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enviva | WHITE PAPER

SEEING THE FOREST:

Sustainable Wood Bioenergy in the Southeast United States

Table of Contents

Executive Summary

Enviva is the world's largest producer of industrial wood pellets, and in this white paper, we discuss the sustainability, scientific, and economic principles that underpin our business. The predominant source for our wood is the privately-owned working forests across the Southeast United States that are managed at the landscape scale to provide a steady stream of forest products over time. Our pellets are used as fuel, and they displace fossil fuels used for power and heating in markets around the world. We recognize that the use of forest biomass can be controversial, so our goal with this paper is to share insights about the ways in which our business respects both forest management and mitigating climate change objectives.

Enviva believes not all forest biomass is suitable for energy use, so we limit our sourcing to forests and feedstocks that are sustainably harvested. We do not take wood from lands that will be converted to other uses or from harvests that might threaten endangered species or harm biodiversity. We work with conservation organizations where we operate to ensure that our operations do not negatively impact areas with high conservation value (HCV). We only use biomass from forest landscapes that have stable or growing carbon stocks, and because such forest landscapes are continually re-sequestering the carbon, the atmosphere does not experience a net increase in carbon.

In this white paper, we discuss how the biomass market impacts forests. We explore how private landowners respond to market incentives to maintain their forests as forests, rather than shift their lands into other uses, and how the forest products marketplace in the Southeast United States has operated sustainably for decades. Except for rare and unusual cases, landowners do not make their harvesting decisions based on the biomass market. Instead, harvests are driven by the markets for higher-value forest products, like sawtimber. Our biomass comes from the lower-value materials that are generated as part of those harvests. Yet at a time when forest products markets are struggling, the ability of forest owners to monetize the full range of products from a harvest helps to maintain the value of working forest ownership and management.

The full picture of forest biomass cannot be assessed without considering the forestry and energy sectors together. International authorities such as the Intergovernmental Panel on Climate Change (IPCC) continue to warn that we remain off track in phasing out fossil fuel use if we are to limit global warming and meet mid-century targets to achieve net-zero emissions. These same experts find that bioenergy (from both forest and non-forest sources) can play a significant role. Forest biomass complements wind and solar, whose intermittency requires dispatchable generation to ensure the grid meets demand at all times. And forest biomass displaces fossil fuels in the heating sector, where fewer non-fossil alternatives are available. In addition, forest biomass can enable negative emissions through bioenergy carbon capture and storage (BECCS). Again, not all forest biomass is an appropriate low-carbon solution. However, we believe that forest biomass that is sustainably harvested from forest landscapes with stable or increasing carbon stocks can serve as an important low-carbon substitute for fossil fuels.

We draw from the latest research and analysis of international experts and data collected from forests in our sourcing regions. We hope this white paper will better inform and strengthen the dialogue around forest biomass and the full range of strategies and options needed to tackle climate change.

Introduction

Tension persists across the policy and scientific landscape about the utility of sustainable biomass in the transition to a low-carbon economy.[1] There is some vocal opposition to the use of biomass as a replacement for fossil fuels in some quarters. On the other hand, some leading scientists have broadly included bioenergy with and without carbon capture and storage (from forest and non-forest feedstocks) as a replacement for fossil energy as a key element in scenarios to meet mid-century decarbonization targets and to stabilize the increase in global temperatures.

In our view, because of the urgency of the climate problem, arguments for the removal or significant restriction of any of the tools relied upon in these decarbonization pathways (whether it be nuclear power, hydropower, or forest biomass) face a high burden of proof. Even with all of the tools in these pathways available, the world is well behind the pace of decarbonization we need, in large part because we are failing to rapidly phase out the use of fossil fuels.

We do not believe that any and all forest biomass should be used for energy. Others believe that it is rarely (if ever) an appropriate energy source. We believe that somewhere between these extremes lies a science-based, environmentally responsible approach that can effectively contribute to mitigating climate change, and we explore that in this paper. We have organized our analysis around the following six points, and we believe that the right policies and positions on forest biomass should take each into account:

1. Wind and solar alone cannot solve our energy sector needs; we also need dispatchable and reliable non-fossil energy generation.
2. Not all forest biomass is appropriate for energy production, but the best policy approach will enable a scalable use of forest biomass that does not contribute net greenhouse gas (GHG) emissions over the near or long term while protecting the health and growth of forests.
3. The climate is not concerned about national boundaries or individual country carbon accounting per se, as much as it is with the net GHG emissions to the atmosphere over relevant time frames from both the energy and the land sectors.
4. Assessments of the impact of forest bioenergy use on carbon stocks that focus on a single tree or stand do not provide an accurate assessment of net GHG emissions over the near or long term.
5. One should not assess the net carbon impact of forest biomass sourced from privately owned working forests (like those in the Southeast U.S.) without considering the economics of that ownership and the feedbacks on land-use decisions.
6. Forest biomass production in the Southeast U.S. has the following attributes:
   a. Harvest decisions are not driven by biomass demand.
   b. Entire mature forest stands are not being clear-cut for pellets.
   c. Biodiversity protections can prevent — and are preventing — the loss of sensitive forests.
   d. There is no evidence that biomass harvest is depleting soil carbon.

1. Wind and solar alone cannot solve our energy sector needs; we also need dispatchable and reliable non-fossil energy generation.

The tremendous growth in wind and solar energy has been a success story, but achieving a 100% renewable electric grid will require additional firm sources of generation to complement wind and solar, which are not available at all times of the day and which vary considerably over seasons. The grid needs controllable and dispatchable resources to meet demand on a 24/7 basis and to balance the intermittent generation. Today, the vast majority of that balancing is handled by fossil resources. Natural gas "peakers" are used to balance intermittent renewables, while natural gas combined cycle generation and coal (in many parts of the world) are often the backbone of dispatchable baseload generation. Natural gas, while better than coal, is responsible for an enormous amount of GHG emissions, and its role will need to be replaced with net-zero emissions alternatives in both thermal and electricity applications.

Energy storage and dispatchable renewable resources like hydropower and geothermal can complement wind and solar, but these resources are geographically limited. Energy storage can pair with wind and solar to store energy for when these resources go offline, but reliance on energy storage faces temporal challenges, particularly on a seasonal basis, in addition to cost. A recent study finds "[a]dding storage technologies to the grid at large scale will have significant costs, which will grow as [intermittent renewable resource] penetration rises. Even if innovation reduces the cost of storage, whatever technologies evolve will still represent an additional cost to the system. The electricity that is used to charge the storage system is not free, the act of storage itself produces efficiency losses of 10–20%, and storage systems require significant investment. To be economical, such equipment must be used frequently—yet seasonal variation requires storage capacity with a very low utilization rate."[2] Demand side and efficiency resources can also help, but given the foreseeable future need for a rapid displacement of fossil fuel-based GHG emissions, utilizing a portfolio of all available options gives us the best chance for success.

Bioenergy can be a part of this portfolio. Bioenergy is not a *substitute* for wind and solar as much as it is a *complementary* resource that enables more intermittent generation and that can accelerate the transition to a fully renewable grid. Biomass is already a viable and financeable feedstock for electric utilities to displace fossil generation[3] and can serve as a controllable resource that the grid can rely upon at all times of the day.

In addition to the need to decarbonize the electric grid, we must tackle the more difficult challenge of decarbonizing the provision of heat. Unlike the grid, where we have seen tremendous growth in the use of renewable energy, heat remains overwhelmingly fossil-based with far fewer clean alternative options readily available. For example, most industrial processes are not currently designed to use electricity, and electrified alternatives are not currently available for many applications.[4] In Sweden, the use of bioenergy for district heat and power has led to a tripling in the use of bioenergy (while the carbon stocks of Swedish forests have increased[5]), and in 2009 biomass surpassed oil as the country's leading source for energy production.[6] Again, while forest biomass is not the only option for decarbonizing heating, the challenge of decarbonizing the heating sector becomes that much greater if biomass is removed from the set of potential solutions.

