Biomass Energy Utilization Whitepaper

Commissioned by the Maryland Forestry Foundation

May 2020

Prepared by Dovetail Partners

Authors: K. Fernholz; J. Bowyer, Ph.D.; A. McFarland

DOVETAIL PARTNERS

Maryland Forestry Foundation

www.marylandforestryboards.org

MARYLAND CLEAN ENERGY CENTER

RMC Rural Maryland Council

MARYLAND DEPARTMENT OF NATURAL RESOURCES

Sustainable Forestry Council

Table of Contents

Executive Summary

Change often introduces uncertainty, and this is certainly the case when considering changes in the source of energy used in our homes and communities. Questions about the impacts to the local environment and beyond quickly arise in discussions about something as basic as energy supply.

This paper addresses environmental concerns and potential impacts associated with development of woody biomass energy in Maryland. The paper relies upon research findings and comparisons of alternative energy systems. Concerns that are addressed include effects on forest harvest rates and health, carbon emissions, and policy considerations. Following is a summary of the discussion points of this white paper.

Forest Harvest Rates and Forest Health

Bioenergy systems include electricity and thermal energy production (i.e., heat for homes, businesses, and other facilities). Sources of biomass fuels include woody materials, such as waste wood, wood chips, residues, and pellets. These wood fuels can be sourced locally, are renewable, and can reduce carbon emissions and other impacts associated with fossil fuel energy systems.

There is strong evidence that forest inventories (i.e., the size and number of trees in the forest) increase as forest product demand increases. Research also shows that tree mortality can increase when forest management activities decline. Management and timber harvesting can be applied to reduce or prevent tree deaths associated with drought, wildfire, and insect or disease outbreaks. In addition, harvesting of trees can support environmental objectives such as improved wildlife habitat and water yields or for social benefits such as enhanced recreation opportunities and public safety. The availability of economic benefits from markets helps support these desired outcomes. What research shows is that with strong markets, landowners participate in forest management and make investments that keep land areas as forests. These efforts also improve natural resource productivity that translates into carbon storage benefits as well as many other conservation values.

The allocation of harvested materials among various wood- using industries is dominated by market forces. Due to these market forces, biomass demand does not threaten large trees. The economic influence of competing markets serve to allocate high-value, larger diameter logs to high-return markets and low-value, smaller diameter materials (including biomass) to low-return markets. Markets for biomass do not provide enough financial incentive to support harvests of large mature, high-value trees. Biomass markets can support improved forest sustainability by utilizing low-value materials and reducing waste in processing. Economics preclude the use of old-growth or large mature trees in the context of harvesting for bioenergy production and additional environmental and social conditions exist to protect these forest values.

Forgoing the harvesting of trees does not necessarily translate to continued growth of trees because of basic tree biology, and because of the economics of land ownership. Property ownership has associated costs and a forest owner who cannot harvest trees or otherwise derive sufficient income will necessarily reduce investment in forest productivity and management activities or consider a change in land use. Forest income potential is one of the strongest deterrents to sale of forest land to developers.

Carbon Emissions

The carbon impacts of woody biomass energy depend upon several factors including the raw material being utilized and the energy production technology. In general, use of biomass from residues, waste materials, low-value materials or sustainably managed forests in highly efficient systems provide the greatest carbon benefits in comparison to non-renewable, fossil-fuel based systems. The International Energy Agency (IEA), the Intergovernmental Panel on Climate Change (IPCC) and a large number of scientists have concluded that biomass from sustainably managed forests is carbon neutral or a low-carbon fuel at the point of combustion (after accounting for emissions linked to harvesting and transport). There is also broad agreement within the scientific community that there are clear benefits to bioenergy versus fossil fuel alternatives if forests are managed sustainably.

Studies have shown that biomass energy use reduces the emissions of pollutants that are linked to negative environmental and human health impacts, such as mercury, smog-forming nitrogen oxides (NOx), and acid rain-forming sulfur oxides (SO_x). Emissions from combustion of woody biomass also have lower concentrations of trace metals relative to coal, including arsenic, beryllium, cadmium, and lead.

Full life cycle analyses consider all aspects of energy systems – including the manufacture and installation of combustion and distribution equipment, mining, extraction and transport of energy raw materials, energy production, disposal of waste, and end of life issues. Such analyses provide insights into total impacts of consumption choices that are otherwise elusive. Several life cycle studies have shown benefits associated with bioenergy that can occur immediately or over a longer timeframe. The period it takes to realize carbon emission reductions and other benefits of utilizing woody biomass energy will depend upon the design of the system and the impacts associated with the energy system it is replacing. One way to think of this is that the sooner a fossil fuel energy system is transitioned to renewable biomass energy, the sooner the carbon benefits will be realized.

Policy Considerations

Maryland has several existing policies that affect biomass energy utilization and activities, including the Maryland Seed Tree Law, forest biomass harvesting policies, and the Forest Conservation Act. The Maryland Department of Natural Resources has prepared "A Guide to Forest Biomass Harvesting and Retention in Maryland", which sets forth a system for sustainable woody biomass harvest for energy generation. The guide is based on a comprehensive review of the potential ecological risks associated with biomass harvesting and a review of Maryland's existing forest management programs. The guide provides for the protection of forest health and productivity, and environmental quality using scientifically credible management practices.

