk management:

> Speculative negative emissions technologies may be worse than chimeras if they result in the false comfort that continued … emissions can simply be offset, thereby diverting financial and policy resources from conventional mitigation. This would be reckless. It is clearly less risky not to emit a tonne of CO2 in the first place, than to emit one in expectation of being able to sequester it for an unknown period of time, at unknown cost, with unknown consequences, at an unknown date and place in the future.

Carbon Brief staff 2016. In-depth: Experts assess the feasibility of 'negative emissions' *citing* Rob Bailey, Director of Energy, Environment and Resources, Chatham House. http://www.carbonbrief.org/in-depth-experts-assess-the-feasibility-of-negative-emissions#bailey

Law & Harmon (2011) conducted a literature review and concluded …

> Thinning forests to reduce potential carbon losses due to wildfire is in direct conflict with carbon sequestration goals, and, if implemented, would result in a net emission of CO2 to the atmosphere because the amount of carbon removed to change fire behavior is often far larger than that saved by changing fire behavior, and more area has to be harvested than will ultimately burn over the period of effectiveness of the thinning treatment.

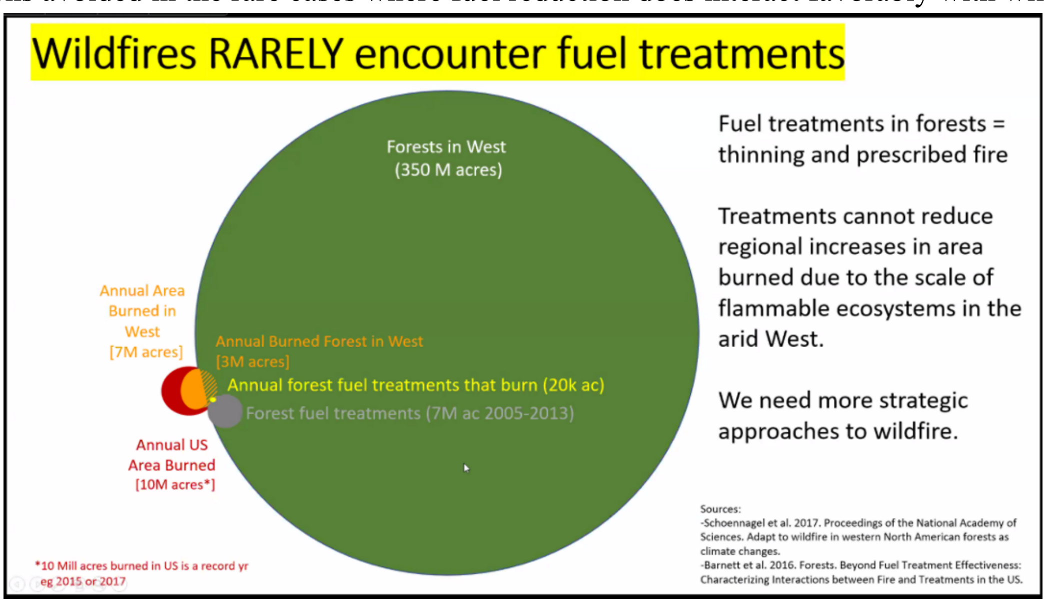
Law, B. & M.E. Harmon 2011. Forest sector carbon management, measurement and verification, and discussion of policy related to mitigation and adaptation of forests to climate change. Carbon Management 2011 2(1). https://content.sierraclub.org/ourwildamerica/sites/content.sierraclub.org.ourwildamerica/files/documents/Law%20and%20Harmon%202011.pdf.

Campbell and Agar (2013) conducted a sensitivity analysis and found robust results indicating that fuel reduction does not increase forest carbon storage.

> … we attempt to remove some of the confusion surrounding this subject by performing a sensitivity analysis wherein long-term, landscape-wide carbon stocks are simulated under a wide range of treatment efficacy, treatment lifespan, fire impacts, forest recovery rates, forest decay rates, and the longevity of wood products. Our results indicate a surprising insensitivity of long-term carbon stocks to both management and biological variables. After 80 years, … a 1600% change in either treatment application rate or efficacy in arresting fire spread resulted in only a 10% change in total system carbon. This insensitivity of long-term carbon stocks is due in part by the infrequency of treatment/wildfire interaction and in part by the controls imposed by maximum forest biomass. None of the fuel treatment simulation scenarios resulted in increased system carbon.

Campbell, J, Agar, A (2013) Forest wildfire, fuel reduction treatments, and landscape carbon stocks: A sensitivity analysis. Journal of Environmental Management 121 (2013) 124-132 http://fes.forestry.oregonstate.edu/sites/fes.forestry.oregonstate.edu/files/PDFs/Campbell_2013_JEM.pdf

This graph shows that logging for fuel reduction rarely interacts with wildfire, which explains why the carbon emissions from widespread fuel reduction logging vastly exceeds the carbon emissions avoided in the rare cases where fuel reduction does interact favorably with wildfire.



There are now webtools available that can help the agencies deal with uncertainty surrounding the efficacy of fuel reduction. For instance, this web-based spreadsheet (http://getguesstimate.com/) allows users to create models with confidence intervals around input variables. Then it runs thousands of Monte Carlo simulations to come up with estimates of model behavior. The agencies could use this to better estimate the improbability that fuel treatments would interact with fire and estimate the improbable carbon benefits of fuel reduction logging.

Before attributing carbon benefits to fuel reduction logging please consider the conclusions of:

- John L Campbell, Mark E Harmon, and Stephen R Mitchell. 2011. Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions? Front Ecol Environ 2011; doi:10.1890/110057 http://forestpolicypub.com/wp-content/uploads/2011/12/campbell-2011.pdf. (Results suggest that the protection of one unit of C from wildfire combustion comes at the cost of removing three units of C in fuel treatments.)
- Mitchell, Harmon, O'Connell. 2009. Forest fuel reduction alters fire severity and long-term carbon storage in three Pacific Northwest ecosystems. Ecological Applications. 19(3), 2009, pp. 643–655. http://www.fs.fed.us/pnw/pubs/journals/pnw_2009_mitchell001.pdf. ("…reducing the fraction by which C is lost in a wildfire requires the removal of a much greater amount of C, since most of the C stored in forest biomass (stem wood, branches, coarse woody debris) remains unconsumed even by high-severity wildfires. For this reason, all of the fuel reduction treatments simulated for the west Cascades and Coast Range ecosystems as well as most of the treatments simulated for the east Cascades resulted in a reduced mean stand C storage…. We suggest that forest management plans aimed solely at ameliorating increases in atmospheric CO2 should forego fuel reduction treatments …")
- Reinhardt, Elizabeth, and Lisa Holsinger 2010. Effects of fuel treatments on carbon-disturbance relationships in forests of the northern Rocky Mountains. Forest Ecology and Management 259 (2010) 1427–1435. http://www.fs.fed.us/rm/pubs_other/rmrs_2010_reinhardt_e002.pdf ("Although wildfire emissions were reduced by fuel treatment, the fuel treatments themselves produced [carbon] emissions, and the untreated stands stored more carbon than the treated stands even after wildfire. … Our results show generally long recovery times …")
- Law, B. & M.E. Harmon 2011. Forest sector carbon management, measurement and verification, and discussion of policy related to mitigation and adaptation of forests to climate change. Carbon Management 2011 2(1). https://content.sierraclub.org/ourwildamerica/sites/content.sierraclub.org.ourwildamerica/files/documents/Law%20and%20Harmon%202011.pdf ("Thinning forests to reduce potential carbon losses due to wildfire is in direct conflict with carbon sequestration goals, and, if implemented, would result in a net emission of CO2 to the atmosphere because the amount of carbon removed to change fire behavior is often far larger than that saved by changing fire behavior, and more area has to be harvested than will ultimately burn over the period of effectiveness of the thinning treatment.")
- Restaino, Joseph C.; Peterson, David L. 2013. Wildfire and fuel treatment effects on forest carbon dynamics in the western United States. Forest Ecology and Management 303:46-60. http://www.fs.fed.us/pnw/pubs/journals/pnw_2013_restiano001.pdf ("… C costs associated with fuel treatments have can exceed the magnitude of C reduction in wildfire emissions, because a large percentage of biomass stored in forests (i.e., stem wood, branches, coarse woody debris) remains unconsumed, even in high-severity fires (Campbell et al., 2007; Mitchell et al., 2009). … Wildfire occurrence in a given area is uncertain and may never interact with treated stands with reduced fire hazard, ostensibly negating expected C benefits from fuel treatments. Burn probabilities in treated stands in southern Oregon are less than

2%, so the probability that a treated stand encounters wildfire and creates C benefits is low (Ager et al., 2010).)"