It is because biomass can displace fossil use in the electric and heating sectors while aiding in the low-carbon integration of intermittent renewable generation that the leading scientific climate authority finds that bioenergy — including forest biomass — can play a critical role in meeting mid-century decarbonization objectives. The Intergovernmental Panel on Climate Change (IPCC) highlights the incorporation of bioenergy from a range of feedstocks in pathways to meet global decarbonization targets.[7] While the IPCC is careful to highlight the potential challenges and risks of scaling up the use of forest biomass worldwide, it acknowledges its potential to displace fossil fuel emissions. And the

International Renewable Energy Agency's (IRENA's)[8] path to a carbon-neutral future also includes *a tripling* of modern bioelectricity worldwide – from 5% today to 16% by 2050.

In addition to displacing fossil fuel use, forest bioenergy also offers the potential for delivering net-negative emissions through bioenergy carbon capture and storage (BECCS). BECCS involves capturing the emissions arising from bioenergy use and permanently sequestering them from the atmosphere, either underground or via an alternative storage mechanism, while biomass feedstocks continually draw more carbon from the atmosphere. The IPCC and others are increasingly confident that negative emissions technologies will be needed to limit warming.[9] In 2018, the IPCC examined what role BECCS and other negative emissions technologies could play in meeting 1.5°C and 2°C targets to limit an increase in global temperature.[10]

While the IPCC identifies scenarios in which BECCS provides a smaller (but still positive) role, it also presents scenarios where BECCS provides hundreds of gigatons of negative emissions by the end of the century. The UK Climate Change Commission includes BECCS as a key part of its strategy to achieve net-zero emissions by 2050.[11]

As countries determine their long-term emissions reductions strategies, nations like Sweden, the UK, and Denmark have used forest bioenergy as part of their move away from fossil energy. The UK has been able to reduce the share of its electricity from coal almost completely **(Figure 1)**, from 40% to 3% in 7 years[12], and Denmark's use of coal has declined by 36% over the same period of time.[13] This reduction in coal consumption has coincided with an increase in the use of forest bioenergy **(Figure 1 shows this for the UK)**.

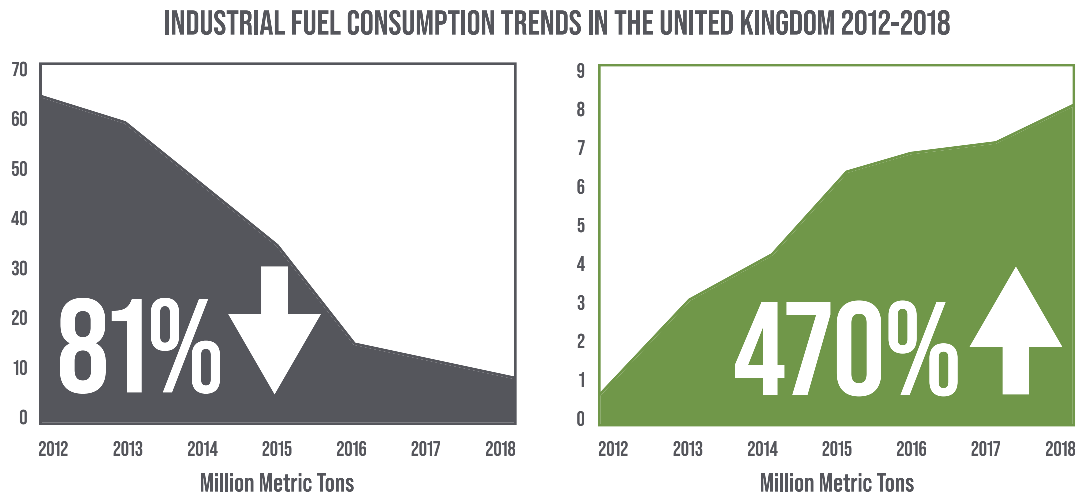


Figure 1: *Industrial coal[14] and wood pellet[15] consumption trends in the UK, 2012-2018.*

2. Not all forest biomass is appropriate for energy production, but the best policy approach will enable a scalable use of forest biomass that does not contribute net greenhouse emissions over the near or long term while protecting the health and growth of forests.

The Southeast U.S. produces one-fifth of the industrial wood used globally each year.[16] This large production base results in a large amount of waste that would normally decay and go unused. The wood pellet industry takes advantage of this very large production base to utilize a small proportion of what is harvested – waste that would otherwise be converted to carbon and go back to the atmosphere without providing any societal or ecological benefits. That being said, not all forest biomass should be used for energy production.

The Southeast U.S. is a unique and productive wood basket, but we cannot allow biomass production here or elsewhere around the world to cause deforestation, degrade forests that have high carbon stocks, threaten endangered species, harm biodiversity, or diminish water quality. There should be – and there are – sourcing standards for biomass and other forest products that ensure these and other negative outcomes do not occur. On the other hand, sustainably harvested forest biomass that utilizes low-value[17] trees, tops, limbs, and other waste from logging and sawmilling operations; that does not jeopardize these other environmental values[18]; and that comes from a sustainably managed forest landscape that is not emitting more from removals than it is sequestering via growth *could* be used to reduce GHG emissions, as there are no net GHG emissions associated with its use.[19]

Of course, the combustion of forest biomass releases carbon dioxide emissions,[20] even surpassing those of coal on an emissions per unit of energy basis in some cases. But again, what is climate-relevant is whether the atmosphere is experiencing a net increase in GHG emissions. As long as the forest landscape is not emitting more from removals than it is sequestering via growth, the atmosphere does not experience a net increase from the production and utilization of biomass produced on this landscape, *and* the atmosphere benefits from the elimination of fossil fuel combustion emissions that would otherwise have continued absent the replacement with forest biomass energy.

In contrast, if the landscape has decreasing carbon stocks, the atmosphere is likely experiencing net positive emissions. We do not support the use of biomass from such landscapes as part of clean energy policies or practices. Effective policy can distinguish between forest biomass produced in landscapes that are accruing carbon and those that are losing carbon. The European Union, for example, only allows forest bioenergy under the second iteration of its Renewable Energy Directive (RED II) if its sourcing meets designated criteria regarding protections for forests and other sustainability measures – *including* the requirement that for any country not a party to the Paris Accord (potentially the United States), "management systems are in place at forest sourcing area level to ensure that carbon stocks and sinks levels in the forest are maintained, or strengthened over the long term."[21] Thus, such a policy provides a backstop that ensures that – whether or not caused by forest biomass production – emissions from forest biomass combustion will not be treated as carbon neutral if the forest sourcing level does not continue to sequester more than it emits.

For Enviva, we ensure a net GHG reduction by only operating in a sustainable forest landscape where the net impact of harvest and regrowth is measured. The Southeast U.S. is a forest landscape where the forest stocks have been stable or increasing; there is continued regrowth and sequestration across 98% of the landscape while only 2% of the forest area is being harvested annually. Forest biomass sourced from the Southeast U.S. meets this test of providing net decarbonization benefits.[22]

Furthermore, wood pellet production in the Southeast U.S. poses little threat to either the stable or increasing forest stocks or to other sustainability values. As shown in **Figure 2**, forest bioenergy is only a small part of the overall forest

products industry. Nevertheless, there are some concerns that increasing demand for bioenergy will negate its climate benefits, which is why we rely on forward-looking and effective policy that only applies a climate-friendly status to forest biomass produced in landscapes that are net accruing carbon.