The Maryland Forest Conservation Act provides regulation affecting forest conservation programs, conservation planning, afforestation and reforestation, inventory, mitigation, variances, and enforcement. These regulations address important sustainability concerns and aid in protecting forests as conditions change, including those resulting from a new market for biomass. The Sustainable Forestry Act (SFA) is the legislation that first mentions creating a market for wood energy as a tool to improve forest health. The Greenhouse Gas Reduction Act (GGRA) and Maryland's Renewable Energy Portfolio Standards (RPS) Program are important additive polices to the goals of the SFA. The Sustainable Forestry Council has referenced these resources in advising the Department of Natural Resources on timely forest conservation issues and appropriate actions.

Maryland's current renewable energy policy emphasizes solar and wind with limited opportunity offered for biomass energy. The Greenhouse Gas Reduction Act (GGRA) mentions the use of wood for thermal energy but is not being strongly pursued. Renewable sources of thermal energy to heat homes, businesses, public buildings, and other facilities, are important strategies for reducing carbon emissions in regions with significant wintertime energy needs. Woody biomass for thermal energy, as well as combined heat and power systems, have been widely developed in other regions with cold winters, including parts of the Northeastern U.S. and northern Europe. Barriers to the use of wood resources to meet renewable energy and climate change mitigation goals could be reduced through policy changes that balance the incentives associated with diverse sources of renewable energy and by emphasizing opportunities to use wood in thermal energy applications to displace fossil fuel consumption.

Conclusions

All energy systems and each consumption choice we make comes with associated impacts and trade-offs. The impacts of these choices vary depending upon several factors and conditions, including technology and available alternatives.

Bioenergy and the use of woody biomass for thermal or electric energy production are important strategies for reducing the dependence on fossil fuel energy sources and for shifting toward the use of alternative renewable energy resources. Use of biomass from residues, waste materials, low-value materials or sustainably managed forests in highly efficient systems provide the greatest carbon benefits in comparison to non-renewable, fossil-fuel based systems.

Research shows that strong markets for forest products, including biomass markets, can support keeping forests as forests and contribute to diverse goals for forest health and resiliency. The carbon benefits of using renewable biomass energy vary with the raw material being used and the technology, but significant carbon and air emission benefits can be gained by reducing the use of fossil fuel resources.

Maryland has existing policies in place to protect forest values and to meet goals for maintaining forest cover, health, and biodiversity. There may be opportunities for further policy analysis to identify approaches to reduce barriers to biomass energy in meeting Maryland's renewable energy goals and climate change mitigation strategies.

1. How will a woody biomass market affect forest harvest rates and forest health?

It is well recognized, and supported in research findings, that there is a market response by forest owners to fiber demand increases. Approximately 90% of harvested wood volume in the U.S. comes from privately owned forest land. Evidence supports forest inventories (i.e., the size, number, and volume of trees in the forest) increasing as fiber demand increases. Some critics refute the argument and evidence that increased demand leads to increased inventory by assuming that if trees are left un-harvested, they will simply be allowed to continue to grow for an undefined period. This is an extremely flawed assumption and ignores the environmental, social, and economic drivers associated with land ownership and land use as well as the myriad of causes of tree mortality. Put simply, in the absence of harvesting, forest stands develop to maturity and then remain largely static in terms of volume and carbon stock – with natural mortality compensated by natural regeneration.[1]

Research also shows that tree mortality can increase when management activities decline, including reduced harvesting activities. A study in 2009 found rapid increases in mortality rates in unmanaged old forests in the western United States that may be linked to regional warming and increased drought.[2] Management and timber harvesting can be applied to reduce or prevent tree deaths associated with drought, wildfire, insect, or disease outbreaks. In addition, harvesting of trees can occur to support environmental objectives such as improved wildlife habitat and water yields or for social benefits such as enhanced recreation opportunities and public safety. The availability of economic benefits from markets helps support these desired outcomes.

One of the important forest management tools for supporting diverse desired outcomes, including forest health benefits, is the practice of thinning. With thinning, a portion of the trees in a stand are removed with the overall impact being increased growing space for the remaining trees. Thinning and the removal of some trees is also a strategy for supporting natural regeneration of new tree seedlings, especially in hardwood or mixed stand management. In the case of thinning in stands where the

[1] Note this section is specific to a discussion of market affects. Mature forests also provide important ecological and social benefits. An effective climate mitigation strategy includes managing for forests of diverse age classes.