- Goslee, K., Pearson, T., Grimland, S., Petrova, S., Walls, J., Brown, S., 2010. Final Report on WESTCARB Fuels Management Pilot Activities in Lake County, Oregon. California Energy Commission, PIER. DOE Contract No.: DE-FC26-05NT42593. http://uc-ciee.org/downloads/Fuels_Management_LakeCo.pdf; AND Pearson, T.R.H., Goslee, K., Brown, S., 2010. Emissions and Potential Emission Reductions from Hazardous Fuel Treatments in the WESTCARB Region. California Energy Commission, PIER. CEC-500-2014-046. http://www.energy.ca.gov/2014publications/CEC-500-2014-046/CEC-500-2014-046-AP.pdf. (Summarized by Restaino & Peterson (2013) as follows: "Pearson et al. (2010) and Goslee et al. (2010) developed methodologies to evaluate C dynamics associated with fuel treatment projects in low to mid-elevation forest in northern California and Oregon. The authors, with consultation from teams of scientists, quantify C storage and release within the context of a six-point conceptual framework: annual fire risk, treatment emissions, fire emissions, forest growth and re-growth, re-treatment, and the shadow effect (i.e., treatment effect outside the treated area). Results indicate that the mean annual probability of wildfire for the study region is less than 0.76%/year, and treatments reduce C stocks by an average of 19%. Where timber is removed, 30% of extracted biomass is stored in long-lasting wood products. Wildfire emissions in treated stands, quantified with the Fuel Characteristic Classification System, are reduced by 6% relative to untreated stands. Growth estimates for a 60-year simulation horizon, derived from FVS, indicate that in the absence of wildfire, untreated stands sequester 17% more C than treated stands. However, in simulations that include wildfire, treated stands sequester 63% more C than untreated stands. The shadow effect is unlikely to be large enough to affect net GHG emissions. In summary, initial reductions in C stocks (e.g., thinning), combined with low annual probability of wildfire, preclude C benefits associated with fuel treatments, even if harvest residues are used for biomass energy.")
- Chiono, Lindsay 2011. Balancing the Carbon Costs and Benefits of Fuels Management. Research Synthesis for Resource Managers. Joint Fire Science Program Knowledge Exchange. http://static1.squarespace.com/static/545a90ede4b026480c02c5c7/t/5527ebd9e4b0f620d0cb5b58/1428679641640/CFSC_Chiono_Carbon_and_Fuel_Mngmt.pdf ("[T]he net carbon impact of fuel treatments is further complicated by the probabilistic nature of wildfire occurrence and the impermanence of post-treatment stand conditions … [T]reatment activities produce an immediate carbon emission while future wildfire emissions are uncertain … Depending on the intensity of treatment, the quantity of carbon removed may be substantial enough to negate gains from avoided wildfire emissions. … cumulative emissions from fuels reduction activities repeated in order to maintain low hazard conditions over time can overwhelm avoided wildfire emissions, resulting in a net carbon loss.")
- Dina Fine Maron 2010. FORESTS: Researchers find carbon offsets aren't justified for removing understory (E&E Report 08/19/2010, reporting on the WESTCARB Project) https://pacificforest.org/pft-in-the-media-2010-climatewire-8-19-10.html. ("'The take-home message is we could not find a greenhouse gas benefit from treating forests to reduce the risk of fire,' said John Kadyszewski, the principal investigator for the terrestrial sequestration projects of the West Coast Regional Carbon Sequestration Partnership. WESTCARB, ... Since there is a relatively low risk of fire at any one site, large areas need to be treated --

which release their own emissions in the treatment process. The researchers have concluded that the expected emissions from treatments to reduce fire risk exceed the projected emissions benefits of treatment for individual projects.”)

- Rachel A. Loehman, Elizabeth Reinhardt, Karin L. Riley 2014. Wildland fire emissions, carbon, and climate: Seeing the forest and the trees – A cross-scale assessment of wildfire and carbon dynamics in fire-prone, forested ecosystems. Forest Ecology and Management 317 (2014) 9–19. http://www.fs.fed.us/rm/pubs_other/rmrs_2014_loehman_r001.pdf (“… management of carbon in fire-prone and fire-adapted forests is more complex than simply minimizing wildfire carbon emissions and maximizing stored carbon in individual stands. The stochastic and variable nature of fires, the relatively fine scale over which fuels treatments are implemented, and potentially high carbon costs to implement them suggest that fuel treatments are not an effective method for protecting carbon stocks at a stand level (Reinhardt et al., 2008; Reinhardt and Holsinger, 2010).”)
- Jim Cathcart, Alan A. Ager, Andrew McMahan, Mark Finney, and Brian Watt 2009. Carbon Benefits from Fuel Treatments. USDA Forest Service Proceedings RMRS-P-61. 2010.
- Chiono, L. A., D. L. Fry, B. M. Collins, A. H. Chatfield, and S. L. Stephens. 2017. Landscape-scale fuel treatment and wildfire impacts on carbon stocks and fire hazard in California spotted owl habitat. Ecosphere 8(1):e01648. 10.1002/ecs2.1648. http://onlinelibrary.wiley.com/doi/10.1002/ecs2.1648/full (“We used a probabilistic framework of wildfire occurrence to (1) estimate the potential for fuel treatments to reduce fire risk and hazard across the landscape and within protected California spotted owl (Strix occidentalis occidentalis) habitat and (2) evaluate the consequences of treatments with respect to terrestrial C stocks and burning emissions. Silvicultural and prescribed fire treatments were simulated on 20% of a northern Sierra Nevada landscape in three treatment scenarios … [A]ll treatment scenarios resulted in higher C emissions than the no-treatment scenarios.”)

Mitchell, Harmon, O'Connell. 2009. Forest fuel reduction alters fire severity and long-term carbon storage in three Pacific Northwest ecosystems. Ecological Applications. 19(3), 2009, pp. 643–655 http://www.fs.fed.us/pnw/pubs/journals/pnw_2009_mitchell001.pdf

> ABSTRACT:... Our simulations indicate that fuel reduction treatments in these ecosystems consistently reduced fire severity. However, reducing the fraction by which C is lost in a wildfire requires the removal of a much greater amount of C, since most of the C stored in forest biomass (stem wood, branches, coarse woody debris) remains unconsumed even by high-severity wildfires. For this reason, all of the fuel reduction treatments simulated for the west Cascades and Coast Range ecosystems as well as most of the treatments simulated for the east Cascades resulted in a reduced mean stand C storage. One suggested method of compensating for such losses in C storage is to utilize C harvested in fuel reduction treatments as biofuels. Our analysis indicates that this will not be an effective strategy in the west Cascades and Coast Range over the next 100 years. We suggest that forest management plans aimed solely at ameliorating increases in atmospheric CO2 should forego fuel reduction treatments in these ecosystems, with the possible exception of some east Cascades Ponderosa pine stands with uncharacteristic levels of understory fuel accumulation. Balancing a demand for maximal landscape C

storage with the demand for reduced wildfire severity will likely require treatments to be applied strategically throughout the landscape rather than indiscriminately treating all stands.

Notes on Mitchell & Harmon:

a. The authors assumed that fire severity was determined exclusively by fuel variables but not weather. This may over-estimate the efficacy of fuel treatments on fire severity. The conclusion that fuel manipulation leads to reduced fire behavior may be an unavoidable result of the assumptions, rather than a reflection of reality.
b. The only treatment that showed some promise was understory removal (not canopy removal) in fire-suppressed dry pine stands, but the carbon storage benefit from reduced fire severity in this best case scenario was minuscule, only about 0.6-1.2%. The modeled treatments on the eastside of the Cascades failed to include canopy removal which is a common practice in fuel reduction efforts and one that removes more carbon than understory treatments.

This latter point is reinforced by Matt Hurteau (2015 blog post)

> … we found that the treatments that included only burning or only thinning small trees recaptured the carbon that was lost from treatment in ten years. The treatment that included thinning *small trees* and burning still had less carbon than it did initially, indicating that we need to keep some *more medium-sized trees*. The treatments that harvested *big trees* still have a carbon debt from treatment. This work provides additional evidence that we can restore these fire-prone forests without having too big an impact on the climate, as long as the trees keep growing.

New Paper - The Carbon Balance of Reducing Wildfire Risk 10-years After Treatment. 8/3/2015. http://www.hurteaulab.org/blog/new-paper-the-carbon-balance-of-reducing-wildfire-risk-10-years-after-treatment. See also, Wiechmann, ML, MD Hurteau, MP North, GW Koch, L Jerabkova. 2015. The carbon balance of reducing wildfire risk and restoring process: an analysis of 10-year post-treatment carbon dynamics in a mixed-conifer forest. Climatic Change, 132:709-719. https://www.fs.fed.us/psw/publications/north/psw_2015_north002_wiechmann.pdf ("Retaining additional midsized trees may reduce the carbon impacts of understory thinning and burning.")

Similar results were found at the stand scale by Reinhardt and Holsinger (2010):

> We simulated effects of fuel treatments on 140 stands representing seven major habitat type groups of the northern Rocky Mountains using the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS). Changes in forest carbon due to mechanical fuel treatment (thinning from below to reduce ladder fuels) and prescribed fire were explored, as well as changes in expected fire behavior and effects of subsequent wildfire. Results indicated that fuel treatments decreased fire severity and crown fire occurrence and reduced subsequent wildfire emissions, but did not increase post-wildfire carbon stored on-site. Conversely, untreated stands had greater wildfire emissions but stored more carbon. … The results do not support the use of fuel treatments soley to protect carbon

stocks or reduce emissions. Although wildfire emissions were reduced by fuel treatments, the fuel treatments themselves produced emissions, and the untreated stands stored more carbon than the untreated stands even after wildfire. [and even considering carbon stored in wood products derived from treated stands.]

Reinhardt, Elizabeth, and Lisa Holsinger 2010. Effects of fuel treatments on carbon-disturbance relationships in forests of the northern Rocky Mountains. Forest Ecology and Management 259 (2010) 1427–1435.

And by Campbell, Harmon & Mitchell 2011.

Abstract

It has been suggested that thinning trees and other fuel-reduction practices aimed at reducing the probability of high-severity forest fire are consistent with efforts to keep carbon (C) sequestered in terrestrial pools, and that such practices should therefore be rewarded rather than penalized in C-accounting schemes. By evaluating how fuel treatments, wildfire, and their interactions affect forest C stocks across a wide range of spatial and temporal scales, we conclude that this is extremely unlikely. Our review reveals high C losses associated with fuel treatment, only modest differences in the combustive losses associated with high-severity fire and the low-severity fire that fuel treatment is meant to encourage, and a low likelihood that treated forests will be exposed to fire. Although fuel-reduction treatments may be necessary to restore historical functionality to firesuppressed ecosystems, we found little credible evidence that such efforts have the added benefit of increasing terrestrial C stocks.

...

In a nutshell:

• Carbon (C) losses incurred with fuel removal generally exceed what is protected from combustion should the treated area burn

• Even among fire-prone forests, one must treat about ten locations to influence future fire behavior in a single location

• Over multiple fire cycles, forests that burn less often store more C than forests that burn more often

• Only when treatments change the equilibrium between growth and mortality can they alter long-term C storage

…

Conclusions

Across a range of treatment intensities, the amount of C removed in treatment was typically three times that saved by altering fire behavior.

…

the protection of one hectare of forest from wildfire required the treatment of 10 hectares, owing not to the low efficacy of treatment but rather to the rarity of severe wildfire event.

…

Long-term simulations of forest growth, decomposition, and combustion illustrate how, despite a negative feedback between fire frequency and fuel-driven severity, a regime of low-frequency, high-severity fire stores more C over time than a regime of high-frequency, low-severity fire.

