References to accompany William Moomaw testimony January18 2023

Statement on 30x30 and 50x50 from IPCC Assessment Report 6 2022 Working Group 2 Summary for Policy Makers Section D

https://www.ipcc.ch/report/ar6/wg2/

Section D: Climate Resilient Development

Climate resilient development integrates adaptation measures and their enabling conditions with mitigation to advance sustainable development for all. Climate resilient development involves questions of equity and system transitions in land, ocean and ecosystems; urban and infrastructure; energy; industry; and society and includes adaptations for human, ecosystem and planetary health. Pursuing climate resilient development focuses on both where people and ecosystems are co-located as well as the protection and maintenance of ecosystem function at the planetary scale. Pathways for advancing climate resilient development are development trajectories that successfully integrate mitigation and adaptation actions to advance sustainable development. Climate resilient development pathways may be temporarily coincident with any RCP and SSP scenario used throughout AR6, but do not follow any particular scenario in all places and over all time.

Safeguarding biodiversity and ecosystems is fundamental to climate resilient development, in light of the threats climate change poses to them and their roles in adaptation and mitigation (*very high confidence*). Recent analyses, drawing on a range of lines of evidence, suggest that maintaining the resilience of biodiversity and ecosystem services at a global scale depends on effective and equitable conservation of approximately 30% to 50% of Earth's land, freshwater and ocean areas, including currently near-natural ecosystems (*high confidence*).

1. Building the resilience of biodiversity and supporting ecosystem integrity can maintain benefits for people, including livelihoods, human health and well-being and the provision of food, fibre and water, as well as contributing to disaster risk reduction and climate change adaptation and mitigation Ecosystem integrity refers to the ability of ecosystems to maintain key ecological processes, recover from disturbance and adapt to new conditions.
2. Protecting and restoring ecosystems is essential for maintaining and enhancing the resilience of the biosphere (*very high confidence*). Degradation and loss of ecosystems is also a cause of greenhouse gas emissions and is at increasing risk of being exacerbated by climate change impacts, including droughts and wildfire *(high confidence).* Climate resilient development avoids adaptation and mitigation measures that damage ecosystems (*high confidence*). Documented examples of adverse impacts of land-based measures intended as mitigation, when poorly implemented, include afforestation of grasslands, savannas and peatlands, and risks from bioenergy crops at large scale to water supply, food security and biodiversity (*high confidence*)
3. Biodiversity and ecosystem services have limited capacity to adapt to increasing global warming levels, which will make climate resilient development progressively harder to achieve beyond 1.5°C warming (*very high confidence*). Consequences of current and future global warming for climate resilient development include reduced effectiveness of Ecosystem-based Adaptation and approaches to climate change mitigation based on ecosystems and amplifying feedbacks to the climate system (*high confidence*).

> **The cumulative scientific evidence is unequivocal: Climate change is a threat to human well-being and planetary health. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and rapidly closing window of opportunity to secure a liveable and sustainable future for all. (*very high confidence*)**

Forest-clearing to create early-successional habitats: Questionable benefits, significant costs 2023

https://www.frontiersin.org/articles/10.3389/ffgc.2022.1073677/full

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ABSTRACT

A campaign is underway to clear established forests and expand early-successional habitats—also called young forest, pre-forest, early seral, or open habitats—with the intention of benefitting specific species. Coordinated by federal and state wildlife agencies, and funded with public money, public land managers work closely with hunting and forestry interests, conservation organizations, land trusts, and private landowners toward this goal. While forest-clearing has become a major focus in the Northeast and Upper Great Lakes regions of the U.S., far less attention is given to protecting and recovering old-forest ecosystems, the dominant land cover in these regions before European settlement. Herein we provide a discussion of early-successional habitat programs and policies in terms of their origins, in the context of historical baselines, with respect to species' ranges and abundance, and as they relate to carbon accumulation and ecosystem integrity. Taken together, and in the face of urgent global crises in climate, biodiversity, and human health, we conclude that public land forest and wildlife management programs must be reevaluated to balance the prioritization and funding of early-successional habitat with strong and lasting protection for old-growth and mature forests, and, going forward, must ensure far more robust, unbiased, and ongoing monitoring and evaluation.