[2] Mantgem, P., et al. 2009. Widespread Increase of Tree Mortality Rates in the Western United States. Science. 23 Jan 2009: 521-524. (http://science.sciencemag.org/content/323/5913)

ultimate goal is high quality saw timber, small trees for which there is no market are often felled and left on the ground. Alternatively, these trees ultimately die if not harvested, as they become crowded out by bigger trees. The dead trees (from felling and leaving or from crowding out) then begin to emit carbon almost immediately as they decompose, continuing over several years rather than displacing fossil fuels immediately if the materials had been harvested and used for bioenergy.[3]

Forgoing harvesting does not necessarily translate to continued growth of trees because of basic tree biology, and because of the economics of land ownership. Property ownership has associated costs and a forest owner who cannot harvest trees or otherwise derive sufficient income will necessarily reduce investment in forest productivity and management activities or consider a change in land use. Recent analyses which have considered both the economy and social dynamics of the US South, the leading woody biomass producing region, have concluded that as many as 23 million acres of forests are vulnerable to urban development in the relatively near term.[4,5] Forest income potential is one of the strongest deterrents to sale of forest land to developers. For further discussion, see Box 1.[6]

For additional details about forest assessment results for Maryland, see Appendix C.

Box. 1. Two Reasons Why Forests Grow in the Face of Strongly Growing Demand

A recent study provides a comprehensive outlook of how a bioenergy future will affect forest harvests, prices, timber management investments, the area of forest, and forest carbon balance when market interactions and management responses are considered. The study authors identified two important reasons why {forest} stocks are enhanced in the face of strongly growing demand.

First, when demand grows, prices rise and landowners with growing forests will typically hold trees to take advantage of the rising prices, as there is a higher opportunity cost of felling them prematurely. If demand for biomass energy turns out to be short-lived, lasting only a couple years, then landowners would be encouraged to harvest trees earlier than otherwise, which would reduce carbon stocks and lead to net emissions. However, biomass energy projections associated with long-run phenomenon like climate change suggest that the demand for wood-based biomass energy will grow over time.

Second, rising prices incentivize foresters to increase regeneration and management expenditures. These include replanting, fertilizing, managing for competition, and other practices aimed at increasing the value and size of the growing stock. Expansion of biomass energy production would increase management over a wide swath of forests around the world, but most intensification would occur in places that are already intensively managed. For context, the stock of forests has increased steadily in the southern United States and has stabilized in the Pacific Northwest since 1950, despite old growth harvesting that continued up to the 1990s.

Source: Favero et al., Sci. Adv. 2020; 6: eaay6792, 25 March 2020.

---

[3] For further discussion of biomass decay rates, see Russell, M., et al. 2014. Scientific Journal. Ecosystems. 17(5): 765-777. (https://www.srs.fs.usda.gov/pubs/46089)

[4] Alig, R., et al. 2011. Conversions of Forest Land: Trends, Determinants, Projections, and Policy Considerations. USDA-Forest Service, Gen. Tech. Rep. PNW-GTR-802. (https://www.fs.fed.us/pnw/pubs/gtr802/Vol1/pnw_gtr802vol1_alig.pdf)

[5] Wear, D. and Greis, J. 2013. The Southern Forest Futures Project. USDA-Forest Service Gen. Tech. Rep. SRS-GTR-178. (https://www.srs.fs.usda.gov/futures/technical-report/04.html)

[6] Favero, A., et al. 2020. Forests: Carbon sequestration, biomass energy, or both? Sci. Adv. 2020; 6: eaay6792. 25 March 2020.

a. **Address whether deforestation has resulted from biomass markets and factors such as price competition that would limit impacts**

The importance of timber markets to forest retention has been confirmed by numerous researchers.[7,8,9] There is further discussion below of how investment in forests, enabled and driven by forestry, has made forests more productive. Forests grow in response to forest product markets.

One study[10], for instance, found that harvest rates, softwood sawtimber price, income levels, cost of capital, and federal and state cost-share programs are all important factors affecting nonindustrial private forestland (NIPF) tree planting. Harvest rates, softwood sawtimber and pulpwood prices, and planting cost are also important factors affecting forest industry tree planting. Another study[11] found that global regions with the highest levels of industrial timber harvest and forest product output are also the regions with the lowest levels of deforestation, and that industrial roundwood demand provides revenue to support sustainable forest management and to prevent conversion to non-forest uses.

The USDA's empirical evidence (not models) shows that there is improved growth in US forests today as compared to the past.[12] The higher growth rates are influenced by several factors, including strong and growing markets. As annual market demand grew from 194 million m^3 in the early 1950's to around 300 million m^3 in recent years, associated average growth rates increased from about 2 m^3 per ha per year to about 5 m^3 per ha per year. (It is worth noting that the most productive forests in the Eastern US today grow at well over 20 m^3 per hectare per year.) At the same time, the forest inventory (e.g., stored carbon) increased from about 5.2 billion m^3 to 10.8 billion m^3. Lastly, during this same period, the total area of forest in the major woody biomass producing region of the US South has remained stable. This trend is supported by a recent study by Forest2Market[13] which demonstrates that the doubling of forest inventory is directly correlated to the increase in demand for wood products. That study found that between 1953 and 2015, timber removals (harvests) in the U.S. South increased 57%. During that same period, the area of forest cover in that region increased by about 3%, and the inventory of fiber in those forests increased 108%. The study found an increase in wood inventory supply in the US South during the period 2000-2014 of 1.2 billion tons, indicating that pellet mill expansions during this time have not resulted in a decrease in forest inventory. The positive trends in forest growth in the Eastern US have been supported by cooperative research and investments which resulted in an almost fourfold increase in the amount of growth achievable in seedlings planted