John L Campbell, Mark E Harmon, and Stephen R Mitchell. 2011. Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions? Front

Ecol Environ 2011; doi:10.1890/110057 http://forestpolicypub.com/wp-content/uploads/2011/12/campbell-2011.pdf It is important to recognize that "the equilibrium between growth and mortality" must consider all forms of mortality, not just that caused by fire, but also mortality caused by logging.

Restaino & Peterson (2013) conducted a literature review of this issue and reported:

> "All studies agree unequivocally that untreated stands release more emissions to the atmosphere during wildfire than treated stands…. However, most studies in this review include assumptions of future wildfire frequency and probability that skew long-term trade-off analyses by overestimating the ability of fuel treatments to reduce wildfire emissions over long time scales. For example, fuel treatments have a finite life expectancy, and fire hazard increases over time as fuels accumulate in treated areas. Repetition and maintenance of fuel treatments are necessary in order to effectively maintain reduced fire hazard over time (Peterson et al., 2005; Johnson et al., 2007, 2011) and thus must be included in analyses of long-term C storage. Although Rhodes and Baker (2008) suggest that 2.0–4.2% of areas treated to reduce surface fuels are likely to encounter wildfires that would otherwise be high or moderate-high severity without treatment, most studies assume future wildfire probability of 100%, reporting inferences that essentially detail a ''best-case scenario'' for wildfire missions mitigation. Annual probability of wildfire in dry temperate forests for a given stand is approximately 1% (Ager et al., 2010; Pearson et al., 2010; Campbell et al., 2011). … To benefit total ecosystem C storage, the removal and release of C through fuel treatments must not exceed the expected reductions in wildfire emissions. Substantial treatment costs through timber harvest, prescribed fire, and milling waste exceed observed and simulated reductions in wildfire emissions. … The ability of fuel treatments to mitigate future fire behavior and move forest structure to a more fire-resistant condition is well documented. However, C costs associated with fuel treatments have can exceed the magnitude of C reduction in wildfire emissions, because a large percentage of biomass stored in forests (i.e., stem wood, branches, coarse woody debris) remains unconsumed, even in high-severity fires (Campbell et al., 2007; Mitchell et al., 2009). … Wildfire occurrence in a given area is uncertain and may never interact with treated stands with reduced fire hazard, ostensibly negating expected C benefits from fuel treatments. Burn probabilities in treated stands in southern Oregon are less than 2%, so the probability that a treated stand encounters wildfire and creates C benefits is low (Ager et al., 2010).)

Restaino, Joseph C.; Peterson, David L. 2013. Wildfire and fuel treatment effects on forest carbon dynamics in the western United States. Forest Ecology and Management 303:46-60. http://www.fs.fed.us/pnw/pubs/journals/pnw_2013_restiano001.pdf. Keep in mind that even if climate change increases fire frequency, it might not make a big difference, because fire frequency is low and multiple of small numbers are still small numbers. The peer review of the NWFP Science Synthesis (p 63) says:

> Use caution with this argument about increasing fire activity being specially important on the wetter side of the study area. We hear this claim (even in a few scientific papers) that the % increase in fire frequency could be highest on the west side compared to the east side. But remember, we are dealing with exceedingly low burn probabilities on the west side as it is – e.g., fire rotations of 300-800 years so annual burn probabilities of 0.0033 to 0.0013. So an X% increase in fire probability on the west side amounts to multiplying a very small number which will still yield a very small number. Arguably, an X% increase in burn probabilities is more important on the east side because the higher current fire probabilities mean greater increases in actual burn acreage.

Ecological Society of America. 7 April 2017. Peer review of the NWFP Science Synthesis. https://www.fs.fed.us/pnw/research/science-synthesis/ESA%20Peer%20review%20nwfp%20synthesis%20final%20all.pdf.

Lindsay Chiono (2011) of the Wildland Fire Science Laboratory at UC Berkeley prepared a synthesis of the research for resource managers and said:

> [T]he net carbon impact of fuel treatments is further complicated by the probabilistic nature of wildfire occurrence and the impermanence of post-treatment stand conditions … [T]reatment activities produce an immediate carbon emission while future wildfire emissions are uncertain … Depending on the intensity of treatment, the quantity of carbon removed may be substantial enough to negate gains from avoided wildfire emissions. East of the Cascade crest in Oregon, a modeling study of carbon dynamics that included modeled wildfires found that while understory removal treatments slightly enhanced carbon storage over the long term, higher levels of biomass removal reduced mean ecosystem carbon (Mitchell et al., 2009)." … [W]hen treatments must be repeated in the interim between wildfires in order to maintain low hazard conditions. Similarly, when wildfire frequency is low, the quantity of carbon removed in treatments over time can overwhelm likely wildfire losses. Net emissions were most pronounced in the west Cascades where historical fire return intervals were very long… [I]n southern Oregon and northern California, Goslee and others (2010) took an approach that incorporates the stochastic nature of wildfire occurrence. Rather than scheduling a wildfire event soon after fuel treatment, a calculation that maximizes treatment benefits, they used an estimate of the local fire return interval for the period of 2001 to 2008 -- an annual burn probability of 0.6% -- to assess carbon emissions. Partly owing to this low wildfire risk, they found that fuel treatments, which included commercial timber harvest and pile burning of noncommercial biomass, produced an effective immediate net emission of 10-20.8 tons of carbon per acre. … [S]ome general principles have begun to emerge. Achieving a net carbon gain appears more likely when the quantity of carbon removed during treatment is minimized, when harvested biomass is converted to long-lived wood products, and where the risk of wildfire occurrence is high… Conversely, cumulative emissions from fuels

> reduction activities repeated in order to maintain low hazard conditions over time can overwhelm avoided wildfire emissions, resulting in a net carbon loss.

Chiono, Lindsay 2011. Balancing the Carbon Costs and Benefits of Fuels Management. Research Synthesis for Resource Managers. Joint Fire Science Program Knowledge Exchange. https://static.squarespace.com/static/50083efce4b0c6fedbca9def/t/51632bf8e4b00b25a8fa21d3/1365453816037/CFSC_Chiono_Carbon_and_Fuel_Mngmt.pdf

Even the Chief of the Forest Service recognizes these trade-offs. "[M]anagement practices, designed to restore ecosystem health, may in the near-term reduce total stored carbon below current levels." Gail Kimball, March 2009 Testimony before House Committee On Natural Resources, Subcommittee On National Parks, Forests, And Public Lands. http://www.fs.fed.us/congress/111thCongress/Documents/CY%202009%20Hearings/HNRC%202009-03-03%20Climate%20Change/2009-03-03A.Kimbell.pdf.

> Strategies for reducing carbon dioxide emissions include substitution of fossil fuel with bioenergy from forests, where carbon emitted is expected to be recaptured in the growth of new biomass to achieve zero net emissions, and forest thinning to reduce wildfire emissions3. Here, we use forest inventory data to show that fire prevention measures and large-scale bioenergy harvest in US West Coast forests
> lead to 2–14% (46–405 Tg C) higher emissions compared with current management practices over the next 20 years.
> …
> In our study region, we found that thinning reduced NBP under all three treatment scenarios for 13 of the 19 ecoregions, representing 90% of the region's forest area. The exceptions where NBP was not reduced were primarily due to high initial fire emissions compared to NEP (for example, Northern Basin and North Cascades; Supplementary Fig. S2). The dominant trend at the ecoregion level was mirrored at the regional level, with the bioenergy production scenario (highest thinning level) resulting in the region becoming a net carbon source (Supplementary Table S2 and discussion of state-level estimates). Regionally, forest biomass removals exceeded the potential losses from forest fires, reducing the in situ forest carbon sink even after accounting for regrowth, as found in previous studies with different approaches or areas of inference8,18. Because we have assumed high reductions in fire emissions for the areas treated in each scenario, it is unlikely we are underestimating the benefit of preventive thinning on NBP.

Tara W. Hudiburg, Beverly E. Law, Christian Wirth, and Sebastiaan Luyssaert. 2011. Regional carbon dioxide implications of forest bioenergy production. Nature - Climate Change. Letters. 23 OCTOBER 2011 | DOI: 10.1038/NCLIMATE1264. http://www.dnr.wa.gov/Publications/em_fp_biomass_regional_carbon_dioxide_implications_of_forest_bioenergy_production.pdf

> Recent studies (Hurteau and North, 2008, 2010; Hurteau et al., 2008a; North et al., 2009; Reinhardt and Holsinger, 2010) have focused on carbon responses to fire in individual forest stands as a basis for gaining insight into terrestrial-atmospheric carbon fluxes. Suggested management treatments to protect, maintain, or enhance forest carbon stocks forest carbon stores include mechanical fuels treatments, prescribed fire, and suppression of wildfires (Canadell and Raupach, 2008; Hurteau and North, 2008, 2010; Hurteau et al., 2008b; McKinley et al., 2011; Stephens et al., 2012). Results from these studies suggest that fuel treatments can reduce wildfire severity and protect forest carbon stocks from future loss from severe wildfires (Hurteau and North, 2008; Hurteau et al., 2008b; Stephens et al., 2009b), but management of carbon in fire-prone and fire-adapted forests is more complex than simply minimizing wildfire carbon emissions and maximizing stored carbon in individual stands. The stochastic and variable nature of fires, the relatively fine scale over which fuels treatments are implemented, and potentially high carbon costs to implement them suggest that fuel treatments are not an effective method for protecting carbon stocks at a stand level (Reinhardt et al., 2008; Reinhardt and Holsinger, 2010).