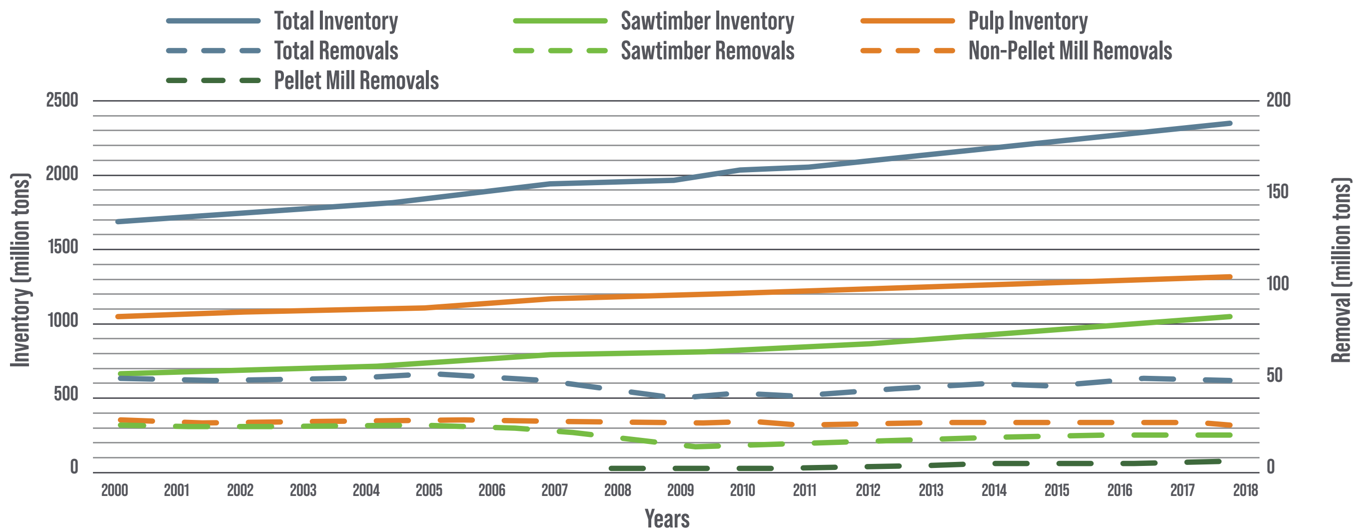


Figure 2*: Total harvest of forest products, including pellets, within Enviva sourcing regions 2000-2018. Forest2Market 2018.*[23]

A single harvest in the region might generate material that will be used in a range of high-value to low-value wood products, which fetch a range of prices and are delivered to different markets for use in a variety of finished goods.[24] Different products from the forest are used to manufacture different kinds of end-products based on the quality of material that comes out of the forest. Everything from lumber, boards, and tissues to labels and packaging is manufactured in the Southeast U.S. The lowest quality wood – largely byproducts of the harvest for more lucrative markets – is the feedstock used to make pellets. Landowners will always, rationally, look to sell their high-value forest products to higher-value product markets before selling their low-value wood to a pellet mill. Reid et al. (2019) finds that "waste biomass" – including "waste wood from sawmills or small-sized timber from logging operations" – as well as "good stewardship biomass" – defined as biomass whose removal enhances the carbon storage potential of the remaining ecosystem, such as fire treatment thinnings or forest restoration projects – has positive attributes with respect to GHG benefits and sustainability.[25]

These feedstocks are precisely the types used by Enviva to make wood pellets.[26] To ensure that our feedstocks have these characteristics, in 2018 we adopted a Responsible Sourcing Policy (RSP) that guides our sourcing decisions.[27] We also created our proprietary Track & Trace® program that allows us to monitor all primary sources of wood and publicly disclose detailed information on an individual forest tract's location, age, species mix, and more.[28] Beyond our direct business practices, we are investing proactively to improve the health and biodiversity of the region's forests. These include our newest efforts related to the restoration of longleaf pine,[29] the Enviva Forest Conservation Fund, the expansion of our High Conservation Value (HCV) policy, and other facets of our RSP as outlined in our Impact Report and our recently released 2020 RSP Implementation Plans.[30,31]

To ensure sustainable production, the region's forest products industry also has created and implemented a set of policies and best practices, including adherence to state best management practices (BMPs) for water quality, as well as sourcing from forests qualifying under one or more certification schemes (though only a very small percentage of forest land in the Southeast U.S. is enrolled in forest management certification through entities like the Forest Stewardship Council®.

3. The climate is not concerned about national boundaries or individual country carbon accounting *per se*, as much as it is with the net GHG emissions to the atmosphere over relevant time frames from both the energy and land sectors.

There is a lot of complexity and disagreement about how to account for carbon emissions from wood-derived bioenergy. We see this disagreement at the international level, where critics charge that international inventory accounting systems create loopholes that allow countries to ignore the emissions arising from some biomass use in their inventories. There is also disagreement at the national level in terms of how national clean energy and emissions reporting regimes document and treat the emissions arising from the stack and supply chain. These national-level policies often address whether emissions from a specific source are considered "carbon neutral."

At the international level, the IPCC has established guidelines for accounting for the biomass used to produce bioenergy that is consistent across parties to the UN Framework Convention on Climate Change (UNFCCC):

1. Reporting under the UNFCCC: Every country in the world is a party to the UNFCCC, including the United States,[32] and as part of their obligations under the UNFCCC, every country in the world must report its GHG emissions annually. Annex I countries do this by preparing a National Inventory Report (NIR)[33] that is peer-reviewed by independent experts.
2. NIRs: Each NIR is required to follow a standard set of protocols developed by the IPCC.[34] NIRs are prepared using sectoral boundaries to keep track of GHG emissions across four sectors: Energy; Industrial Processes and Product Use; Agricultural, Forest and Other Land Use (AFOLU); or Waste. In a given country, every last source of GHG emissions is counted and categorized in one of these four sectors. These sectoral boundaries are clear so that no GHG emissions source is unaccounted for and no source is counted twice.

This is the key: in the country-level inventory accounts, the IPCC instructs countries to count CO_2 emissions and removals from the use of biomass for energy in the AFOLU sector to account for any emissions and/or removals from forest harvest and regrowth, respectively. As such, two things are important:

1. Emission sources or sinks of CO_2 from land-use change and forestry activities in the AFOLU sector are measured as changes in carbon stocks. An increase in land carbon means that the AFOLU (land) sector is a net sink of carbon, while a decrease in land carbon would mean the sector is a net emissions source.
2. When wood crosses the system boundary from AFOLU to Energy — when sustainable wood bioenergy is combusted to generate energy — any source or sink associated with growing and harvesting that wood product has already been counted in the net carbon stock change measured in the AFOLU sector.

Under this current regime, the question frequently arises — are wood pellets produced in one country and used in another being properly accounted for under each country's emissions inventory?[35] This is a reasonable question because the emissions from combusting the pellets are not included in the consuming country's emissions accounts for energy. These emissions are instead captured in the pellet-producing country's land use-sector emissions because pellets are a forest product.

What does this mean for carbon accounting for bioenergy? It means that countries should not count emissions from bioenergy in their energy sector inventory, though policy to ensure that feedstocks are having the desired net GHG impact would still be required. If a country did count the stack emissions from wood bioenergy used as fuel in the energy sector it would be double-counting emissions. Those emissions are already covered in the forest carbon stock reporting in the AFOLU sector in the source country. As Marland (2010) explains, "[t]he IPCC inventories do not exempt bioenergy systems. They very purposefully

account for emissions from fossil fuels where and when they occur, and they account for changes in biological stocks of carbon where and when they occur."[36]

We think that if all parties follow the reporting methods, there is no loophole at the international level.[37] A country that uses forest biomass in its energy sector to meet its emissions reductions targets is not hiding or ignoring the emissions from biomass in its own inventory accounts – it does not belong there because the GHG emissions are already counted in the producing country's ledger in the AFOLU sector. Therefore, policies that set stack emissions for certain types of forest bioenergy to zero for the consuming country do not create a "loophole" nor a perverse incentive for countries to use imported biomass (in fact it is a positive incentive for those countries to displace fossil fuels).[38]

While individual country accounting is important, the atmosphere is indifferent about where carbon is stored or emitted. The important things are that the global net emissions are falling, the sum of all accounts is accurate, and no source or sink is double counted. Because every country is reporting an inventory that includes the AFOLU sector, there is no situation where biomass emissions are going undetected.