---

[7] Li, Y. and Zhang, D. 2007. A Spatial Panel Data Analysis of Tree Planting in the US South. Southern Journal of Applied Forestry 31(4): 192-198. (http://www.auburn.edu/~zhangd1/RefereedPub/SJAF2007.pdf)
[8] Ince, P. 2010. Global Sustainable Timber Supply and Demand. In: Sustainable Development in the Forest Products Industry, Chapter 2. pp. 29-41. (https://www.fpl.fs.fed.us/documnts/pdf2010/fpl_2010_ince001.pdf)
[9] Abt, K., et al. 2014. Effect of Policies on Pellet Production and Forests in the U.S. South. USDA-Forest Service. (https://www.srs.fs.usda.gov/pubs/47281)
[10] Li and Zhang, op. cit.
[11] Ince, op. cit.
[12] Oswalt, S., et al. 2014. Forest Resources of the United States, 2012: a Technical Document Supporting the Forest Service 2015 Update of the RPA Assessment. Gen. Tech. Rep. WO-91. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 218 p. (https://www.srs.fs.usda.gov/pubs/gtr/gtr_wo091.pdf)
[13] Forest2Market. 2015. Wood Supply Market Trends in the U.S. South 1995-2015. (http://www.forest2market.com/uploads/Forest2Market/documents/US-South-Wood-Supply-Trends.pdf)

in the 2000s compared to those planted in the early 1950s.[14] What this data shows is that with strong markets, landowners participate in forest management and make investments that keep land areas as forests while improving productivity that translates into carbon storage benefits as well as many other conservation values. Markets provide an incentive and the economic means for forest owners to increase productivity which results in increases in forest (and associated carbon) inventory. As of 2015, the harvest of forest biomass for bioenergy amounted to only 3 percent of the total forest harvest activity in the Southern U.S.[15], and consequently a biomass-driven change in forest land area would hardly be expected. However, these markets in tandem with other forestry markets increase the overall value proposition and return on investment for sustainable forestry.[16,17,18]

The allocation of harvested materials among various wood- using industries is dominated by market forces. Due to these market forces, biomass demand does not threaten large trees. If harvested at all, the economic value of large trees (logs) as a raw material for production high-value products (such as large timbers, lumber, or veneered products), rather than low-value products (such as energy), determine use and decisions on rotation length. Numerous studies of U.S. timber markets have shown this.[19,20] These economic influences serve to allocate high-value larger diameter logs to high-return markets and low-value materials (e.g., biomass) to low-return markets. In situations in which market forces (i.e., price competition) determine which forms of biomass will be used for energy production, old-growth trees or forests will not be harvested for bioenergy. References to old-growth forests or to large mature trees in the context of harvesting for bioenergy production have no basis. Markets for biomass do not provide enough financial incentive to support harvests of high-value trees. Biomass markets can support improved forest sustainability by utilizing low-value materials and reducing waste in processing. Economics precludes such practice and additional environmental and social conditions exist to protect these forest values.

Another study[21] concluded that Southern forests currently have a greater capacity for commercial softwood timber production (sawtimber and pulpwood combined) than any time in the last 15 years or even longer. The long-term investment in pine plantations has transformed the potential for commercial timber production, and forest management techniques have been able to more than

---

[14] Jefferies, H. and Leslie, T. 2017. Historical Perspective on the Relationship Between Demand and Forest Productivity in the U.S. South. Forest2Market, July 26. (https://www.forest2market.com/hubfs/2016_Website/Documents/20170726_Forest2Market_Historical_Perspective_US_South.pdf)

[15] Stewart, P. 2015. Wood Supply Trends in the South. Forest2Market. http://nafoalliance.org/images/issues/pellets/Forest2Market_USSouthWoodSupplyTrends.pdf

[16] Li, Y. and Zhang, D. 2007. A Spatial Panel Data Analysis of Tree Planting in the US South. Southern Journal of Applied Forestry 31(4): 192-198. (http://www.auburn.edu/~zhangd1/RefereedPub/SJAF2007.pdf)

[17] Ince, P. 2010. Global Sustainable Timber Supply and Demand. In: Sustainable Development in the Forest Products Industry, Chapter 2. pp. 29-41. (https://www.fpl.fs.fed.us/documnts/pdf2010/fpl_2010_ince001.pdf)

[18] Abt, K., et al. 2014. Effect of Policies on Pellet Production and Forests in the U.S. South. USDA-Forest Service. (https://www.srs.fs.usda.gov/pubs/47281)

[19] Miner, R., et al. 2014. Forest Carbon Accounting Considerations in US Bioenergy Policy. J. For. 112(6):591–606. (https://www.fpl.fs.fed.us/documnts/pdf2014/fpl_2014_miner001.pdf)

[20] USDA Forest Service. 2012. Future of America's Forest and Rangelands: Forest Service 2010 Resources Planning Act assessment. USDA-Forest Service, Gen. Tech. Rep. WO-87, pp. 76-78 and Fig. 83. (https://www.fs.fed.us/research/publications/gtr/gtr_wo87.pdf)

[21] RISI. 2015. (http://www.risiinfo.com/risi-store/do/product/detail/us-southern-pulpwood-study.html)