Rachel A. Loehman, Elizabeth Reinhardt, Karin L. Riley 2014. Wildland fire emissions, carbon, and climate: Seeing the forest and the trees – A cross-scale assessment of wildfire and carbon dynamics in fire-prone, forested ecosystems. Forest Ecology and Management 317 (2014) 9–19. http://www.fs.fed.us/rm/pubs_other/rmrs_2014_loehman_r001.pdf

North and Hurteau (2009) note that the carbon costs of fuel reduction may be mitigated by focusing on small fuels -

> When evaluating carbon released by different fuels treatments, managers will need to weigh tradeoffs between immediate prescribed burn emissions, increased fuel reduction with thinning and an increase in milling waste, and potential future wildfire emissions. … Previous Teakettle studies (Innes et al. 2006, North et al. 2007, Hurteau and North 2009) coupled with this research suggest treatments could be modified to more effectively minimize carbon stock reductions while still significantly reducing fuels and promoting large tree development. Significant increases in wildfire resistance can be achieved by thinning only smaller ladder fuels and fire-sensitive intermediate trees without reducing the majority of the live-tree carbon pool in intermediate pines and large trees of all species. … Thinning and prescribed fire treatments that reduce small tree densities may influence stand development by redirecting growth resources and carbon storage into more stable stocks such as large, long-lived fire-resistant pines (Hurteau and North 2009). … Our research suggests most of the benefits of increased stand-level fire resistance can be achieved with small reductions in carbon pools.

North, Hurteau, Innes. 2009. Fire suppression and fuels treatment effects on mixed-conifer carbon stocks and emissions. Ecological Applications, 19(6), 2009, pp. 1385–1396.

http://www.plantsciences.ucdavis.edu/affiliates/north/Publications/Eco%20Apps%20article%20North%20et%20al%20Fuel%20treatments%20forest%20carbon.pdf

The NEPA analysis should also recognize that as the climate warms, fire occurrence becomes more decoupled from fuel conditions. There is almost always enough fuel to carry fire. The agency can never remove so much fuel as to "prevent" fire, while climate conditions will become more conducive to fire (e.g. longer fire season) regardless of fuel conditions.

Avoid "before-and-after" carbon accounting

Some NEPA analyses say that logging is *carbon neutral* because the forest captures and stores the same pre-harvest amount of carbon after a period of regrowth. This is highly misleading. The proper analysis requires comparison of the amount of carbon *with* the project and *without* the project, not *before* and *after* logging. This is not only required to accurately determine the effect of vegetation removal on forest carbon storage but it is also consistent with NEPA requirements to compare *action* and *no action* alternatives.

> The only way to properly evaluate the net carbon impacts of energy from forest biomass [or any vegetation management] is to estimate … net change in atmospheric CO_2 levels over time *with* and *without* the harvest of wood biomass for energy. …[I]t is necessary to construct a baseline, or control, scenario (that is no biomass harvest). … Once a baseline is established, one can assess how switching to wood biomass would change atmospheric carbon levels. … [T]he information provided by only comparing forest carbon stocks before and after biomass harvest could be a very misleading indicator of the impact of biomass energy on the atmosphere.

Cardellichio, P., Walker, T. 2010. Commentary: The Manomet Study Got the Biomass Carbon Accounting Right. The Forestry Source. 4 Nov 2010. https://web.archive.org/web/20110420145203/http://www.nxtbook.com:80/nxtbooks/saf/forestrysource_201011/index.php.

Even a before-after ecological study design should emply a control. See Krebs, C. J. 1999. Ecological methodology. Second edition. Addison Wesley Longman Inc, Menlo Park, California, USA.

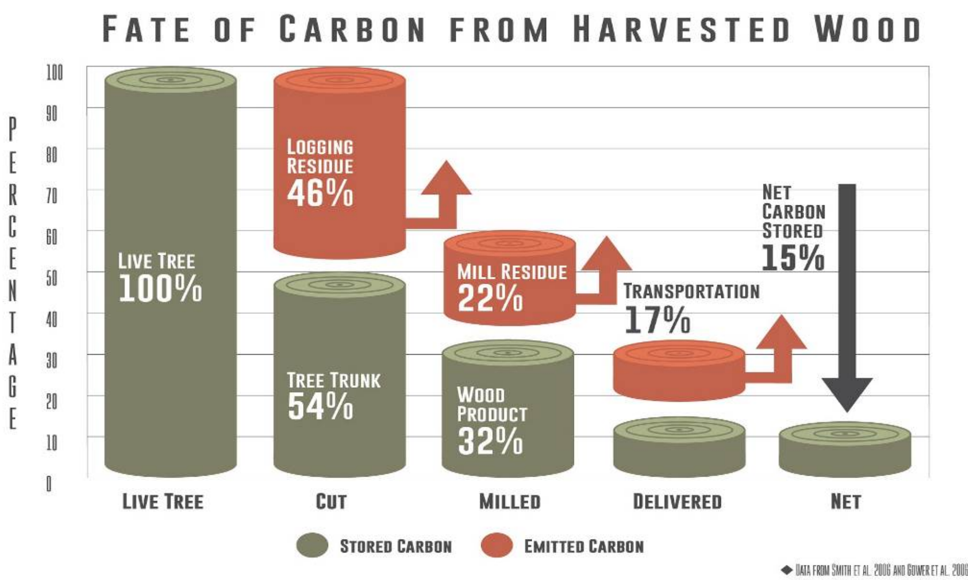
The Carbon Value of Wood Products is Over-estimated.

Forest Service NEPA analyses often state "Utilizing trees to create long-lived wood products sequesters carbon (IPCC 2007) (FAO 2007) (Stavins 2005) (Upton 2007). Some have shown that using wood to build houses has a more favorable carbon balance when compared to other building materials such as steel, concrete or plastic (Wilson 2006)." This is inaccurate and misleading.

From a climate perspective, wood products represent net carbon emissions, NOT net carbon sequestration, because only a small fraction of the carbon in a logged forest ends up in wood products. Logging to create wood products causes the majority of forest carbon to be transferred to the atmosphere, not to wood products. Science clearly shows that carbon is more safely stored in forests, not in wood products.

Some argue that wood products are a good place to store carbon. This is a counter-productive climate strategy, because –

Only a small fraction of carbon from logged forests ends up in long-term storage in wood products, most is transferred to the atmosphere. Of all the carbon that is killed and/or exposed to accelerated decay in a logging operation only a small fraction ends up as durable goods and buildings -- most ends up as slash, sawdust, waste/trim, hog fuel, and non-durable goods like paper. Some say that converting forest to wood products "delays" emissions, but in fact logging accelerates emissions because they are the result of a process that kills trees that would continue to actively sequester carbon if not logged, and logging involves tremendous waste in the logging process, milling process, construction/manufacturing process.



Carbon remains stored much longer in forests than in wood products. Much of the wood products which can reasonably be considered "durable" are in fact less durable than leaving the carbon stored safely inside a mature tree that might live to be hundreds of years old. Most of our wood products are disposable. It turns out that well-conserved forests on average store carbon more securely than our “throw-away” culture and economy does. Law, B. & M.E. Harmon 2011. Forest sector carbon management, measurement and verification, and discussion of policy related to mitigation and adaptation of forests to climate change. Carbon Management 2011 2(1). https://content.sierraclub.org/ourwildamerica/sites/content.sierraclub.org.ourwildamerica/files/do cuments/Law%20and%20Harmon%202011.pdf ("To the extent that management can direct carbon into longer lived pools, it can increase the stores of carbon in the forest sector. Harvest of carbon is one proposed strategy to increase carbon stores. However, harvesting carbon will increase the losses from the forest itself and to increase the overall forest sector carbon store, the lifespan of wood products carbon (including manufacturing losses) would have to exceed that of the forest. Under current practices this is unlikely to be the case. A substantial fraction (25–65%) of harvested carbon is lost to the atmosphere during manufacturing and construction depending on the product type and manufacturing method. The average lifespan of wood buildings is 80 years in the USA, which is determined as the time at which half the wood is no longer in use and either decomposes, burns or, to a lesser extent, is recycled. However, many forest trees have the potential to live hundreds of years (e.g. 800 years in the Pacific northwest USA). Mortality rates of trees are generally low, averaging less than 2% of live mass per year in mature and old forests; for example, in Oregon, mortality rates average 0.35–1.25% in forests that are older than 200 years in the Coast Range and Blue Mountains, respectively [8]. Moreover, the average longevity of dead wood and soil carbon is comparable to that of live trees. When the loss of carbon associated with wood products manufacturing is factored in, it is highly unlikely that harvesting carbon and placing it into wood products will increase carbon stores in the overall forest sector. This explains why in all analyses conducted to date, wood products stores never form the majority of total forest sector stores.")

Reliance on wood products prevents forests from reaching their potential for carbon storage. Shanks (2008) said "There are also losses of carbon that occur during the creation of forest products. These losses to decay and wood products make carbon sequestration slower when harvesting is allowed. The young timberlands that replace older harvested lands grow quickly, but hold less in total carbon stores than their older counterparts; the net sequestration from forest products adds to total carbon stores, but does not come close to the vast amounts of carbon stored in non-harvested older timberlands. This finding differs from other papers that have shown that the highest carbon mitigation can be reached when high productivity lands are used exclusively for wood products creation (Marland and Marland, 1992). The wood products considered in these studies were either long lasting or used for fuel purposes. Allowing harvested timber to be allocated to all types of wood products increases carbon emissions and results in no harvest regimes sequestering more carbon." Alyssa V. Shanks. 2008. Carbon Flux Patterns on U.S. Public Timberlands Under Alternative Timber Harvest Policies. MS Thesis. March 2008. http://ir.library.oregonstate.edu/dspace/bitstream/1957/8326/1/A_Shanks_Thesis_04%2002%2008_final.pdf.

"[W]ood product usage is reducing the potential annual sink by an average of 21%, suggesting forest carbon storage can become more effective in climate mitigation through reduction in harvest, longer rotations, or more efficient wood product usage. ... Allowing forests to reach their biological potential for growth and sequestration, maintaining large trees (Lutz et al 2018), ...

will remove additional CO2 from the atmosphere. Global vegetation stores of carbon are 50% of their potential including western forests because of harvest activities (Erb et al 2017). Clearly, western forests could do more to address climate change through carbon sequestration if allowed to grow longer." Tara W Hudiburg, Beverly E Law, William R Moomaw, Mark E Harmon and Jeffrey E Stenzel 2019. Meeting GHG reduction targets requires accounting for all forest sector emissions. 23 August 2019. Environmental Research Letters, Volume 14, Number 9. https://iopscience.iop.org/article/10.1088/1748-9326/ab28bb/pdf.