4. Assessments of the impact of forest bioenergy use on carbon stocks that focus on a single tree or stand do not provide an accurate assessment of net greenhouse gas emissions over the near or long term.

When biomass is combusted, stack emissions of CO_2 result. This is an immutable fact, of course, and not up for debate. The question is how to link the stack emissions with the carbon dynamics on the forest landscape where the biomass was produced in order to quantify the lifecycle emissions benefits that accrue from bioenergy — or, stated more simply, what is the actual and total impact on the atmosphere?

Some argue for accounting methods that examine how long it will take the carbon released by a *given unit* (or stand) of biomass to be re-sequestered through replacement growth for that unit. Manomet (2010) proposed one such "carbon debt" approach that has been influential and is held out as a superior approach to assessing climate impact.[39] But stand-level accounting is fundamentally flawed. Such an approach does not account for the fact that harvests across a landscape are very dynamic and that regrowth occurs along with individual harvests, such that relevant accounting must be based on the integrated effect of all of the simultaneous harvest and regrowth events occurring in that wood basket. Drawing narrow boundary conditions may seem logical, but it will lead to inaccurate net results. In addition, carbon debt models are heavily reliant on their input assumptions. Rolls and Foster (2020) find that carbon payback models may vary significantly in their conclusions depending on inputs like forest growth curves.[40]

Further, stand-level accounting is totally dependent on the start date of the analysis, and whether one finds that there is a carbon "debt" to pay back when bioenergy emissions occur is a function of where one begins the accounting.[41] If one starts the "accounting clock" at the moment of harvest, the emissions created from that particular harvest are immediately incurred to the atmosphere and will not be "paid back" until that particular tree or stand of trees is regrown. "However, if the accounting begins with the forest establishment, e.g., at tree planting, then post planting growth is building up a stock of carbon that will be released at harvest. Thus, any future debt from that stand will have been offset in advance of the harvest and no intertemporal net carbon debt is incurred."[42] Favero et al. (2020) reinforce this conclusion:

> *This outcome is different than that of Schlesinger et al. (2018)[43] and others, who do acknowledge regrowth of forests but argue that emissions in the near term are particularly harmful because they cause damages during the entire time it takes for forests to regrow. This stance ignores the benefits of the past accumulation of carbon embodied in current forest stocks, which is an important component of the global carbon budget.[44]*

The accounting for a single stand is illustrated in **Figure 3a**, and in **Figure 3b (on the next page)**, we show cumulative emissions and regrowth (in the forest) at the scale of multiple (30) stands when the accounting clock is started at the time of regrowth, thereby capturing and accounting for prior carbon uptake across many stands. This figure shows that if one turns the clock back 30 years — to the moment that same stand was planted — the release of carbon from the bioenergy is simply returning the carbon to the atmosphere that had been sequestered gradually over the 30 years prior.

By discounting all of the sequestration that occurred in the forest before it was harvested, and starting the clock at the time of combustion, yes — it will take a number of years for that particular carbon to be recaptured by the forest. **(see Figure 3c on page 15)**. Again, no individual stand is harvested *for* biomass; biomass is a by-product of harvest where the primary output is a higher-value product like sawlogs for lumber production.

For working forests, it is a landscape-scale approach to carbon accounting that more appropriately assesses the net impact on the climate. Working forests are made up of assemblages of stands, and it is these "assemblages" that are in a continuous cycle of harvest

and regrowth.[45,46] Because these assemblages of stands are all harvested at different times, the more appropriate way to think about the "carbon debt" clock is to overlay multiple stands on the same graph, with overlapping cycles of growth and harvest **(Figure 3d on the next page)**.[47] If the forest landscape is at a steady state (or net growing), each harvest event is compensated simultaneously by regrowth occurring elsewhere on the landscape.[48] As stated by Cowie et al. (2013):

> *In order to fully understand the climate change effects of bioenergy from existing forests, it is important to consider the entire forest landscape and the wide range of conditions within which forest bioenergy systems operate, long term as well as short term effects and climate objectives, and the interactions between human actions and forest growth.*[49]

Forest biomass sourced from a stable or growing working forest landscape provides immediate carbon benefit in displacing the emissions released by fossil fuels and does not cause a net increase in emissions experienced by the atmosphere.[50]

kg Ceq / tonne wood-pellet combustion over 90 years
1 source location, linear growth

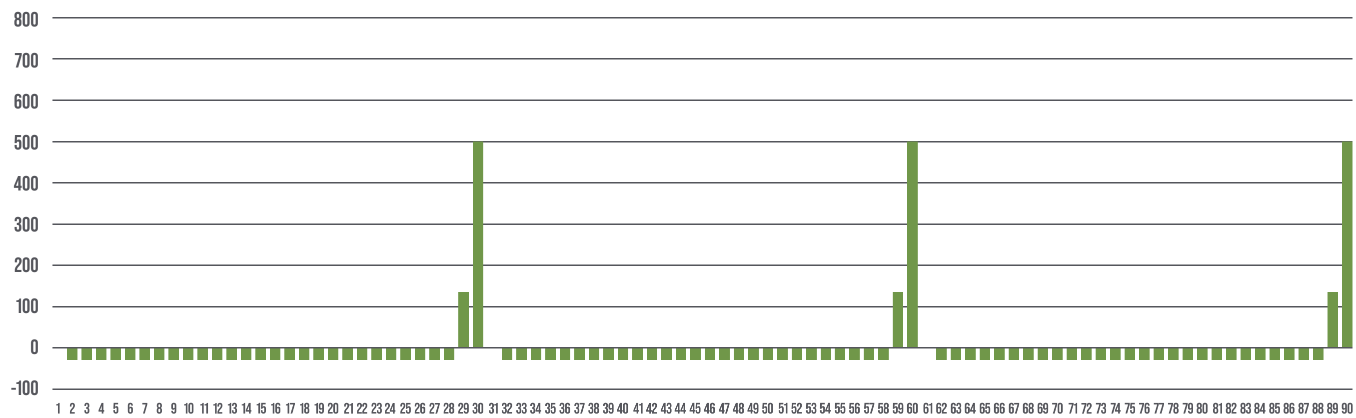


Figure 3(a): *Carbon cycle of wood pellet combustion over a 90-year period, one source location. In year 1, there is forest establishment with small fossil inputs, and then 29 years of growth. In year 29, processing occurs with wood heating, fossil inputs to harvest, process, and transport the pellets. And in year 30, combustion of the wood pellets releases CO_2. This cycle is repeated three times over 90 years in this figure.*[51]

kg Ceq / tonne wood-pellet combustion over 90 years
30 source locations, linear growth