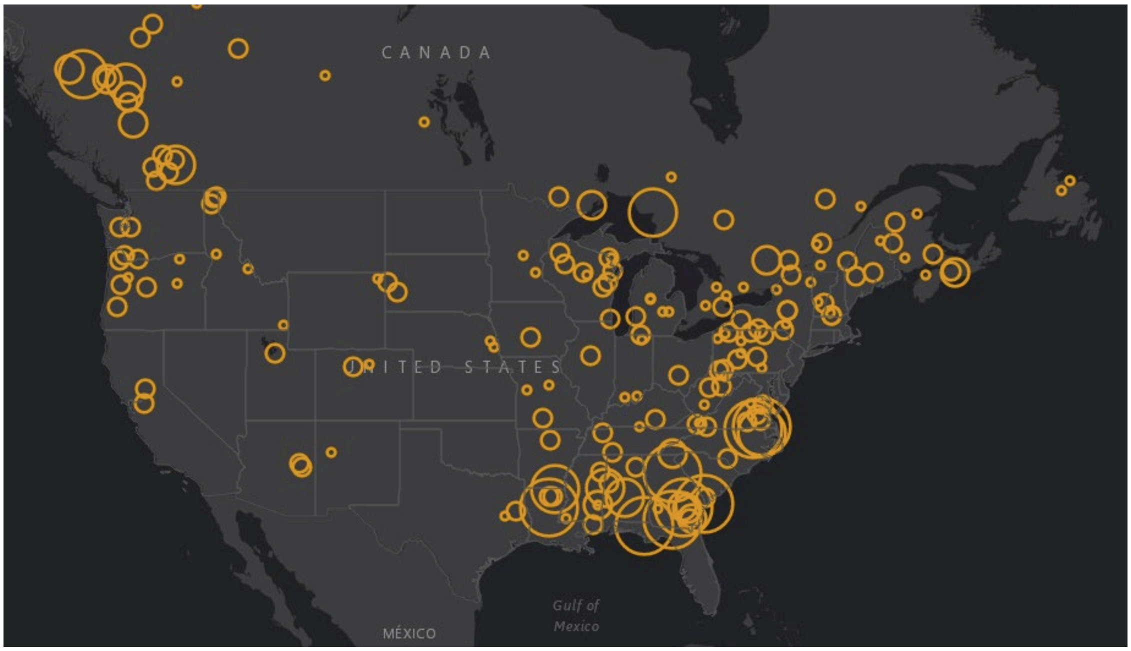
double annual per acre growth rates. Thinning yields from plantations averaged nearly 64 million tons per year in 2010-2014, up 160% from the 1990s.

There is evidence that the existence of highly productive plantations makes loss of forest cover less likely (i.e., reduce the risk of deforestation or land use conversion). For instance, during the period 1989 to 1999 – the only period for which this kind of data is available – 5.4 million acres of stocked timberlands in the U.S. South were converted to non- forest uses (i.e., to development). Of these, the overwhelming majority (94%) were naturally regenerated forests, and not planted stands. As noted by report authors, "Not only does demand for forest products increase the productivity of forests and provide an incentive for landowners to continue growing trees, it also helps counter factors – like development – that irrevocably – destroy this natural resource.[22]"

b. **Present information on forest cover trends and harvest rates elsewhere in the United States where biomass markets were added**

As of January 2018, operating manufacturers of densified biomass fuel (pellets) in the U.S. had a production capacity of 15.15 million tons per year.[23] Canadian plants had an annual capacity of 4.66 million tons. The following figure (Figure 1) shows the location of pellet mills in the U.S. and Canada, and, as shown, much of the activity is in the Southeastern U.S.[24]

Figure 1. Pellet Mills (2018)[22]



The U.S. South has been the region with the most extensive development of biomass fuel products, specifically wood pellet manufacturing primarily for export to the EU driven by climate change policies

[22] Jefferies, H. and Leslie, T. 2017. Historical Perspective on the Relationship Between Demand and Forest Productivity in the U.S. South. Forest2Market, July 26. (https://www.forest2market.com/hubfs/2016_Website/Documents/20170726_Forest2Market_Historical_Perspective_US_South.pdf)

[23] The State of America's Forests. Forest Products and Services. Accessed 2 April 2020. (https://usforests.maps.arcgis.com/apps/Cascade/index.html?appid=6d3076faddfb4b8c8b6933cfcf4963cb)

[24] A full listing of US pellet plants is available at: http://biomassmagazine.com/plants/listplants/pellet/US/

and renewable energy commitments in those nations. Recent research has concluded that economic values associated with the U.S. South's forests may be a critical factor in keeping private lands as forest, and in maintaining the conservation values provided by a mosaic of native and plantation forests, in a variety of ages and successional stages.[25] The U.S. Forest Service estimates that as much as 23 million acres of forest in the South could be impacted by urbanization as the region's population continues to grow, and that the greatest forest losses are expected to occur in areas where forest product markets are weak and development pressures strong.[26] Regarding biodiversity, a recent study[27] examined prospects for increased forest activity in the U.S. South and found that this could negatively impact the region's biodiversity. However, report authors noted that there are other forces at work in the South's forests, such as land use change from development, which may have a far greater impact on biodiversity and wildlife habitat. Another study, that examined 33 separate studies of the effects of forest thinning (a substantial feedstock source for pellet plants) on biodiversity on sites located across the U.S. and Canada[28], found that forest thinning treatments had generally positive or neutral effects on biodiversity and abundance across all taxa, although thinning intensity and the type of thinning conducted partially drives the magnitude of response.