The amount of carbon missing from our forests vastly greater than the amount of carbon that can be accounted for in wood products storage. BLM's Western Oregon Plan Revision FEIS shows that decades of converting old growth forests to plantations has reduced current forest carbon stores on BLM lands in western Oregon by 149 million tons, while some of that wood was converted into wood products, only 11 million tons of that carbon remains stored in wood products today, so logging our public forests to make wood products results in approximately 13 times more carbon emissions than carbon storage. This is pieced together from WOPR FEIS Figures 3-17 (p 3-221) and Figure 3-18 (p 3-224). Further logging of mature forests will exacerbate this outcome.

A lot of wood products are "stored" in landfills where they emit methane which has a global warming effect much greater than CO2. Ingerson, A. 2009 Wood Products and Carbon Storage: Can Increased Production Help Solve the Climate Crisis? Washington, D.C.: The Wilderness Society. http://web.archive.org/web/20100601080813/http://wilderness.org/files/Wood-Products-and-Carbon-Storage.pdf. ("Key Points - 1. When wood is removed from the forest, most of it is lost during processing. The amount lost varies tremendously by region, tree species and size, and local infrastructure. 2. The majority of long-term off-site wood carbon storage occurs in landfills, where decomposing wood gives off significant amounts of methane, a gas with high global warming potential. 3. In addition to wood processing losses, fossil fuels are required to turn raw logs into finished products and ship them from forest to mill to construction site to landfill. 4. Once wood losses and fossil emissions are accounted for, the process of harvesting wood and turning it into products may release more greenhouse gases than the emissions saved by storing carbon in products and landfills. … 9. Properly managed, wood can be a renewable source of building materials and fuels, but solving the climate crisis will require reducing the use of all materials and energy.")

Living trees, even if they are "suppressed" store and accumulate carbon better than dead wood products. Even a suppressed tree stores carbon better than a dead tree after it is logged, limbed, bucked, debarked, milled, planed, processed, trimmed, manufactured, used, and then discarded. Recent evidence shows that slower-growing older trees tend to channel their energy into structural support and defense compounds to "maximize durability while minimizing … damage". Colbert & Pederson. 2008. Relationship between radial growth rates and lifespan within North American tree species. Ecoscience 15(3), 349-357 (2008). http://fate.nmfs.noaa.gov/documents/Publications/Black_et_al_2008_Ecoscience.pdf. See also, University of Montana. June 18, 2019. Cell structure linked to longevity of slow-growing Ponderosa Pines. https://www.sciencedaily.com/releases/2019/06/190618174358.htm ("Slow-growing ponderosa pines may have a better chance of surviving longer than fast-growing ones, especially as climate change increases the frequency and intensity of drought, according to new research from the University of Montana. ... [A] key difference between fast and slow growers resides in a microscopic valve-like structure between the cells that transport water in the wood, called the pit membrane. The unique shape of this valve in slow-growing trees provides greater safety against drought, but it slows down water transport, limiting growth rate.") *citing* Beth Roskilly, Eric Keeling, Sharon Hood, Arnaud Giuggiola, Anna Sala. Conflicting functional effects of xylem pit structure relate to the growth-longevity trade-off in a conifer species. Proceedings of the National Academy of Sciences, 2019; 201900734 DOI: 10.1073/pnas.1900734116.

The "substitution" value of wood products is vastly over-estimated. The timber industry must not be allowed to continue business-as-usual and call it "climate friendly" because logging mature & old-growth forests on public lands and short-rotation clear-cutting on private lands are NOT climate friendly. Many in the timber industry like to promote logging as a solution to climate change because (they say) building with wood helps off-set construction using alternative materials such as steel and cement that may release more CO_2 during their manufacture. (See e.g., CORRIM analysis, http://www.corrim.org/reports/2005/swst/140.pdf , http://www.masonbruce.com/wfe/2004Program/1B1_Bruce_Lippke.pdf) Others appropriately promote protection of mature and old-growth forests as more reliable ways to store carbon in forests and long-rotation forestry as the most appropriate way to obtain wood products. It's absurd to conclude that we can continue to destroy our forests to save the climate. Life on earth, especially forests, are the bilge pump that keeps our climate boat afloat.

The timber industry vastly over-states the alleged climate benefit of storing carbon in wood products or using wood as a *substitute* for alternative building materials. While wood may be preferable to other materials in some applications and there is a grain of truth in the substitution analysis, the timber industry's efforts to show a "substitution" benefit from short-rotation forestry is severely flawed. Most of the analyses that tout this effect are produced and advocated by the timber industry with unreasonable assumptions that don't stand up to scrutiny. Note that the mission of the CORRIM group is to promote the use of wood products, not to develop sound forest policy or climate policy. The substitution argument is an example of the timber industry carefully choosing assumptions to guarantee a certain result and then stopping the analysis short of a complete picture of the issue.

> Substitution of wood for more fossil carbon intensive building materials has been projected to result in major climate mitigation benefits often exceeding those of the forests themselves. A reexamination of the fundamental assumptions underlying these projections indicates long-term mitigation benefits related to product substitution may have been overestimated 2- to 100-fold. This suggests that while product substitution has limited climate mitigation benefits, to be effective the value and duration of the fossil carbon displacement, the longevity of buildings, and the nature of the forest supplying building materials must be considered. ... Conversion of older, high carbon stores forests to short rotation plantations would over the long term likely lead to more carbon being added to the atmosphere despite some of the harvested carbon being stored and production substitution occurring.

Mark E Harmon 2019. Have product substitution carbon benefits been overestimated? A sensitivity analysis of key assumptions. Environ. Res. Lett. *in press* https://doi.org/10.1088/1748-9326/ab1e95.

The benefits of wood product substitution are vastly over-stated:

1) Wood, concrete and steel are not the only building materials. The analysis must consider a wider range of alternatives, including reducing demand for building materials. Or, what if we converted annual plants such as grasses into long-term storage in buildings? Here's an idea: Take a portion of the land devoted to growing subsidized livestock feed and instead grow annual or semi-annual fiber crops that are made into wood substitutes. Unlike wood from trees that could better protect the climate if allowed to grow and store carbon hundreds of years, these alternative fiber products will store carbon far longer than the annual lifecycle of the fiber crops. We can grant legitimate carbon credits to promote their use. Then we can let forests grow and help save the climate.

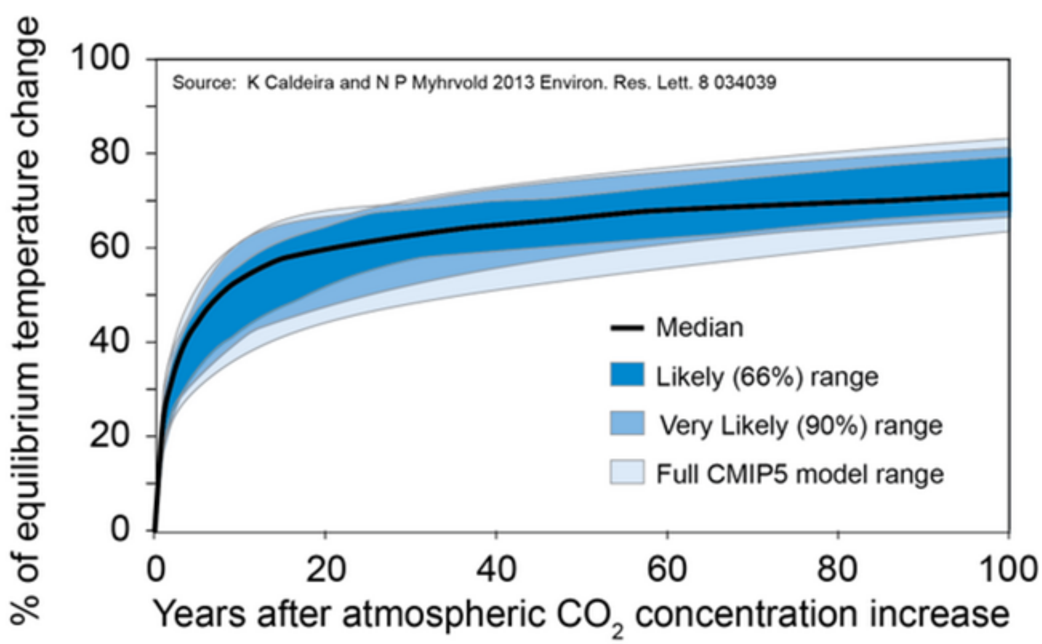
2) Buildings made of steel and concrete have longer useful lifespans than wood and might outperform wood, over the long term. A credible analysis of substitution must account for factors such as the time it takes to reabsorb the carbon after forests are logged, differences in the useful lifespan of different building materials (steel and cement typically last longer), the improving carbon efficiency of the energy input used to make alternative building materials, the possibility of demand-side policies such as recycling and "demand reduction."

3) Making cement does not require fossil fuels. It can be made with electricity which is becoming increasingly renewable. Ellis et al 2019. Toward electrochemical synthesis of cement—An electrolyzer-based process for decarbonating $CaCO_3$ while producing useful gas streams. PNAS September 16, 2019 https://doi.org/10.1073/pnas.1821673116. https://www.pnas.org/content/pnas/early/2019/09/10/1821673116.full.pdf. In effect, the carbon footprint of steel and concrete shrink as the energy sector becomes decarbonized via expansion of wind and solar. Mooney 2016. Wind power is going to get a lot cheaper as wind turbines get

even more enormous. The Washington Post, Sept 12, 2016. https://www.washingtonpost.com/news/energy-environment/wp/2016/09/12/wind-power-is-going-to-get-a-lot-cheaper-as-wind-turbines-get-enormous/. Justin Gillis. NYT, October 16, 2019. The Steel Mill That Helped Build the American West Goes Green - Wind and solar power will replace coal at a Colorado furnace. https://www.nytimes.com/2019/10/16/opinion/solar-colorado-steel-mill.html?smtyp=cur&smid=tw-nytimesscience.