INTRODUCTION

In this paper we conduct a wide-ranging and integrated assessment of the campaign to expand early-successional forest habitats in two regions of the United States: (1) the Northeast, i.e., New England states (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont) and mid-Atlantic states (New York, Pennsylvania, New Jersey, Maryland, Delaware); and (2) the Upper Great Lakes areas of Michigan, Wisconsin, and Minnesota north and east of the prairie-forest border [see Cochrane and Iltis (2000), Frelich and Reich (2010), Anderson et al. (2018)]. We review the history of forest disturbance and biodiversity research, the genesis of the forest-clearing campaign and the conservation rationales, the contrasts between natural old-growth forests and intensively managed forests, the impacts of forest-clearing projects, and the current balance of activity between forest management and protection. We conclude that instead of intensive and costly management to create additional early-successional habitats, a new "natural" alternative should be considered which would protect and allow the dynamic growth of established aggrading, mature, and old-growth forests alongside maintaining existing early-successional habitats, where appropriate, for targeted species and cultural values. Although the focus of our analysis is two regions, we believe it offers useful lessons for many other parts of the U.S. and world experiencing similar situations (DellaSala et al., 2022b).

Assessing carbon stocks and accumulation potential of mature forests and larger trees in U.S. federal lands

2023 https://www.frontiersin.org/articles/10.3389/ffgc.2022.1074508/full

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ABSTRACT

Mature and old-growth forests (collectively "mature") and larger trees are important carbon sinks that are declining worldwide. Information on the carbon value of mature forests and larger trees in the United States has policy relevance for complying with President Joe Biden's Executive Order 14072 directing federal agencies to define and conduct an inventory of them for conservation purposes. Specific metrics related to maturity can help land managers define and maintain present and future carbon stocks at the tree and forest stand level, while making an important contribution to the nation's goal of net-zero greenhouse gas emissions by 2050. We present a systematic method to define and assess the status of mature forests and larger trees on federal lands in the United States that if protected from logging could maintain substantial carbon stocks and accumulation potential, along with myriad climate and ecological co-benefits. We based the onset of forest maturity on the age at which a forest stand achieves peak net primary productivity. We based our definition of larger trees on the median tree diameter associated with the tree age that defines the beginning of stand maturity to provide a practical way for managers to identify larger trees that could be protected in different forest ecosystems. The average age of peak net primary productivity ranged from 35 to 75 years, with some specific forest types extending this range. Typical diameter thresholds that separate smaller from larger trees ranged from 4 to 18 inches (10–46 cm) among individual forest types, with larger diameter thresholds found in the Western forests. In assessing these maturity metrics, we found that the unprotected carbon stock in larger trees in mature stands ranged from 36 to 68% of the total carbon in all trees in a representative selection of 11 National Forests. The unprotected annual carbon accumulation in live above-ground biomass of larger trees in mature stands ranged from 12 to 60% of the total accumulation in all trees. The potential impact of avoiding emissions from harvesting large trees in mature forests is thus significant and would require a policy shift to include protection of carbon stocks and future carbon accumulation as an additional land management objective on federal forest lands.

INTRODUCTION

Nature-based climate solutions are needed to meet anticipated national targets associated with the Paris Climate Agreement which establishes a global framework to avoid dangerous climate change by limiting warming to less than 2°C (United Nations, 2015). In the United

States, the Biden administration announced a "roadmap" for nature-based solutions during the COP27 climate summit (White House, 2022a). Reducing carbon dioxide (CO_2) emissions and increasing CO_2removals from the atmosphere using forests are considered to be the most significant of terrestrial natural climate solutions globally and in the U.S. (Griscom et al., 2017; Fargione et al., 2018).

Protecting mature forests to achieve their potential to reduce greenhouse gases is controversial in part because it restricts logging (Law and Harmon, 2011; Moomaw et al., 2020). Forests in the later stages of seral development (mature and old-growth, DellaSala et al., 2022a) and the large trees within them (Stephenson et al., 2014; Mildrexler et al., 2020) play an outsized role in the accumulation and long-term storage of atmospheric carbon, and consequently enabling their protection where lacking has been recognized as an effective nature-based climate solution (Griscom et al., 2017). Notably, President Joe Biden issued an executive order (White House, 2022b) recognizing the climate value of mature and old-growth forests and directed federal officials to define and inventory them on Federal lands and develop policies for their conservation. Thus, providing techniques for defining when forests qualify as mature and quantifying their relative carbon content and storage potential has high policy relevance.