Regarding the thinning that commonly takes place where pellet production is occurring in the U.S., a common silvicultural regime for productive southern pine plantations would include a first thinning 12 years after establishment, a second thin at age 18 and a final harvest at a stand age of 25. The common need for further stocking reduction just 6 years after the first thinning indicates stocking recovery within only several years. Carbon implications of thinning have been examined by several investigators who have generally found thinning to have little impact on forest carbon stores.[29,30,31]

c. Address effect of the Maryland Seed Tree Law, forest biomass harvesting policy, and the Forest Conservation Act

Maryland has several existing policies that can affect biomass energy utilization and activities, including the Maryland Seed Tree Law[32], forest biomass harvesting policies, and the Forest Conservation Act. In 2010, The Maryland Department of Natural Resources together with the Pinchot Institute for Conservation issued "A Guide to Forest Biomass Harvesting and Retention in Maryland", which provides guidelines for sustainable woody biomass harvest for energy generation.[33]

---

[25] Wear, D. 2013. Forecasts of Land Uses. In: Wear, D. and Greis, J. Southern Forest Futures Technical Report. USDA-Forest Service, Gen. Tech. Rep. SRS-GTR-178, pp. 45-72. (http://www.srs.fs.fed.us/pubs/gtr/gtr_srs178.pdf)
[26] Ibid
[27] Kittler, J. 2013. Forest Bioenergy and Biodiversity: Commitment to Sustainable Sourcing. Pinchot Institute for Conservation. (http://www.pinchot.org/doc/510)
[28] Verschuyl, J., et al. 2011. Biodiversity Response to Intensive Biomass Production from Forest Thinning in North American Forests – A Meta-analysis. Forest Ecology and Management 261(2011): 221-232.
[29] Harrington, T. 2001. Silvicultural Basis for Thinning Southern Pines: Concepts and Expected Responses. Georgia Forestry Commission. (http://www.gfc.state.ga.us/resources/publications/SilviculturalBasis.pdf)
[30] Kingsley, E. 2012. Importance of Biomass Energy Markets to Forestry: New England's Two Decades of Biomass Energy Experience. University of Georgia Warnell School of Forestry. (https://plumcreek.app.box.com/s/92duinawd1zd82z0sjmcvpn5bx9r2uts)
[31] Parker,B., and Bennett, N. n.d. Reducing Hazardous Fuels on Woodland properties: Thinning. Oregon State University. (http://oregonforests.org/sites/default/files/publications/pdf/Haz_Fuels_Thinning_LR.pdf)
[32] Maryland Seed Tree Law: https://dnr.maryland.gov/forests/Pages/programapps/treelaw.aspx
[33] A Guide to Forest Biomass Harvesting and Retention in Maryland (http://www.pinchot.org/uploads/download?fileId=915)

The guidelines are based on a comprehensive review of the potential ecological risks associated with biomass harvesting and a review of Maryland's existing forest management programs. The guidelines are meant to work in concert with existing forest management plans (FMPs), Best Management Practices (BMPs), and other natural resource management programs to provide for the protection of forest health and productivity, and environmental quality through the use of scientifically credible management practices. The guidelines provide several steps to protect key resource values (e.g., soil health and retention) during and following biomass harvests. These steps include recommendations for the retention of some onsite biomass with significant structural and functional value for forests, such as, coarse woody debris (CWD), snags, stumps, roots, brush, and fine woody debris (FWD). In addition to a number of general recommendations that offer guidance for all sites, several additional recommendations apply to either mixed-hardwood forests or softwood dominant plantation forests exclusively.

Box 2. Maryland Seed Tree Law

Purpose: Provide for the maintenance and reproduction of the pine resources to provide significant recreational, aesthetic, wildlife and environmental benefits as well as wood fiber essential to commerce and industry.

Scope: The law applies to harvested areas that are at least five acres in size, are at least 25% loblolly, shortleaf or pond pine prior to harvest and will NOT be converted to a non-forest land use such as agricultural or residential.

Description: Eligible land must be regenerated to pine through the use of seed trees or through the use of pine seedlings as per a pine reforestation plan. If seed trees are to be left there must be at least 8 cone-bearing loblolly, shortleaf or pond pine per acre. Seed trees should be healthy, wind firm and well distributed throughout the harvested area. Regeneration will be deemed successful if there are at least 400 loblolly, shortleaf or pond pine seedlings per acre which are well distributed and are free to grow.

Annual Accomplishments: Approximately 40-50 harvests per year on 2,500-3,000 acres are subject to the Seed Tree Law.