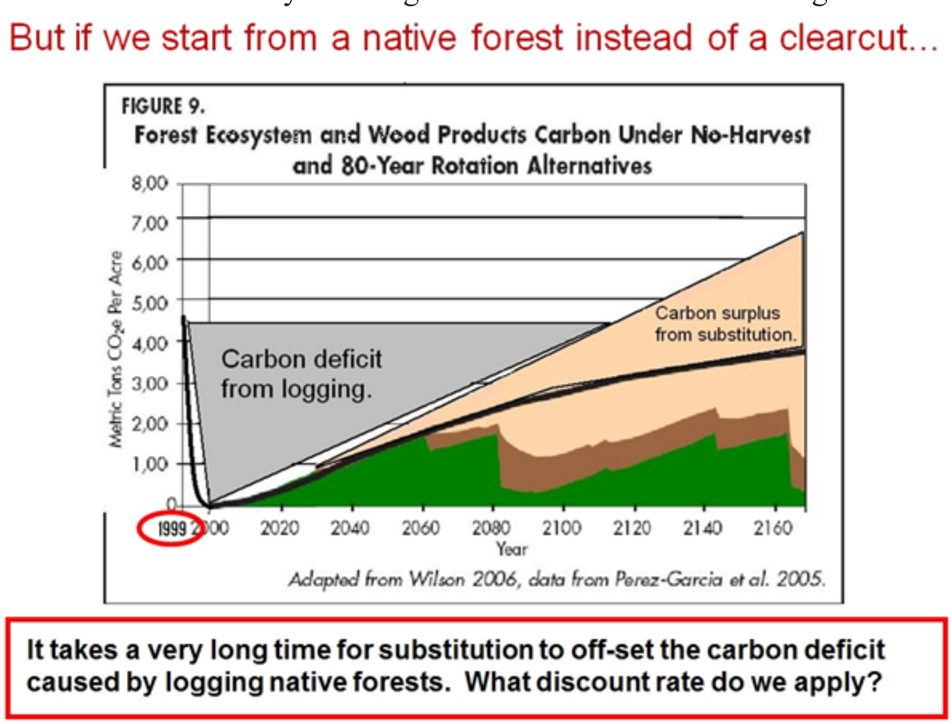
4) Substitution is speculative because the alleged benefits are in the distant future, and it takes more than a century to off-set the carbon emissions (carbon debt) caused by logging forests. Only a small fraction of the carbon in a logged forest ends up in long-term storage in wood products. Most of the carbon in a logged forest is subject to an accelerated transferred to the atmosphere where it causes warming and ocea acidification. For every ton of carbon stored in wood products, there are several times more carbon from the forest prematurely transferred to the atmosphere. Since the alleged carbon benefits from substitution are typically realized in the distant future and must be discounted. The CORRIM study appears to assume a 0% discount rate which is inconsistent with rational decision making because it effectively places no value on the carbon stored in forests in the short-term under a no-harvest scenario compared to a harvest scenario. Near-term carbon storage is critically important while the economy transitions to low carbon methods, yet it will take over a century for substitution to off-set the initial carbon deficit associated with logging mature forests.

Under well-established principles of discounting, it is clear that the net present value of current carbon storage in existing mature forests exceeds the net present value of distant future benefits of substitution. This graph shows why the near term matters (most of the warming happens within 20 years and then slowly continues to increase):



Related: the IPCC made a policy decision to place more value on the near-term because the majority of warming happens within 10-20 years after emissions. If it is true that we need to be more concerned about the near-term, then we can also say that forests are more valuable as places to store carbon and wood products are less valuable. This is because every effort to transfer carbon from the forest into wood products results in a net near-term pulse of carbon to the atmosphere, and this carbon "debt" is not repayed until the distant future when the replacement forest grows (not to the poin that it stores the same amount of carbon as before harvest) but rather to a point that recaptures all the carbon PLUS mitigates for the climate impacts caused during the "carbon debt" payback period. See Katsumasa Tanaka & Brian C. O'Neill. 2018. The Paris Agreement zero-emissions goal is not always consistent with the 1.5 °C and 2 °C temperature targets. Nature Climate Change (2018) doi:10.1038/s41558-018-0097-x. https://www.nature.com/articles/s41558-018-0097-x#Abs1, and see Brack, Duncan 2017. Woody Biomass for Power and Heat: Impacts on the Global Climate. Chatham House. https://www.chathamhouse.org/sites/files/chathamhouse/publications/research/2017-02-23-woody-biomass-global-climate-brack-embargoed.pdf.

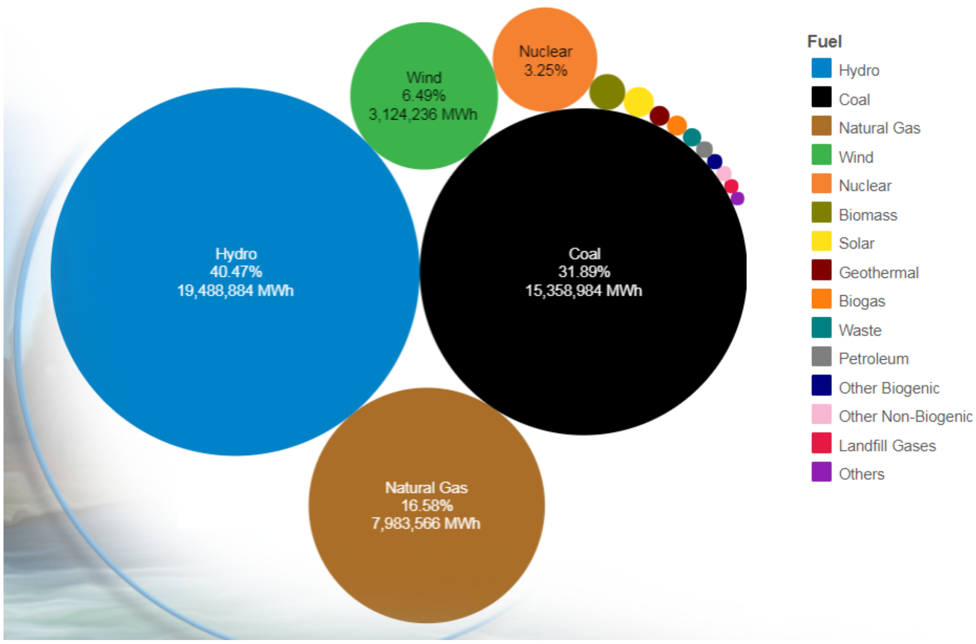
5) Many analyses of substitution fail to account for the carbon debt associated with logging. They do this by starting with "bare ground" instead of an existing forest, which biases the analysis by crediting wood products with growing the forest in the first place instead of debiting wood products for dramatically reducing the carbon stored in an existing forest.



6) Substitution offers no guarantees that fossil fuels will stay in the ground. Fossil fuel use associated with the manufacture of steel and concrete will not be permanently avoided, but just delayed. The longest it could be delayed will be the earlier of:

- The point in time when the rising price of fossil fuels is undercut by the declining price of renewable energy.
- The point in time when we stop using fossil fuels for making steel and cement.
- The point in time when the fossil fuels that would have been used to make steel and cement are extracted and used for some alternative activity.

7) The CORRIM analysis fails to recognize that the production techniques used to make steel and concrete are continually improving leading to increased energy efficiency. For instance, steel recycling rates are always increasing, the addition of fly ash during the manufacture of concrete reduces its carbon footprint. Cement producers recently agreed to a voluntary 25% reduction in carbon emissions. http://www.reuters.com/article/GCA-GreenBusiness/idUSTRE54J5L420090520; http://www.wbcsdcement.org/pdf/agenda.pdf; There are several ways that emissions from cement and steel can be reduced, e.g., Reduce use; Clinker substitution; Carbon capture & storage; Alternative 'novel' cement https://www.carbonbrief.org/qa-why-cement-emissions-matter-for-climate-change ("Progress so far has come in three main areas. First, more efficient cement kilns have made production less energy-intensive. This can improve further ... [R]educing the proportion of Portland clinker in cement has also cut emissions. "High-blend" cements can reduce emissions per kilogram by up to four times, ... Geopolymer-based cements, for example, have been a focus of research since the 1970s. These do not use calcium carbonate as a key ingredient, harden at room temperature and release only water. Zeobond and banahUK are among firms producing these, with both claiming around 80-90% reduction in emissions compared to Portland cement. There are also several firms developing "carbon-cured" cements, which absorb CO_2, rather than water, as they harden. If this CO_2 absorption can be made higher than CO_2 released during their production, cements could potentially be used as a carbon sink. US firm Solidia, for example, claims its concrete emits up to 70% less CO_2 than Portland cement, including this sequestering step. The firm is now in a partnership with major cement producer LafargeHolcim. ... Other firms are using completely different materials to make cement. North Carolina-based startup Biomason, for example, uses bacteria to grow cement bricks which it says are both similarly strong to traditional masonry and carbon-sequestering."). The energy grid that powers the steel mills and concrete plants are always becoming less carbon intensive. For instqance, here in Oregon, only about 32% of electricity is from coal:



http://www.oregon.gov/energy/energy-oregon/Pages/Electricity-Mix-in-Oregon.aspx.

See also, Johanna Lehne and Felix Preston. 2018. Making Concrete Change - Innovation in Low-carbon Cement and Concrete. Chatham House Report. https://www.chathamhouse.org/sites/default/files/publications/2018-06-13-making-concrete-change-cement-lehne-preston-final.pdf; Maddie Stone 2019. CONCRETE JUNGLE - Cement has a carbon problem. Here are some concrete solutions. Grist Nov 20, 2019. https://grist.org/article/cement-has-a-carbon-problem-here-are-some-concrete-solutions/; Oberhaus, D. 2019. A Solar 'Breakthrough' Won't Solve Cement's Carbon Problem - A Bill Gates–backed startup called Heliogen uses concentrated solar power to produce cement. Wired 11-22-2019. https://www.wired.com/story/a-solar-breakthrough-wont-solve-cements-carbon-problem/

People must give fair treatment to the merits of the competing ideas by disclosing the flaws and caveats associated with the substitution argument.