This undertaking supports the nation's goal of achieving net-zero greenhouse gas emissions by 2050 and to conserve 30% of the nation's land by 2030 (White House, 2021). Protecting older, larger trees and mature forests would also help reverse the global degradation of older forests that have diverse ecological values (Lindenmayer et al., 2012), and facilitate the continued growth of mid-sized trees toward maturity (Moomaw et al., 2019). Mature forests provide refugia for many imperiled species (Buotte et al., 2020; DellaSala et al., 2022a), store disproportionate amounts of above-ground carbon in forests (Stephenson et al., 2014; Lutz et al., 2018; Mildrexler et al., 2020), and historically constitute a large volume of valuable timber (Johnson and Swanson, 2009). These values often conflict with one another resulting in contentious policy debates about land management objectives and best practices, particularly on federal lands in the U.S. where much of the remaining mature forest area resides according to national forest inventory data (Bolsinger and Waddell, 1993; DellaSala et al., 2022a). Recent studies of land values reveal that the importance of mature forests for ecosystem integrity and non-timber ecosystem services far exceeds their value for timber products (Watson et al., 2018; Gilhen-Baker et al., 2022).

Some researchers argue that it is necessary to log larger trees in fire-suppressed forests in the western U.S. to restore fire regimes, reduce biomass, and minimize emissions from wildfires (Kirschbaum, 2003; Hessburg et al., 2020; Johnston et al., 2021). However, these assertions have been challenged (Stephenson et al., 2014; Lutz et al., 2018; Mildrexler et al., 2020; DellaSala et al., 2022b) in part because removing larger trees from forests having high carbon stocks creates a significant "carbon debt" that can take decades or centuries to repay (Moomaw et al., 2019; Law et al., 2022).

It follows that our objectives are to (1) present an approach to defining larger trees and mature forests on federal lands; (2) estimate the current carbon stock and annual carbon accumulation in larger trees in mature forests across a representative selection of national forests, and (3) estimate the carbon stock and accumulation left unprotected by current binding designations.

We do not identify the proportion of mature forest area and carbon stocks that could be classified more specifically as "old growth." Defining old-growth in a consistent way across the diversity of temperate forests is challenging since existing definitions are based on structural, successional, and biogeochemical factors that are unique for individual forest types and researcher's interests (Wirth et al., 2009). Our characterization of mature forests has ecological and policy relevance for restoring old-growth characteristics over time, pursuant to the presidential executive order as well (DellaSala et al., 2022a). Thus, we determined that this paper would be more broadly focused on mature forests rather than old-growth forests.

Intact Forests in the United States: Proforestation Mitigates Climate Change and Serves the Greatest Good

https://www.frontiersin.org/articles/10.3389/ffgc.2019.00027/full

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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 (CO_2), 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 CO_2 to reduce national annual *net* emissions by 11%. U.S. forests have the potential for much more rapid atmospheric CO_2 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 *reforestation* and *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.

INTRODUCTION

Life on Earth as we know it faces unprecedented, intensifying, and urgent imperatives. The two most urgent challenges are (1) mitigating and adapting to climate change (Intergovernmental Panel on Climate Change, 2013, 2014, 2018), and (2) preventing the loss of biodiversity (Wilson, 2016; IPBES, 2019). These are three of the Sustainable Development Goals, Climate, Life on Land and Life under Water (Division for Sustainable Development Goals, 2015), and significant international resources are being expended to address these crises and limit negative impacts on economies, societies and biodiverse natural communities. The recent *1.5 Degree Warming Report* of the Intergovernmental Panel on Climate Change (2018) was dire and direct, stating the need for "rapid, far-reaching and unprecedented changes in all aspects of society." We find that growing additional existing forests as intact ecosystems, termed *proforestation*, is a low-cost approach for immediately increasing atmospheric carbon sequestration to achieve a stable atmospheric carbon dioxide concentration that reduces climate risk. Proforestation also provides long-term benefits for biodiversity, scientific inquiry, climate resilience, and human benefits. This approach could be mobilized across all forest types.