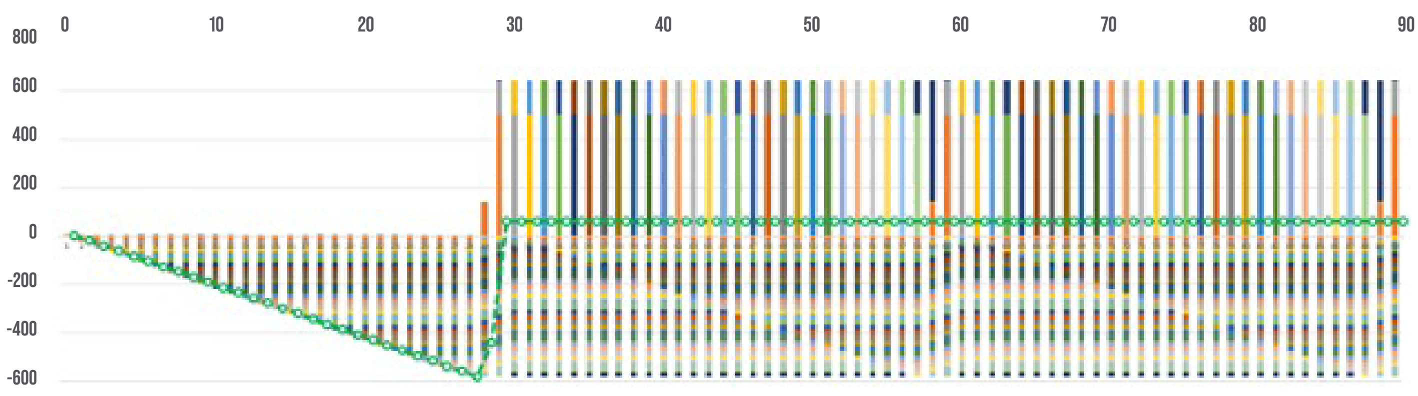


Figure 3(b): *Cumulative emissions crediting prior C-uptake (forest growth from year 0-30 across 30 stands), wood-pellet combustion over 90-year period for 30 source locations (each color is a stand).*[52]

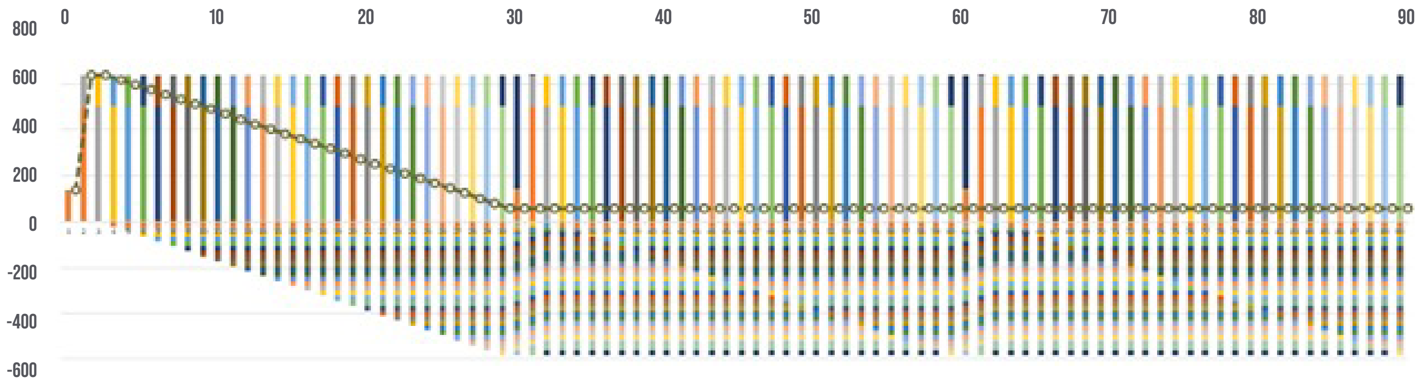


Figure 3(c): *This figure shows cumulative emissions with carbon release upon wood pellet combustion if one starts the clock at the point of combustion and gives no credit to prior carbon uptake by forest growth over the 30 stands and 90 years. The decision on when to start the clock increases the short-term transient emissions but the stead state emissions remain the same over time. .*[53]

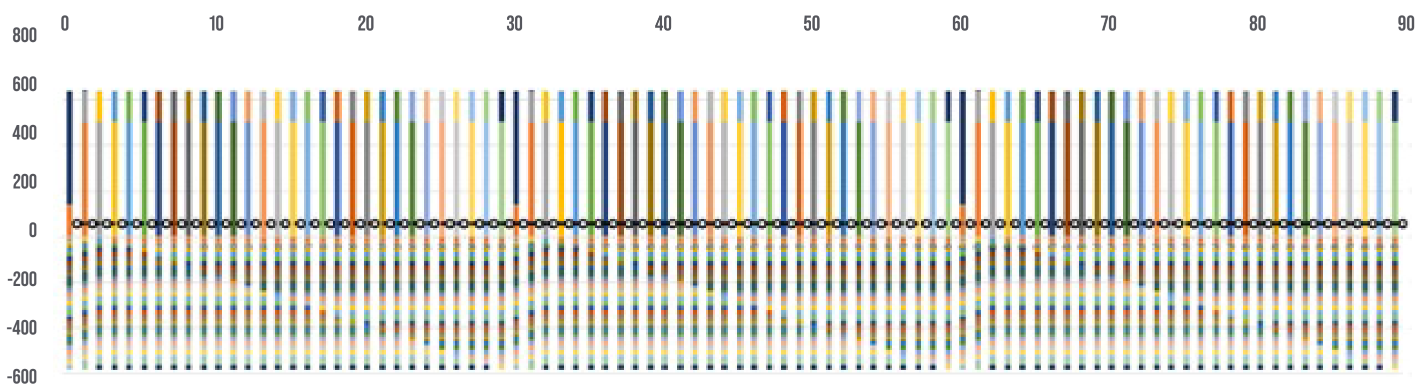


Figure 3(d): *This figure illustrates the lifecycle accounting (LCA) accounting practices assuming a continuous steady state, where carbon stocks are continuously replenished. This is a reasonable and generally practiced approach for any type of bioenergy.*[54]

Khanna et al. (2017) explain that for a system like the Southeast U.S., where bioenergy is generated as part of a supply chain that produces a variety of products annually, the landscape view is appropriate:

If biomass for bioenergy is being obtained from a forest that is being managed as a plantation as a part of a supply chain of biomass to a forest industry that requires continuous supply of biomass annually then a landscape view is appropriate.[55]

Other researchers agree. For example, Jonker et al. (2014) found that "[w]e consider the landscape-level carbon debt approach more appropriate for the situation in the Southeast U.S., where softwood plantation is already in existence, and under this precondition, we conclude that the issue of carbon payback is basically nonexistent."[56] And the same thing is true for European forests as well, as discussed by Nabuurs et al. (2016).[57]

But what if the forest landscape is not sequestering more carbon than that resulting from harvests? This is where a "carbon debt" approach *at the landscape scale* does make sense.[58] If growth and sequestration are not keeping up with harvest, then we agree that the emissions from biomass combustion should not be treated as climate friendly[59] (and as discussed above,

current policies provide for this). Some, however, might want to go further and speculate that, absent forest biomass demand, even a stable or net-growing forest might have grown more, and thus biomass should be penalized. Such a contention, however, is inconsistent with private forest economics and practices (see next section) and not supported by analysis.

The Southern Forest Futures Project observed that expanding demands for bioenergy would not automatically mean a reduction in forest inventory, and that simulations show that increased demand, when paired with increased forest productivity, could lead to higher levels of inventory and removals in the U.S. South.[60] And Favero et al. (2020) demonstrate that we can have both increased carbon sequestration and biomass energy whereby increased bioenergy demand leads to more afforestation and intensive[61] management relative to a no-bioenergy case.[62] Baker et al. (2019) similarly conclude that an expansion of forest bioenergy can increase carbon sequestration opportunities through forests.[63]

Finally, what tends to get obscured in the stand-level "carbon debt" versus landscape debate is the need to develop a policy approach to biomass and energy sector decarbonization that is workable and that can encourage the replacement of fossil energy with biomass in a way that is a net benefit to the climate. Attempting to analyze and assign "carbon debt" labels to every load of material landing at a pellet mill is impractical and would make it extremely difficult for a supplier to offer a long-term agreement to a customer needing a secure and bankable source of supply meeting that customer's specifications. For an owner of a fossil generation facility looking to finance a conversion to biomass pursuant to clean energy policy mandates or incentives, that certain supply is necessary. If, on the other hand, the supplier knows that their product will meet customer specifications based on the state of the source landscape, considerable risk is eliminated. Under this approach, the supplier is also disincentivized against any level of harvest that might jeopardize the net stability of the forest landscape.