Source: Maryland Seed Tree Law: https://dnr.maryland.gov/forests/Pages/programapps/treelaw.aspx

The Maryland Forest Conservation Act[34] provides regulation affecting forest conservation programs, stand delineation, conservation planning, afforestation and reforestation, inventory, mitigation, variances, and enforcement. There are additional reports, directives and laws that affect Maryland's forests, including the Sustainable Forestry Act of 2009[35], Chesapeake Forest Conservation Directive 06-1, and The State of Chesapeake Forests report. The Sustainable Forestry Act (SFA) is the legislation for Maryland that first mentions creating a market for wood energy as tool to improve forest health specifically. The Greenhouse Gas Reduction Act (GGRA)[36] and Maryland's Renewable Energy Portfolio Standards (RPS) Program[37] are important additive polices to the goals of the SFA. The Sustainable Forestry Council has referenced these resources in advising the Department of Natural Resources on timely forest conservation issues and appropriate actions to help Maryland

[34]Natural Resources Article 5-1601 - 1613, Forest Conservation Act, enacted in 1991. (https://dnr.maryland.gov/forests/Pages/programapps/newfca.aspx)

[35] Sustainable Forestry Act of 2009: https://dnr.maryland.gov/forests/Pages/sfcouncil.aspx

[36] https://mde.maryland.gov/programs/Air/ClimateChange/MCCC/Pages/GGRAPlans.aspx

[37] https://www.psc.state.md.us/electricity/maryland-renewable-energy-portfolio-standard-program-frequently-asked-questions/

implement a no net loss of forest policy. The recommended actions build on existing programs and regulations including the recent development of Watershed Implementation Plans to meet the Total Maximum Daily Load requirements for the Chesapeake Bay, the Forest Conservation Act, and local planning and zoning requirements.

The existence of the Maryland Seed Tree Law, the guidelines for woody biomass harvest, the Forest Conservation Act, and the Sustainable Forestry Act provide an important basis for ensuring that any increase in demand for woody biomass production in the state can occur within the established bounds of sustainable forestry practices, including emphasis on protecting forest functions and values and requiring successful forest regeneration.

Box 3. The Sustainable Forestry Act of 2009

The Sustainable Forestry Act of 2009 (SB549) was landmark legislation that expressed the importance of Maryland's forest to the environmental and economic well-being of the State. One section of the Act replaced the Forest Advisory Commission with the Sustainable Forestry Council. The purpose of this Governor appointed Council is to advise the Department on all matters related to:

1. Sustainable forestry management in the State,
2. The expenditure of funds from the Woodland Incentive Fund,
3. Existing regulatory and statutory policies that are perceived as economic barriers to a viable forest products industry,
4. New markets to enhance forest health, including renewable energy development through biomass energy, to offset fossil fuel consumption and reduce greenhouse gas emissions,
5. Creative strategies to help privately owned forest lands better compete with real estate market values that are driving forest conversion and fragmentation,
6. The means to promote forest-based economies and processing capability that contribute to economic and employment growth and
7. Assigning a nutrient benefit to forest stewardship plans and other forest conservation management plans that can be measurably tracked and reported by the number of forested acres covered by the plans.

Source: Sustainable Forestry Act of 2009: https://dnr.maryland.gov/forests/Pages/sfcouncil.aspx

d. Address forest health consequences with and without a biomass or pulpwood market

Research shows that tree mortality can increase when management activities decline, including reduced harvesting activities due to weak markets. Management and timber harvesting can be applied to reduce or prevent tree deaths associated with environmental stressors (i.e., wildfire, drought, insect, or disease). In addition, harvesting of trees can support environmental objectives and provide social benefits. The availability of economic incentives from biomass or pulpwood markets helps support these desired outcomes. Research also recognizes that current forest health problems in the U.S. have been caused by a lack of understanding of the importance of disturbance in forest ecosystems, including the occurrence of natural disturbances like low-intensity fires as well as human disturbance through harvesting.[38]

[38] Kolb, T.E., et al. 1995. Forest Health from Different Perspectives. (https://www.fs.fed.us/rm/pubs_rm/rm_gtr267/rm_gtr267_005_013.pdf)

In most forest types there will be a diversity of trees, including small-diameter trees for which there is less or no market demand. In the absence of a strong enough market, the removal of these trees would cost more than the market will pay. There are many reasons why it may be beneficial to remove some of the trees in a forest, including the smaller diameter trees that are often in the understory. These reasons include environmental, social, and economic considerations as well as forest health implications. In some instances, it is important to remove some trees to improve the growth of the remaining trees and increase their market value as sawtimber. In other instances, it is important to remove smaller trees to reduce fuel loading and manage the risk of catastrophic wildfire. There are also situations where dense or thick forests are more prone to pathogens and the removal of smaller trees or improved spacing of the trees can improve forest health and reduce tree mortality. Without markets for the material that the landowner would like to remove, the landowner may be forced to leave the forest untreated and bear the consequences or the landowner may have to pay for the treatment as a cost of forest management. Per acre costs for treatments like this can easily exceed $500 per acre and is cost prohibitive for many landowners. Even if a landowner is able to pay for the treatment, often the trees are felled and left on the ground, which may provide some benefits to the soil or biodiversity, but it also results in the release of carbon as the wood decays.

e. Address relationship of thinning to sawlog harvest and effect on carbon balance