Forests are essential for carbon dioxide removal (CDR), and the CDR rate needs to increase rapidly to remain within the 1.5 or 2.0°C range (Intergovernmental Panel on Climate Change, 2018) specified by the Paris Climate Agreement (2015). Growing existing forests to their biological carbon sequestration potential optimizes CDR while limiting climate change and protecting biodiversity, air, land, and water. Natural forests are by far the most effective (Lewis et al., 2019). Technologies for direct CDR from the atmosphere, and bioenergy with carbon capture and storage (BECCS), are far from being technologically ready or economically viable (Anderson and Peters, 2016). Furthermore, the land area required to supply BECCS power plants with tree plantations is 7.7 million km^2, or approximately the size of Australia (Intergovernmental Panel on Climate Change, 2018). Managed plantations that are harvested periodically store far less carbon because trees are maintained at a young age and size (Harmon et al., 1990; Sterman et al., 2018). Furthermore, plantations are often monocultures, and sequester less carbon more slowly than intact forests with greater tree species diversity and higher rates of biological carbon sequestration (Liu et al., 2018). Recent research in the tropics shows that natural forests hold 40 times more carbon than plantations (Lewis et al., 2019).

Alternative forest-based CDR methods include *afforestation* (planting new forests) and *reforestation* (replacing forests on deforested or recently harvested lands). Afforestation and reforestation can contribute to CDR, but newly planted forests require many decades to a century before they sequester carbon dioxide in substantial quantities. A recent National Academy study titled *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda* discusses afforestation and reforestation and finds their contribution to be modest (National Academies of Sciences, 2019). The study also examines changes in conventional forest management, but neglects proforestation as a strategy for increasing carbon sequestration. Furthermore, afforestation to meet climate goals requires an estimated 10 million km^2–an area slightly larger than Canada (Intergovernmental Panel on Climate Change, 2018). The massive land areas required for afforestation and BECCS (noted above) compete with food production, urban space and other uses (Searchinger et al., 2009; Sterman et al., 2018). More importantly, neither of these two practices is as effective quantitatively as proforestation in the next several decades when it is needed most. For example, Law et al. (2018) reported that extending harvest cycles and reducing cutting on public lands had a larger effect than either afforestation or reforestation on increasing carbon stored in forests in the Northwest United States. In other regions such as New England (discussed below), longer harvest cycles and proforestation are likely to be even more effective. Our assessment on the climate and biodiversity value of natural forests and proforestation aligns directly with a recent report that pinpointed "stable forests" – those not already significantly disturbed or at significant risk – as playing an outsized role as a climate solution due to their carbon sequestration and storage capabilities (Funk et al., 2019).

Globally, terrestrial ecosystems currently remove an amount of atmospheric carbon equal to one-third of what humans emit from burning fossil fuels, which is about 9.4 GtC/y (10^9 metric tons carbon per year). Forests are responsible for the largest share of the removal. Land use changes, i.e., conversion of forest to agriculture, urban centers and transportation corridors, emit ~1.3 GtC/y (Le Quéré et al., 2018). However, forests' potential carbon sequestration and additional ecosystem services, such as high biodiversity unique to intact older forests, are also being degraded significantly by current management practices (Foley et al., 2005; Watson et al., 2018). Houghton and Nassikas (2018) estimated that the "**current gross carbon sink in forests recovering from harvests and abandoned agriculture to be −4.4 GtC/y, globally." This is approximately the current gap between anthropogenic emissions and biological carbon and ocean sequestration rates by natural systems.** If deforestation were halted, and secondary forests were allowed to continue growing, they would sequester −120 GtC between 2016 and 2100 or ~12 years of current global fossil carbon emissions (Houghton and Nassikas, 2018). Northeast secondary forests have the potential to increase biological carbon sequestration between 2.3 and 4.2-fold (Keeton et al., 2011).