Law et al (2018) said:

> Increased long-term storage in buildings and via product substitution has been suggested as a potential climate mitigation option. Pacific temperate forests can store carbon for many hundreds of years, which is much longer than is expected for buildings that are generally assumed to outlive their usefulness or be replaced within several decades (7). By 2035, about 75% of buildings in the United States will be replaced or renovated, based on new construction, demolition, and renovation trends (31, 32). Recent analysis suggests substitution benefits of using wood versus more fossil fuel-intensive materials have been overestimated by at least an order of magnitude (33). Our LCA accounts for

> losses in product substitution stores (PSSs) associated with building life span, and thus are considerably lower than when no losses are assumed (4, 34). While product substitution reduces the overall forest sector emissions, it cannot offset the losses incurred by frequent harvest and losses associated with product transportation, manufacturing, use, disposal, and decay. Methods for calculating substitution benefits should be improved in other regional assessments.

Beverly E. Law, Tara W. Hudiburg, Logan T. Berner, Jeffrey J. Kent, Polly C. Buotte, Mark E. Harmon. 2018. Land use strategies to mitigate climate change in carbon dense temperate forests. Proceedings of the National Academy of Sciences Mar 2018, 201720064; DOI: 10.1073/pnas.1720064115 https://web.archive.org/web/20180727130028/http://www.pnas.org/content/pnas/115/14/3663.full.pdf.

Shafer et al (2011) state:

> An alternative to increasing carbon stores within the forest is to harvest wood and store some of this carbon within wood products (Perez-Garcia et al., 2005). Under current manufacturing, use, and disposal practices this alternative is unlikely to increase the overall carbon store of the forest sector, which includes the forest and wood products derived from the forest (Harmon et al., 2009). Manufacturing, use, and disposal of harvested wood all entail significant carbon losses that are either as large as or larger than those in the forest itself (Krankina and Harmon, 2007). Wood products carbon offsets associated with biofuels and substitution of wood for more energy intensive building materials, such as steel and concrete, can theoretically increase the carbon "stores" of wood products beyond that stored in the forest itself (Perez-Garcia et al., 2005; Lippke et al. 2010). However, **several issues need to be recognized regarding these offsets. First, most analyses have presented theoretical maximum product substitution offsets** and ignored the effects of additionality (i.e., degree to which practices differ from business as usual or statutory requirements), permanence and replacement of existing wood products, and enduser preferences for building materials. If these factors are included, then **substitution effects are substantially lower than the theoretical maximum and unlikely to surpass carbon stores in forests for many centuries if at all**. **Second**, depending on the starting condition of the forest, both product **substitution and forest-related biofuels can create carbon debts that delay carbon benefits**. For example, biofuels harvested from existing forests could offset fossil fuel releases of carbon, but recent studies have indicated that carbon debts associated with the energy used during biofuel harvests, decreased carbon stores in forests, and differences in carbon to energy ratios could persist for decades to centuries, implying a significant temporal lag in net carbon uptake (Fargione et al., 2008; Searchinger et al., 2009). **Third**, being offsets, the **effectiveness of both biofuel and product substitution will vary with the duration of the offset**; the longer the delay in releasing fossil fuel carbon, the more

effective offsets become: An offset with a 1 year delay would have little impact on atmospheric CO2 concentrations, whereas an offset of hundreds of years would have a much greater impact. **Unfortunately, the duration of offsets is not well understood at this point, but it is unlikely to be infinite as tacitly assumed in many current analyses**. Finally, while offsets are often counted as carbon stores, they are difficult to directly inventory because they are not physically in an identifiable location, whereas carbon stored in forests can be more directly inventoried and quantified.

Sarah L. Shafer, Mark E. Harmon, Ronald P. Neilson, Rupert Seidl, Brad St. Clair, Andrew Yost 2011. Oregon Climate Assessment Report (OCAR) http://occri.net/ocar Chapter 5. The Potential Effects of Climate Change on Oregon's Vegetation. http://occri.net/wp-content/uploads/2011/04/chapter5ocar.pdf.

If the agency wishes to rely on substitution to justify carbon emissions from logging, they cannot assume the project will result in the theoretical maximum substitution benefits. They must instead consider and analyze the real world substitution effects based on several key factors. Fain et al (2018) explain--

> [S]ubstitution is a key variable in determining cumulative carbon benefits over time. Franklin et al. discuss 6 key factors in determining the magnitude of substitution effects through time: (1) the amount of product-in-use created from the harvest, (2) the displacement factor, (3) percent of the harvest that will substitute for non-wood products like concrete or steel, (4) the cumulative nature of the substitution effects, (5) the length of time the substitution effect accumulates, and (6) the effect on the average lifespan of buildings if wood is substituted for fossil fuel intensive materials. ... The displacement factor ... varies depending on the building system and the embedded GHG emissions factor within displaced materials. ... [E]ngineering studies found the average displacement factor value to be 2.1, ... [T]his number is a global reference average and likely not accurate for any given place and time. Uniquely local and dynamic biological and socio-economic factors such as, silvicultural systems, tree species, form and age of trees, amount of wood degrade, mortality rates, market demand, economics of transporting to processing facilities, and supply quota agreements, greatly influence commercial wood products and thus any attempts to quantify substitution rates and life cycles. ... [A]s technology, wood use, and energy sources evolve into the future, so will the displacement factor associated with substitution, most likely declining.

Fain, S.J.; Kittler, B.; Chowyuk, A. Managing Moist Forests of the Pacific Northwest United States for Climate Positive Outcomes. Forests 2018; 9(10):618. https://www.mdpi.com/1999-4907/9/10/618 *citing* Franklin, J.; Johnson, N.; Johnson, D. Ecological Forest Management; Waveland Press: Long Grove, IL, USA, 2018.

> … benefits attributed to product substitution are commonly overestimated. Substituting wood for aluminum and steel can displace fossil fuel emissions, but the displacement

> period needs to be part of the accounting. Displacement occurs until the building is replaced, and then the substitution can be renewed by a new building or it can be lost by using a material with a higher energy cost. In addition, it is often assumed that product substitution will reduce the demand for fossil fuel. However, due to human behavior and current economic systems that ignore adverse externalities, reducing resource consumption through substitution or improvements in efficiency rarely reduce fossil fuel use (York, 2012). Therefore, benefits may be substantially lower and the payback period much longer and smaller for the carbon debt from intensified management and avoided fossil fuel combustion than commonly assumed (Haberl et al., 2013).

Law, B.E., Waring, R.H. 2015. Review and synthesis - Carbon implications of current and future effects of drought, fire and management on Pacific Northwest forests. Forest Ecology and Management 355 (2015) 4–14. http://people.forestry.oregonstate.edu/richard-waring/sites/people.forestry.oregonstate.edu.richard-waring/files/publications/Law%20and%20Waring%202015.pdf

Law & Harmon conducted a literature review and concluded …

> Most LCA [life cycle analysis] studies rely heavily on wood product substitution for GHG benefits, and these have been grossly overestimated, with many ambiguous assertions that gloss over forest carbon dynamics; for example:
>
> · Biofuel emissions are assumed to be zero because they are balanced by net growth, yet this would depend on the state of the preceding forest system – they could be positive, neutral or negative;
>
> · Old forests are assumed to always be carbon sources, while young forests are always assumed to be carbon sinks, contrary to forest carbon dynamics findings;
>
> · Dead wood and soil carbon stores are either not included or assumed to be constant;
>
> · In one LCA, dead wood is not present in older forests, contrary to findings in the extensive ecological literature;
>
> · The wood product pool is assumed to be an increasing carbon stock over time.
>
> …
>
> Substitution of more energy-intensive building materials with a less energy intensive one can, in theory, result in a fossil fuel offset; for example, when wood replaces a construction material with higher emissions (e.g., concrete or steel), the fossil CO2 emission avoided by choosing wood is credited as an offset. Thus, harvest of forest carbon and placement into buildings can impact the overall carbon balance of the forest sector [33,42]. However, several additional factors need to be considered. First, changes in the carbon stores of the forest ecosystem have to be considered relative to a base case that includes a lower level of harvests. As noted above, decreasing the interval between harvests, or increasing harvest intensity will lower the carbon store in the forest [9–11,31]; the question is whether stores in forest products combined with substitution

offsets surpass losses from shorter rotations. Since the forest has a maximum carrying capacity, just the growth in carbon stores and offsets would seem to eventually exceed old forest carbon, although it could take centuries to happen, even using the most generous substitution effects. With more realistic substitution effects, it may never happen. In some cases, the amount of live and dead biomass in unharvested forests was grossly underestimated leading to an overestimation of the relative benefits of substitution. Second, in substitution effects calculations, it is often tacitly assumed that wood that is removed from forests and used in long-term wood products, specifically buildings, continues to accumulate infinitely over time. While building carbon stores have increased in many areas (e.g., the USA), this is largely because more forest area is being harvested and not because the harvest-related stores per harvest area are increasing. The trend that is being used as evidence of increasing building stores is based on the fact that because a greater area has been harvested, the total store has increased. This is not the same thing as the increase associated with a particular area of forest. A fixed per area basis is how substitution effects have largely been evaluated in the past, so arguing on an expanding area basis is inappropriate. The reason that wood products saturate is that housing and other wood products have a finite lifespan and are eventually replaced [43]. Although there can be some reuse of wood, essentially assuming an infinite lifespan or 100% reuse of wood products is completely unrealistic. Carbon is always lost as wood products are used or disposed of, which means release of CO2 to the atmosphere. Since long-term storage in forest products saturates over time (i.e., eventually does not increase), the effect of substituting wood for fossil fuel energy is also likely to saturate. Third, in most cases, the substitution offset was calculated based on the assumption that each time a house is to be built, the preference is for nonwood materials. This results in an estimate of the maximum substitution effect possible, but does not account for actual preferences for building materials. Granted, preferences vary by region and over time, but without accounting for these one cannot possibly estimate realistic substitution benefits. Fourth, current substitution accounting appears to violate a key principle of carbon offsets, namely permanence. In fact the ever-increasing substitution offset presented in these analyses appears to depend on impermanence of wooden buildings. Fifth, most, if not all, current analyses of substitution effects ignore the effects of additionality and whether wooden buildings are initially present. Given that many forests have already been harvested to produce wood products, replacing wooden buildings with more wooden buildings results in no additional substitution effect. Finally, these studies assume that it is a permanent benefit to GHG removal from the atmosphere. That is, they assume there is a continual increase in the carbon credit, and maintenance of a sustainable productive forest dedicated to providing substitutes for nonwood fuels and materials [44].