So, when biomass is combusted, stack emissions of CO_2 result. But by linking the stack emissions with the carbon dynamics on the forest landscape, we can be assured that the climate impacts are accurately and more fully accounted for.

5. One should not assess the net carbon impact of forest biomass sourced from privately-owned working forests (like those in the Southeast U.S.) without considering the economics of ownership and the feedbacks on land-use decisions.

One of the often disregarded or misunderstood aspects of the debate over Southeast U.S. forest biomass production (and the Southeast U.S. forest products industry in general) is that on private working forest lands, there is a *positive* correlation between market demand for forest products and forest growth and carbon stocks. We recognize that it is intuitive to assume that if there is more demand for forest products, fewer trees (and less carbon) result. But in these systems, that is not the case.

Someone evaluating forest bioenergy and its environmental impacts will draw very different conclusions depending on a few key assumptions about economics.[64] One of these is whether and how you include people in your model.[65] People own land, working forest landowners have choices, and those landowners will make decisions that respond to the markets for their products. Much like farmers, working forest landowners will invest in more and better forests if they can capture value from the trees that grow there.[66,67] As Sedjo and Tian (2012) explain, "forest management responding to the markets for wood products involves the simultaneous management of multiple stands and an anticipation of future market conditions. Indeed, the market coordinates wood use and forest management across many stands and ownerships as multiple managers and forests are directed by market signals."[68,69] And when markets are healthy, this behavior results in more, not less, forest.[70,71] Favero et al. (2020) also make the point: "[e] conomic incentives promote more forest management".[72]

In the Southeast U.S., the market demand for forest products is strong and circular – forest landowners who produce forest products as a primary use of their lands harvest trees to earn income from current demand and also plant trees and/or manage growth in anticipation of meeting future demand – both near term and longer term. In this region, these dynamics lead to only about 4% of forest volume **(see Figure 4)** being harvested annually.[73] In evaluating the dynamics between forest product demand and forest growth (including the role of forest biomass) these economic factors are critical, especially in a region like the Southeast U.S. that is predominantly privately owned and where amounts are increasingly owned (20-41% of forest land in our Southeast sourcing states) by private corporate timber investment management organizations (TIMOs).[74,75]

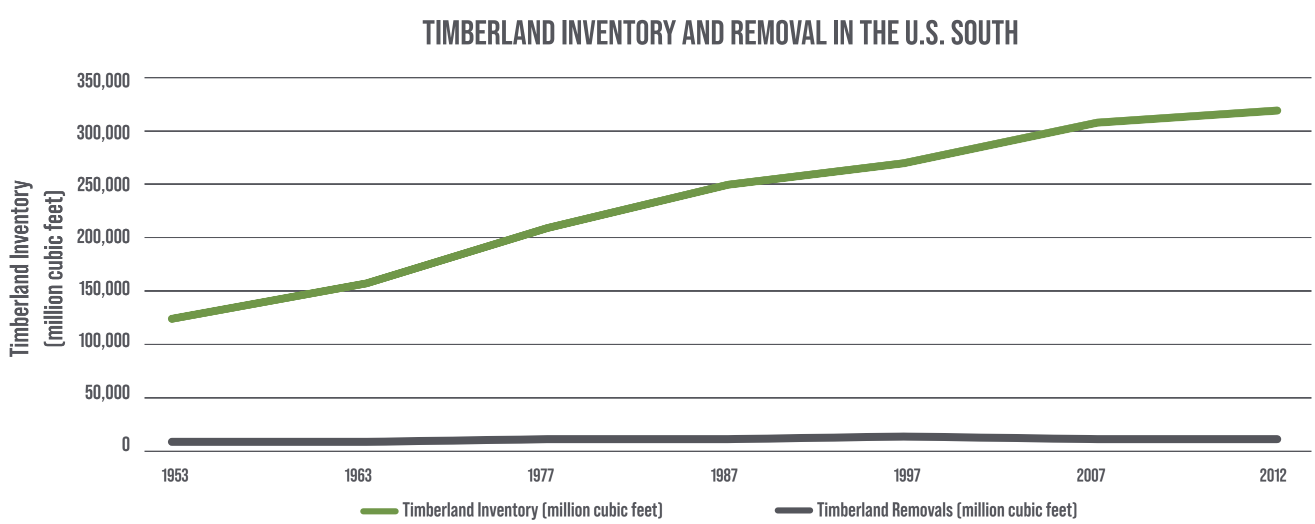


Figure 4: *Timber Inventory and Removals in the Southeast U.S. 1953-2012*[76]

The importance of forest management for improved carbon storage on the landscape is a well-studied phenomenon. For example, Oliver et al. (2014) concluded that "[m]ore CO_2 can be sequestered synergistically in the products or wood energy and landscape together than in the unharvested landscape."[77] This is not say, however, that all forests should be harvested.

We agree that there is both carbon and biodiversity value in some forests being set aside for conservation. Other forests are best suited to continue to provide wood products – and the sustainable production of them supports and enables the continued conservation of others. There are both carbon values and economic realities for why this combination of approaches to forests makes sense. Forest products provide additive carbon value, including when wood is used to replace highly carbon intensive alternatives such as cement and steel, and when sustainable forest biomass is used to keep fossil fuel in the ground. Furthermore, absent a comprehensive and extremely well-funded policy regime that pays private forest landowners to not harvest, the reality is that forest product revenue incentivizes management and growth and disincentivizes conversion to non-forest use. [78]

This balance of approaches to forests in the Southeast U.S. is working. These forests make up just 2% of the world's forest cover, and yet produce around 12% of the world's industrial roundwood and 19% of its pulp and paper products. Data show that forest inventory and productivity in the Southeast U.S. have been increasing year over year since the U.S. Department of Agriculture's recordkeeping began in the 1950s **(see Figure 5a and 5b)** – even as removals have remained relatively constant through time **(see Figure 4 on previous page)**.