Existing proposals for "Natural Climate Solutions" do not consider explicitly the potential of proforestation (Griscom et al., 2017; Fargione et al., 2018). However, **based on a growing body of scientific research, we conclude that protecting and stewarding intact diverse forests and practicing proforestation as a purposeful public policy on a large scale is a highly effective strategy for mitigating the dual crises in climate and biodiversity and ultimately serving the "greatest good" in the United States and the rest of the world.**

Does wood bioenergy Help or harm the Climate? 2022

https://thebulletin.org/premium/2022-05/does-wood-bioenergy-help-or-harm-the-climate/

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ABSTRACT

ABSTRACT

The EU, UK, US, and other nations consider wood to be a carbon neutral fuel, ignoring the carbon dioxide emitted from wood combustion in their greenhouse gas accounting. Many countries subsidize wood energy – often by burning wood pellets in place of coal for electric power – to meet their renewable energy targets. But can wood bioenergy help cut greenhouse emissions in time to limit the worst damage from climate change? The argument in favor seems obvious: wood, a renewable resource, must be better than burning fossil fuels. But wood emits more carbon dioxide per kilowatt-hour than coal – and far more than other fossil fuels. Therefore, the first impact of wood bioenergy is to increase the carbon dioxide in the atmosphere, worsening climate change. Forest regrowth might eventually remove that extra carbon dioxide from the atmosphere, but regrowth is uncertain and takes time – decades to a century or more, depending on forest composition and climatic zone – time we do not have to cut emissions enough to avoid the worst harms from climate change. More effective ways to cut greenhouse gas emissions are already available and affordable now, allowing forests to continue to serve as carbon sinks and moderate climate change.

KEYWORDS:

- Biomass
- bioenergy
- carbon dioxide
- climate change
- forestry
- greenhouse emissions
- wood combustion

The bioenergy industry and many governments argue that wood bioenergy is carbon neutral. The “Claims and Facts” tables throughout the text below list some of the common claims the industry makes, together with the science showing these claims to be incorrect. For example, the UN Food and Agriculture Organization claims that “While burning fossil fuels releases CO_2 that has been locked up for millions of years, burning biomass simply returns to the atmosphere the carbon dioxide that was absorbed as the plants grew” (Matthews and Robertson 2001). But the fact that the carbon in wood was previously removed from the atmosphere as the trees grew is irrelevant: A molecule of carbon dioxide added to the atmosphere today has the same impact on radiative forcing—its contribution to global warming—whether it comes from fossil fuels millions of years old or biomass grown last year. When burned, the carbon in those trees immediately increases atmospheric carbon dioxide above what it would have been had they not been burned.

CLAIM

To stop climate change, it is necessary to replace fossil fuels with renewable energy, including wood bioenergy.

"Well, that's the prime objective, to go to full renewables. But simply looking at how fast we need to do that, we just can't reach the levels of renewables we would need to have [to stop burning fossil fuels and meet European Union energy needs] to completelyexclude biomass."

— Frans Timmermans, Vice President, European Commission, speaking at the 2021 UN Climate Summit, Glasgow (COP 26) (Catanoso, 2021).

FACT

To stop climate change, greenhouse gas emissions including CO2 must drop rapidly, reach net zero by approximately 2050 and be net negative beyond 2100.

Burning wood for bioenergy emits carbon dioxide. Trees harvested for bioenergy may regrow, but regrowth is not certain and even if itoccurs, would not remove the excess CO2 from burning wood for many decades to a century or longer. In the meantime, the excess carbon dioxide remains in the atmosphere and worsens global warming. To meet our climate goals, steep CO2 emission cuts from all sources are needed now (IPCC, 2022; IPCC, 2021).

CLAIM

Wood bioenergy only adds carbon that was recently taken up by trees back to the atmosphere.

"While burning fossil fuels releases CO2 that has been locked up for millions of years, burning biomass simply returns to the atmosphere the CO2 that was absorbed as the plants grew."
UN Food and Agriculture Organization (Matthews and Robertson 2001)

FACT

A molecule of CO2 added to the atmosphere causes the same global warming whether it came from fossil fuels, trees, or other plants.

"Burning biomass for energy provision increases the amount of carbon in the air just like burning coal, oil or gas if harvesting the biomass decreases the amount of carbon stored in plants and soils, or reduces carbon sequestration." The result is a "fundamental accounting error" that "will likely have substantial adverse consequences" (Haberl et al., 2012).

Regrowth takes time: Even if land conversion, repeated harvests, fire, drought, disease, and other adverse events never arise, regrowth takes time. The time required for regrowth to remove the carbon dioxide emitted when wood is burned for energy is known as the “carbon debt payback time.”

CLAIM

Wood bioenergy is carbon neutral. Carbon that is emitted now and reabsorbed later has no impact on the climate.