These caveats all suggest that while there is likely to be some building material substitution effect that is valid, it is far lower than generally estimated and as subject to saturation as other forest-related carbon pools. In summary, the substitution effect appears to have been grossly overestimated. Substitution is an offset, not a store. Offsets depend on the use of appropriate accounting rules. Until rules such as permanence, additionality and leakage are followed, the values being presented in many analyses are not credible.

…

Life cycle analysis (including substitution, proposed considerations)

…

- **Substitution of more energy intensive building materials with less energy intensive ones can in theory result in a fossil fuel offset, but important considerations suggest that the substitution effect is substantially lower than estimated, and is subject to saturation.**

Beverly Elizabeth Law & Mark E Harmon 2011. Forest sector carbon management, measurement and verification, and discussion of policy related to mitigation and adaptation of forests to climate change. Carbon Management 2011 2(1). https://content.sierraclub.org/ourwildamerica/sites/content.sierraclub.org.ourwildamerica/files/documents/Law%20and%20Harmon%202011.pdf.

Although we estimated the stores in forest products, we did not include the so-called substitution effects of using wood versus other more energy intensive materials for construction. As pointed out by Hennigar and others (2008), there is little consensus on the values to be used (that is, they vary 10-fold). The other issue is that these estimates represent maximal values that assume that all future buildings will be primarily constructed of materials other than wood. Thus, it counts the substitution effect over and over even when a wooden building is replaced by a wooden building.

Mark E. Harmon, Adam Moreno, and James B. Domingo. 2009. Effects of Partial Harvest on the Carbon Stores in Douglas-fir/Western Hemlock Forests: A Simulation. Ecosystems (2009) 12: 777-791. DOl: 10.1007/510021-009-9256-2 ECOSYSTEMS. https://www.fs.fed.us/pnw/pubs/journals/pnw_2009_harmon001.pdf

… the document need also rectify a persistent mischaracterization of dead trees as solely a source of carbon emissions compromising the capacity of California forests to function as net sinks. So long as mortality outpaces decay, which appears to be the case for many California forests today, dead trees collectively represent an aggrading carbon pool, not a shrinking one; just like that regularly claimed to occur in products made from wood thinned from forests. Moreover, there is no evidence I am aware of that trees surviving pulses of natural mortality pulses do not xperience compensatory growth in the same manner in which trees surviving selective harvest are regularly claimed to. … As currently written, the CFCP is peppered with claims that dead trees are driving California forests into a net sink (pages 1, 49, 59, 62, 75), but nowhere is this miss-calculation so glaring than in Tables 12 and 13 where forest carbon balance is compared across ownership classes. In this otherwise informative section, net forest carbon stores are calculated as growth minus mortality minus harvest when net forest carbon stores are, by definition, growth minus decomposition of dead trees minus harvest. Simply put, the sequestration of carbon in forests is defined by stocks, not fluxes, and dead trees are carbon stocks which function to keep carbon away from the atmosphere regardless of the fact that they are releasing it. The CFCP's dogmatic obsession with minimizing natural mortality, dismissing dead trees as a carbon loss, and building markets to afford their salvage runs counter to its stated objective of thinning forests, returning natural disturbance to the ecosystem, and building carbon stocks on the landscape.

Campbell, J.L. 2017, Comments on the Jan 2017 draft California Forest Carbon Plan. http://www.fire.ca.gov/fcat/downloads/FCAT_PublicComment/Campbell_CFCP_Review_Final-2nd.pdf.

The UK Royal Academy of Engineering (Royal Society) looked at the potential for wood buildings to serve as a method of Greenhouse Gas Removal (GGR) and found --

> Generally, the lifespan of wooden buildings and lifetime emissions associated with electricity and heating costs are comparable to that of concrete and steel structures149. ... Life cycle assessment studies of the carbon emissions saved by timber building relative to steel and concrete have been inconclusive153,154. ... [A]t the end of their lives the wooden infrastructure materials would have to be repurposed for the carbon to remain captured, which may be a challenge if adopted at scale. ... [I]ncreased afforestation will compete with agricultural land. ... There is an additional risk that processing and transportation reduce the extent of the benefits of this GGR method. ... The benefits of extending the longevity and security of carbon storage, originally created through forestation, in the built environment needs to be recognised by carbon accounting agreements. ... Incentives for tree planting and sustainable forest management would be needed to significantly expand the scale of building with wood. ... As with BECCS, if biomass used for building is imported, there will need to be international agreement about the country that can claim the carbon credit and a mechanism to monitor the storage.

Royal Society 2018. Greenhouse gas removal. https://royalsociety.org/~/media/policy/projects/greenhouse-gas-removal/royal-society-greenhouse-gas-removal-report-2018.pdf *citing* (149) Aye L, Ngo T, Crawford RH, Gammampila R, Mendis P. Life cycle greenhouse gas emissions and energy analysis of prefabricated reusable building modules. Energy and Buildings. 2012 Apr;47:159–68. Available from: http://dx.doi.org/10.1016/j.enbuild.2011.11.049; (153) Buchanan AH, Honey BG. Energy and carbon dioxide implications of building construction. Energy and Buildings. 1994 Jan;20(3):205–17. http://dx.doi.org/10.1016/0378-7788(94)90024-8; (154) Gustavsson L, Sathre R. Variability in energy and carbon dioxide balances of wood and concrete building materials.

Building and Environment. 2006 Jul;41(7):940–51.
http://dx.doi.org/10.1016/j.buildenv.2005.04.008.

The courts also understand that indirect effects, such as downstream emissions of GHG caused by federal actions, must be accounted for even if there may be off-setting factors such as displacement or substitution:

> The Commission is wrong to suggest that downstream emissions are not reasonably foreseeable simply because the gas transported by the Project may displace existing natural gas supplies or higher-emitting fuels. Indeed, that position is a total non-sequitur: as we explained in Sierra Club, if downstream greenhouse-gas emissions otherwise qualify as an indirect effect, the mere possibility that a project's overall emissions calculation will be favorable because of an "offset . . . elsewhere" does not "excuse[]" the Commission "from making emissions estimates" in the first place. 867 F.3d at 1374–75.
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> ...
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> Although it is true that "[a]n agency has no obligation to gather or consider environmental information if it has no statutory authority to act on that information," in the pipeline certification context the Commission does have statutory authority to act. Sierra Club, 867 F.3d at 1372. As we explained in Sierra Club, "Congress broadly instructed the [Commission] to consider 'the public convenience and necessity' when evaluating applications to construct and operate interstate pipelines." Id. at 1373 (quoting 15 U.S.C. § 717f(e)). Because the Commission may therefore "deny a pipeline certificate on the ground that the pipeline would be too harmful to the environment, the agency is a 'legally relevant cause' of the direct and indirect environmental effects of pipelines it approves"—even where it lacks jurisdiction over the producer or distributor of the gas transported by the pipeline. Id. Accordingly, the Commission is "not excuse[d] . . . from considering these indirect effects" in its NEPA analysis. Id.
>
> ...
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> "NEPA analysis necessarily involves some 'reasonable forecasting,' and . . . agencies may sometimes need to make educated assumptions about an uncertain future." Sierra Club, 867 F.3d at 1374 (quoting Delaware Riverkeeper Network, 753 F.3d at 1310)). It should go without saying that NEPA also requires the Commission to at least attempt to obtain the information necessary to fulfill its statutory responsibilities. See Delaware Riverkeeper Network, 753 F.3d at 1310 ("While the statute does not demand forecasting that is not meaningfully possible, an agency must fulfill its duties to the fullest extent possible." (internal quotation marks omitted)); see also Barnes v. U.S. Department of Transportation, 655
> F.3d 1124, 1136 (9th Cir. 2011) ("While foreseeing the unforeseeable is not required, an agency must use its best efforts to find out all that it reasonably can." (internal quotation marks omitted)).

BIRCKHEAD v. FERC (D.C. Circ.) No. 18-1218. June 4, 2019. https://www.cadc.uscourts.gov/internet/opinions.nsf/F280040B0F48BE8C8525840F004D7275/$file/18-1218.pdf. In the context of federal land management, the agencies have broad authority to decide whether, where, and how to manage vegetation and those decisions have direct impact on GHG emissions.

Dead Trees Store Carbon Too

The NEPA analysis must avoid any implication that dead trees emit carbon while wood products store carbon. This is inaccurate and misleading.

> … the document need also rectify a persistent mischaracterization of dead trees as solely a source of carbon emissions compromising the capacity of California forests to function as net sinks. So long as mortality outpaces decay, which appears to be the case for many California forests today, dead trees collectively represent an aggrading carbon pool, not a shrinking one; just like that regularly claimed to occur in products made from wood thinned from forests. Moreover, there is no evidence I am aware of that trees surviving pulses of natural mortality pulses do not experience compensatory growth in the same manner in which trees surviving selective harvest are regularly claimed to. … As currently written, the CFCP is peppered with claims that dead trees are driving California forests into a net sink (pages 1, 49, 59, 62, 75), but nowhere is this miss-calculation so glaring than in Tables 12 and 13 where forest carbon balance is compared across ownership classes. In this otherwise informative section, net forest carbon stores are calculated as growth minus mortality minus harvest when net forest carbon stores are, by definition, growth minus decomposition of dead trees minus harvest. Simply put, the sequestration of carbon in forests is defined by stocks, not fluxes, and dead trees are carbon stocks which function to keep carbon away from the atmosphere regardless of the fact that they are releasing it. The CFCP's dogmatic obsession with minimizing natural mortality, dismissing dead trees as a carbon loss, and building markets to afford their salvage runs counter to its stated objective of thinning forests, returning natural disturbance to the ecosystem, and building carbon stocks on the landscape.

Campbell, J.L. 2017, Comments on the Jan 2017 draft California Forest Carbon Plan. http://www.fire.ca.gov/fcat/downloads/FCAT_PublicComment/Campbell_CFCP_Review_Final-2nd.pdf.

"Longevity of carbon stocks determines the degree of climate benefit. ... [T]he dead wood generated by fire is longer-lived than 95% of wood products." INTACT Factsheet: Primary Temperate Forests Harbor Unique Biodiversity And Ecosystem Services, Including Climate Regulation. International Action for Primary Forests. https://primaryforest.org/fact-sheets/