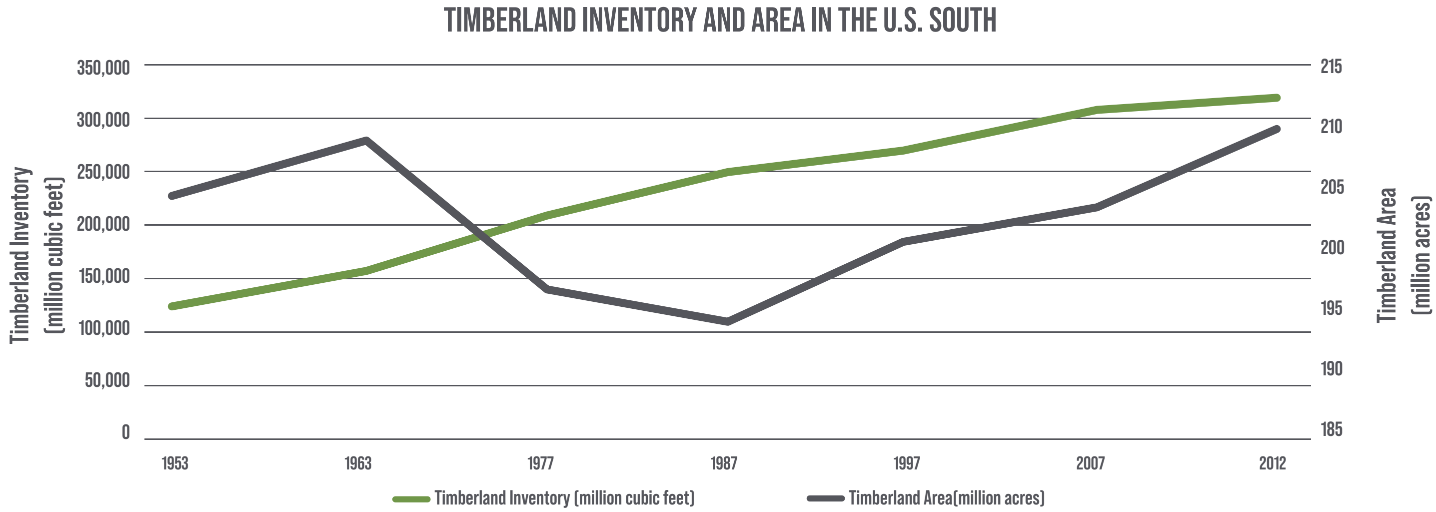
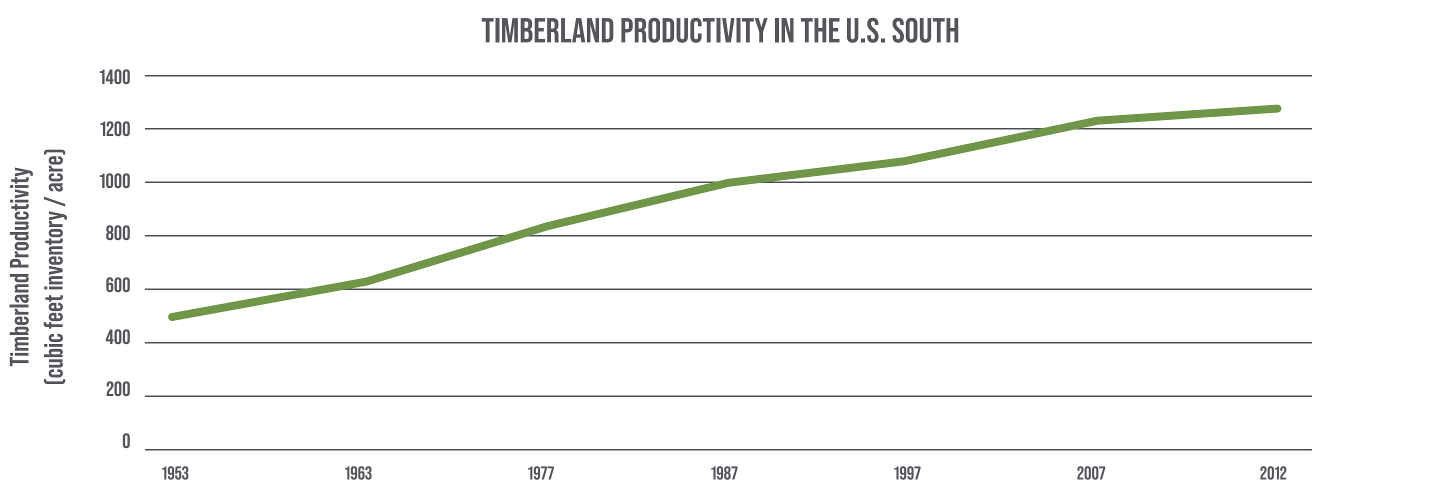


Figure 5 (a) *(above) and* **(b)** *(below): Timberland productivity in the U.S. South and Timberland Inventory and Area in the U.S. South.*[79]



The positive correlation between demand and forest growth has been studied and demonstrated specifically with regard to forest biomass. Galik and Abt (2012) found that "assessment scales that do not include possible market effects attributable to increased biomass demand, including changes in forest area, forest management intensity, and traditional industry production, generally produce less-favorable GHG balances than those that do."[80] Similarly, Daigneault et al. (2012) concluded that "when market factors are included in the analysis, expanded demand for biomass energy increases timber prices and harvests, but reduces net global carbon emissions because higher wood prices lead to new investments in forest stocks."[81] Duden et al. (2017) concluded that the demand induced by the wood pellet market would retain more natural timberland areas (up to 750,000 hectares), and that without additional demand for wood pellets, that natural timberland would likely decline by up to 1.5 million hectares.[82] Other studies estimate that additional wood pellet demand could move up to 1.4 million hectares into forestry by 2032.[83] Abt et al. (2012) found that these supply responses would be critical for understanding the environmental effects of bioenergy demand.[84] Favero et. al (2020) conclude that "[i]ncreased bioenergy demand increases forest carbon stocks thanks to afforestation activities and more intensive management relative to a no bioenergy case."[85] These studies answer the question often posed as a "counterfactual" by forest biomass critics: "but if there was not harvest for biomass wouldn't the result be *more* forest and forest carbon?" The answer is no. In examining broader trends in the bioeconomy, the European Forest Institute finds that demand for different forests products is always evolving, yet overall demand for forest products tends to remain stable:[86]

> *"Some of the traditional products will require more roundwood (e.g. packaging products), some less due to decline in demand (e.g., wood fuel in Africa, and graphics papers globally). Some of the new emerging bioeconomy products will increase roundwood demand (e.g. engineered wood products), while others may use the side-streams of current products, such as pulp side-products (e.g. lignin) for new biochemical, or forest residues for biofuels. The latter therefore do not generate "new" demand for roundwood, but are based on increasing resource-efficiency."*

We recognize that similar dynamics for the Southeast U.S. are not found in other parts of the world. Demand for forest products, but also drivers such as development and agriculture, lead to declining forest and carbon stocks and deforestation following land use conversion. It is true that market demand for trees in other parts of the world can lead to deforestation, but that is because the market for trees in other regions is used to fund the land clearance that makes way for products with even stronger market demands like beef, soy, and palm oil. Forest biomass harvested from regions being deforested should not be considered "good" biomass.

6. Forest biomass production in the Southeast U.S. has the following attributes:

a. Harvest decisions are not driven by biomass

Some forest biomass critics claim that forests are being "clear cut" or even "decimated" for biomass production.[87] As discussed, wood biomass is a low-value commodity, which is least likely to drive harvest decisions, and biomass used for bioenergy comprises less than 3% of the total removals in the entire Southeast U.S. region.[88] For the stands from which Enviva purchases biomass, on average we take about 30% of what's harvested (and considerably less than that in terms of economic value given sawtimber is worth at least twice our low-value wood sources).[89] The distinct majority of both the physical and economic harvest goes to other forest products facilities, such as sawmills or paper mills – and it is the combination of each of these markets that drive harvest decisions.

Markets respond to price, and the highest-priced product is material that can be sawn and converted to lumber. Most owners of working forests manage their forestland to ensure they maximize the value for their property. While demand for wood pellets has opened new markets in the Southeast U.S., biomass is not driving harvests because landowners continue to manage their land for higher-value timber products to get the desired return on investment.[90] While landowner strategy may change over time, for example, shifting from hardwood to pulpwood rotations, biomass is unlikely to represent the highest value stream that will influence landowner decision-making.

b. Entire mature forest stands are not being clear-cut for pellets

The most common method to sell material from a tract at final harvest in a Southeast U.S. working forest is through clearcutting, and from a clear-cut comes multiple products: timber, chip-n-saw, pulpwood, and harvest residues. Only the last two products are economically feasible for biomass production. Before that final harvest is thinning on some managed forest lands, which yields small diameter, low-value material usually 15 years after forest establishment. The rare occasion when we allow for 100% of the material from a tract to come to Enviva might be, for example, when early forest establishment was done poorly and a landowner needs to clear the land early to replant for timber, or when a loblolly pine tract is cut to be replanted and restored to native longleaf pine to support biodiversity in the region. Again, forest biomass is not driving the underlying harvest decisions.[91]

c. Biodiversity protections can prevent – and are preventing – the loss of sensitive forests

Enviva operates in a global biodiversity hotspot, the North American Coastal Plain.[92] As part of this hotspot, the Southeast U.S. is home to a number of endemic species that are at risk, threatened or endangered. Many NGO, agency, landowner, and industry partners, including Enviva, are working to conserve the habitat required by these at-risk species. At Enviva, we are taking ever stronger steps to ensure that our sourcing does not negatively impact HCV areas. Enviva's Responsible Sourcing Policy (adopted in 2018) states that "the primary wood we purchase must be sourced from sustainably-managed forests and harvesting operations. Enviva will only source primary materials from suppliers when High Conservation Values (HCVs) are not threatened by harvest activities."