"Jen Jenkins, vice president at Enviva, the world's largest pellet producer, said her industry helped solve the climate crisis: The pellets displace coal, and even though their combustion releases carbon emissions, those would be sucked out of the atmosphere by replanted trees." (Ouzts, 2019).

FACT

Eventual carbon neutrality is not climate neutrality.

The climate damage caused by adding CO2 to the atmosphere when wood is burned is not reversed even if forest regrowth eventually removes that CO2. Even if trees grow back, the additional warming creates irreversible changes: Greenland and Antarctica ice sheets will not return, sea level will not drop, and thawing permafrost will have released more methane. These changes are not undone even if trees grow back (Solomon et al. 2009, Sterman et al. 2018b, IPCC, 2022).

CLAIM

If trees are burned at the same rate that the forest grows, the amount of carbon stored in the forest remains constant. Therefore, woodbioenergy is carbon neutral.

"In the Southeast U.S., privately owned and well managed forests produce one-fifth of the world's wood products. And even as they produce these harvested wood products, forests in the region are adding more carbon." (Enviva)

"… the carbon neutrality of biomass harvested from sustainably managed forests has been recognized repeatedly by numerous studies, agencies, institutions, and rules around the world …." US Senator Susan Collins (R, Maine) on the amendment to the Energy Policy Modernization Act, S. 2102 in 2016.

"We are enormously grateful to … all co-sponsors of this amendment, which accurately reflects the carbon beneficial impacts of power from forest biomass," Bob Cleaves, President and CEO of

FACT

Growing use of wood bioenergy removes carbon from existing forests and emits it as CO2 into the atmosphere.

The stock of carbon on the land immediately falls. If wood for bioenergy is harvested at a constant rate and the land is replanted and allowed to regrow, regrowth may eventually equal the harvest. Until then, carbon removal exceeds carbon sequestration, causing the stock of carbon on the land to fall. If the carbon added from regrowth eventually equals the carbon removed by harvest and other losses, then the stock of carbon in the forests would stabilize and the harvest might be deemed "sustainable." But the total stock of carbon on the land stabilizes at a level lower than before wood bioenergy usebegan. The carbon lost from the land is added to the atmosphere, worsening climate change (Sterman et al., 2018a; Sterman et al.,2018b).

When wood is taken from growing forests, the carbon that those growing trees would have removed from the atmosphere is also lost.

And if bioenergy harvest grows over time, as projected, then emissions will exceed regrowth every year, even if replanting equals theharvest every year (Sterman et al., 2018a).

Although the harvested land begins to regrow immediately, seedlings and saplings have much smaller leaf area for photosynthesis and accumulate carbon slower than older trees. Consequently, the carbon sequestered by regrowth is initially less than the carbon the forest would have stored had it not been harvested.

CLAIM

New trees will be planted that offset the carbon emitted from wood used for bioenergy.

Dale Greene, dean of forestry at the University of Georgia, and an advisor to Drax (said) "If we harvest more (for bioenergy), we plant more and there is more carbon in the forest" (Pearce, 2020).

FACT

Regrowth is uncertain. Land harvested for bioenergy may be converted to other uses (pasture, cropland, development).

Newly planted trees may be reharvested as soon as it is economically worthwhile to do so (Newman, 1988), releasing the carbon they accumulated back into the atmosphere. The result is lower stocks of carbon on the land and more in the atmosphere, worseningclimate change.

Newly planted trees have a high mortality rate, contain very little carbon and do not accumulate much carbon for decades (Besnard et al., 2018; Stephenson et al., 2014). Fire, drought, extreme weather, insects, and disease would cause the carbon accumulating in forestsharvested for bioenergy to return to the atmosphere, worsening climate change. Climate change increases these risks (Brecka et al., 2018; Xu et al., 2019), making it less likely that forests will fully recover carbon lost.

CLAIM

Wood bioenergy is carbon neutral when waste wood, thinnings, and wood that is not suitable for timber are burned.

"Wood biomass is sourced from industrial wood waste (like sawdust), or low-grade wood, including "thinnings," limbs, tops or crookedand knotted trees that would otherwise not get used for lumber or other higher-value products."

Seth Ginther, Executive Director, U.S. Industrial pellet Association (Booth, 2018; Ginther, 2018).

FACT

(i) Wood waste take years or decades to decompose, while burning it releases carbon immediately (Booth, 2018).