In 2016, based on expert input, Enviva adopted a set of HCV procedures to ensure the protection of four rare bottomland forest types and that our sourcing would be appropriate and compatible with regeneration in other bottomland forest types.[93]

In addition, Enviva committed in 2019 to extend our HCV policies and apply the HCV Network Approach, particularly for certain upland HCV types, like longleaf forests for which we have a five-year restoration plan with The Longleaf Alliance.[94] In 2019 and 2020, we have been working with Earthworm Foundation and NatureServe to obtain data on an expanded set of HCV types, which we will implement in 2021.

d. No evidence that biomass harvest is depleting soil carbon.

We know that the foundation for the working forests in our region are soils, which play a critical role in storing carbon and preserving nutrient quality for a productive forest. There have been concerns raised that biomass extraction

risks depleting soil carbon, but these concerns lack clear evidence that the industry could act on, are issues that are dependent on site and stand conditions, and do not acknowledge that forestland owners practice sound stewardship of their property to protect the productive capability of their soils for the next forest rotation. There are no consistent observations of negative effects of forest biomass harvesting on soil productivity.[95] And any negative impacts of biomass harvesting on soil nutrient pools are more often observed in the forest floor than in mineral soil. Based on the literature, forest site characteristics and sensitivities — rather than biomass extraction — are the critical determinants for whether harvest activities may deplete soil carbon or other nutrients.[96]

Parolari et al. (2016) states that "while biomass harvest inevitably intensifies ecosystem C [soil carbon] and N [nitrogen] losses, there is little consensus on the magnitude and direction of the aggregate effects on soil C storage, soil C and N fluxes, and primary production."[97] There are meta-analyses that found no change in soil C and N storage after harvest, although the individual studies showed positive or negative changes.[98] And there are meta-analyses that found soil C losses on average from harvest, and full recovery of carbon storage within several decades.

Individual studies of forest management effects on surface soil carbon found that measures over multiple decades in the southern Appalachians of undisturbed hardwood, hardwood, and pine sites experiencing whole tree harvest and commercial saw log harvest showed no long-term decreases in soil carbon and nitrogen.[99]

Johnson et al. (2002) looked at the effects of harvest intensity (including saw log, whole tree, and complete tree harvests) on biomass and soil carbon across forest sites in the Southeast U.S. (Tennessee, North Carolina, South Carolina, and Florida). Notably, harvesting had no lasting effects on soil C.[100] The North Carolina site had a 51% increase in soil C during the first three years after sawlog harvesting and remained above pre-harvest levels for 18 years, and the site with whole tree harvest had a decline that averaged 13% over 15 years post-harvest. The South Carolina sites experienced positive and negative short-term changes in soil C during the first four years after the sawlog harvest, and no significant long-term change in soil C after 16 years with either harvest type. In Tennessee there were long-term increases in soil C over 15 years for both sawlog and whole tree harvests, and this may be due to residues left behind and root decomposition after whole tree harvest.[101] Other studies on the effects of organic matter removal have shown that removal of stems and whole trees did not have a detrimental effect on soil C and N contents. In fact study sites in North Carolina had large increases of C and N.[102] And studies that looked at bole-only versus whole tree harvests showed that soil carbon was no different between harvest types and that soil carbon increased in both harvest area types over time.[103]

The science seems to indicate that forest biomass harvesting can benefit, do no harm, or degrade soil carbon depending on the forest site characteristics and responsible forest management. We recognize that the maintenance of forest soil carbon stocks is critical for climate change mitigation, and we will continue to support forest biomass harvesting that protects sensitive areas like wetlands and peatlands where site characteristics increase the likelihood of soil carbon depletion.

Conclusion

We embrace the urgency with which the global community must address climate change. The challenge is immense, and meeting it will require unprecedented commitment on the part of individuals, nations, and corporations. The outlook for 2030 is presently not very encouraging and requires better solution and actions, with global coal consumption slowing but not yet rapidly decreasing, and with natural gas use soaring. However, despite slow progress thus far, groups like the IPCC confirm that the tools we have at our disposal today and in the near future are sufficient to address climate change. What's important is that we use these tools in the ways that are appropriate to achieve these aggressive goals.

We do not believe that all forest biomass that could be sources for bioenergy are beneficial for the climate. Proper utilization of biomass requires that we pay diligent attention to carbon stocks, land use, biodiversity, sustainable forest management, and forest economics. When sourced responsibly, wood-based bioenergy is renewable, reliable, cost-effective, and can be used in energy systems that exist today. Critically, placing a positive value on wood in the global economy promotes avoided deforestation and increased accumulation of carbon in forest ecosystems.

Biographies

Dr. Jennifer Jenkins is Vice President and Chief Sustainability Officer at Enviva., She leads the team responsible for Enviva's environmental stewardship, from guiding the development and implementation of policies that ensure the sustainability and traceability of the wood supply chain, to interacting with policymakers and other stakeholders on regulatory matters. With a technical background in carbon cycling and ecosystem science, she brings more than 20 years of experience working in government, academia, and the private sector at the interface between forests and climate. She holds a Ph.D. in ecosystem ecology from the University of New Hampshire, an M.B.A. from the University of Maryland's RH Smith School of Business, a Master of Forest Science from Yale University, and a B.A. in Biology and Environmental Studies from Dartmouth College.

Alan Kroeger is Director of Sustainability and Climate Initiatives at Enviva. He is responsible for natural climate solutions at Enviva and working with external stakeholders to fight climate change through our bioenergy supply chain and across the forest landscape through improved forest management. Alan has a technical and policy background in forest conservation, restoration, and international climate policy working for large international NGOs. He holds a M.S. in environmental policy from Bard College, and a B.S. in natural resources policy and management from Cornell University.

Endnotes

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17 Low value in terms of their economic value for timber products.

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19 Reid, W. M.K. Ali and C.B.Field. 2019. The Future of Bioenergy. Global Change Biology https://doi.org/10.1111/gcb.14883

20 The forest biomass supply chain also releases emissions from the harvesting, manufacturing, and transportation of wood pellets. The supply chains of other renewable resources also produce emissions, yet those emissions are not often considered when describing the carbon impact of these resources.

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22 There are of course GHG emissions arising from the forest biomass supply chain from harvesting to pellet production through to transportation. Many of our customers are required under their laws to ask biomass suppliers like Enviva to measure and document these emissions, as does our Sustainable Biomass Programme (SBP) certification. Supply chain emissions from the biomass supply chain are typically a small fraction of the stack emissions of fossil fuels. We are not aware of any other fuels source (fossil or renewable) that is subject to such supply chain emission disclosure requirements. Furthermore, supply chain emissions are not considered in the accounting of emissions at the point of generation for any other fuel source, whether coal, gas, solar or wind (i.e, coal emissions are measured as CO_2/MWh at the stack without regard to supply chain emissions; wind and solar are accounted as zero CO_2/MWh irrespective of the supply chain emissions of the turbine or the solar panel).

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90 We do recognize that markets drive merchandising decisions, and that these markets are local. And where local demand for sawtimber is weak, the market for pulp may determine harvest timing. If landowners begin to manage their land on a pulp rotation, our merchandising percentage will likely go up on average; but those management decisions are not being driven by forest biomass.

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