Allowing wood waste to decompose provides nutrients important for forest health.

(ii) Much 'waste wood' unsuitable for lumber can be used in other long-lived wood-based products, like cellulose building insulation and oriented strand board keeping it out of the atmosphere for decades (Reuse Wood, 2020).

The situation is analogous to a government that runs a continually growing fiscal deficit. The outstanding debt rises every year even if the government fully repays every bond it issues at maturity. In the same way, the growing use of wood bioenergy adds more carbon dioxide to the atmosphere every year, increasing the outstanding carbon debt, even if the forests are managed sustainably and all harvested lands eventually recover enough to fully repay the carbon debt incurred when the wood was extracted and burned.

CLAIM

Young trees grow faster than older trees. So we should harvest older trees.

Therefore we should harvest older trees that are not accumulating much carbon, use them for bioenergy, and replace them with fastergrowing younger trees.
"...young forests grow rapidly, removing much more CO2 each year from the atmosphere than an older forest covering the same area"(NCASI, 2021).

FACT

Harvesting and burning old trees releases large amounts of carbon immediately.

The young trees that may grow if the land is reforested will not accumulate as much carbon as the existing forest emitted for a century or more.
Older forests accumulate more carbon in trees and soils per year than do younger forests (Stephenson et al., 2014).

CLAIM

Forests that are growing today are removing CO2 from the atmosphere, which makes wood bioenergy carbon neutral and justifies omitting the CO2 from burning wood from carbon accounting.

Therefore we should harvest older trees that are not accumulating much carbon, use them for bioenergy, and replace them with fastergrowing younger trees.
"...young forests grow rapidly, removing much more CO2 each year from the atmosphere than an older forest covering the same area"(NCASI, 2021).

FACT

The CO2 ("stack emissions") from burning wood for energy does not instantly increase forest growth on the harvested land or in forestsmiles away.

The young trees that may grow if the land is reforested will not accumulate as much carbon as the existing forest emitted for a century or more.
Older forests accumulate more carbon in trees and soils per year than do younger forests (Stephenson et al., 2014).

Policy implications

What can be done? First, policies that treat wood bioenergy as carbon neutral must end. These policies allow power plants and nations to ignore the carbon dioxide they emit by burning wood on the false assumption that those emissions are quickly offset by forest growth somewhere else, creating a “critical climate accounting error” (Searchinger, et al. 2009). The carbon dioxide emitted from wood should be counted the same way emissions from other fuels are: fully, at the point of combustion.

Second, subsidies for wood bioenergy must end. Subsidizing wood bioenergy means taxpayers are paying pellet and power producers to make climate change worse.

Third, the fact that wood bioenergy is worse than coal in no way justifies the continued use of coal or any fossil fuel. To avoid the worst harms from climate change we must not only keep the vast majority of remaining fossilized carbon in the ground, we must also keep the vast majority of the carbon in our forests on the land.

The good news is that existing technologies such as energy efficiency, and the use of renewables such as solar, wind, and geothermal energy, can meet people’s needs for comfort, light, mobility, communication, and other purposes. The costs of these technologies are falling rapidly, and in many places are already lower than fossil fuels (IEA 2021a). Innovations in clean energy, energy storage, smart grids, and other technologies are expanding our ability to meet everyone’s energy needs affordably. Unlike wood bioenergy, these technologies allow forests to continue growing and sequestering atmospheric carbon dioxide. Investments in energy efficiency and clean energy also generate multiple co-benefits including increased community resilience, jobs, and improved health and economic well-being, especially for low-income individuals and households (Belesova et al. 2020; Burke et al. 2018; IEA 2021a; IPCC 2018; Pollin et al. 2014; Shindell et al. 2018). In contrast, particulate emissions and other pollutants from wood bioenergy damage human health (Allergy & Asthma Network et al. 2016).

To keep global warming under 2 degrees Celsius, net greenhouse gas emissions must fall to net zero by approximately mid-century, less than 30 years from now. Wood bioenergy increases greenhouse gas emissions and makes climate change worse during these critical years and beyond, even if the wood displaces coal. More effective ways to cut greenhouse gas emissions and meet human needs are available and affordable now. Ending subsidies and policies that promote wood bioenergy will reduce emissions and allow forests to continue to grow, preserving their vital role as carbon sinks that moderate climate change.