Harvesting removes carbon from forests; however, despite the short-term impact on forest carbon stores, there are clear benefits of sustainable forest management. Forest management done responsibly helps to:

- Prevent overstocking and reduce risks of catastrophic fire, disease, and insect infestation thereby protecting the long-term carbon storage capacity of forests;
- Capture a portion of what would otherwise be natural mortality and associated release of carbon;
- Create new carbon pools within long-lived forest products (i.e., furniture or lumber used in construction); and
- Avoid substantial fossil carbon emissions when wood is used in place of high energy intensity products and materials, or when used as a source of energy in place of fossil fuels.[39]

Young, fast-growing forests sequester carbon rapidly and can be managed to reduce and capture mortality. Over-crowding and high natural mortality are avoided through thinning, a practice that also enhances growth of remaining trees and their potential value to sawlog harvest. Older forests tend to have higher carbon densities than younger forests, but low or near-zero rates of additional carbon sequestration as they reach maturity.

Temperate forests worldwide continue to expand as carbon sinks even though large quantities of wood products are removed from these forests annually. The quantity of carbon stored within forest products is continuing to increase as well. In the United States forest cover has increased and net growth has exceeded removals and mortality for more than 70 continuous years, which has resulted in increasing carbon stocks, despite the removal of over 850 *billion* cubic feet of timber during that time frame. The current rate of carbon accumulation in temperate forests may decline, however, if the

[39] Bowyer, J., et al. 2011. Managing Forests for Carbon Mitigation. Dovetail Partners. (https://www.dovetailinc.org/portfoliodetail.php?id=5e46270598c21)

average age of the forest continues to increase and if various factors, including climate change, result in increased tree mortality.

The rate of net carbon accumulation in U.S. forests during the period 2005–2007 is estimated to have been 220 million metric tons per year. In addition, carbon continues to accumulate in harvested wood products pools. Carbon within wood products is stored for the life of the product. Carbon is stored in the structure of homes and other wooden buildings, within furniture, and within a myriad of other long-lived products that contain wood. Across the whole United States, carbon removed from the atmosphere by forest growth or stored in harvested wood products each year is equal to 12% to 19% of annual fossil fuel emissions.[40, 41]

Reducing tree density and carbon stocks in forests through thinning and the management for commercial products like sawlogs decreases environmental and economic risks. Management can address the risk of financial and carbon losses due to episodic disturbances, such as wildfires or severe storms. At the same time, management results in increasing carbon storage within the remaining trees and within the wood products made from the harvested products. This can include the carbon benefits of thinned materials being used to produce biomass energy and reduce the reliance on fossil fuels. A no-harvest strategy focused on increasing standing forest carbon stocks can increase the volume of carbon stored in the forest in the near-term. However, a no-harvest strategy can mean missed opportunities for greater carbon mitigation over the long term and increase the risk of loss. It is important to recognize that forests are living and dynamic systems that undergo change with or without management. Choosing not to manage has its own carbon consequences. There are direct carbon benefits associated with the substitution of woody biomass for fossil fuel energy.

2. If trees take decades to regrow, how will burning woody biomass today result in a net reduction in greenhouse gases?

The primary mechanism by which burning woody biomass provides a near-term reduction in greenhouse gases is by reducing the use of fossil fuels. A study that examined 930 different scenarios for producing wood pellets in the U.S. included the carbon impacts of delivering them to the UK and found the relative savings in GHG emissions (in comparison to a unit of electricity derived from fossil fuels) ranged between 50% and 68% depending upon the capacity of power plant and rotation age.[42]

Over the longer-term, the net reduction in greenhouse gases is further improved by the regrowth of trees and ongoing carbon sequestration. Furthermore, the most cost competitive material to be utilized in generating woody biomass is not sourced from older, larger trees. Small, fast growing trees are the most suitable for woody biomass utilization and are generated and replaced on much shorter time cycles. Waste wood is also a prime source for bioenergy production. The International Council on

---

[40] Ryan, M.G., et al. 2010. A Synthesis of the science on forest and carbon for U.S. Forests. Issues in Ecology 13:1-16.
[41] U.S. Environmental Protection Agency (USEPA). 2011. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. Washington DC: U.S. Environmental Protection Agency. EPA 430-R-11-005.
[42] Dwivedi, P., et al. 2014. Potential greenhouse gas benefits of transatlantic wood pellet trade. Environmental Research Letters. Vol 9. No. 2. 18 Feb 2014. (https://iopscience.iop.org/article/10.1088/1748-9326/9/2/024007/pdf)

Clean Transportation found payback periods for harvest of forest residues for biomass energy to be zero (i.e., immediate). Use of thinnings was found to have a 15-year carbon payback period.[43]

The International Energy Agency's (IEA) Bioenergy Task 38, the Intergovernmental Panel on Climate Change (IPCC, 2007), and a large number of scientists have concluded that biomass from sustainably managed forests is carbon neutral or a low-carbon fuel at the point of combustion (after accounting for emissions linked to harvesting and transport). Further, there is broad agreement within the scientific community that there are clear benefits to bioenergy versus fossil fuel alternatives if forests are managed sustainably.

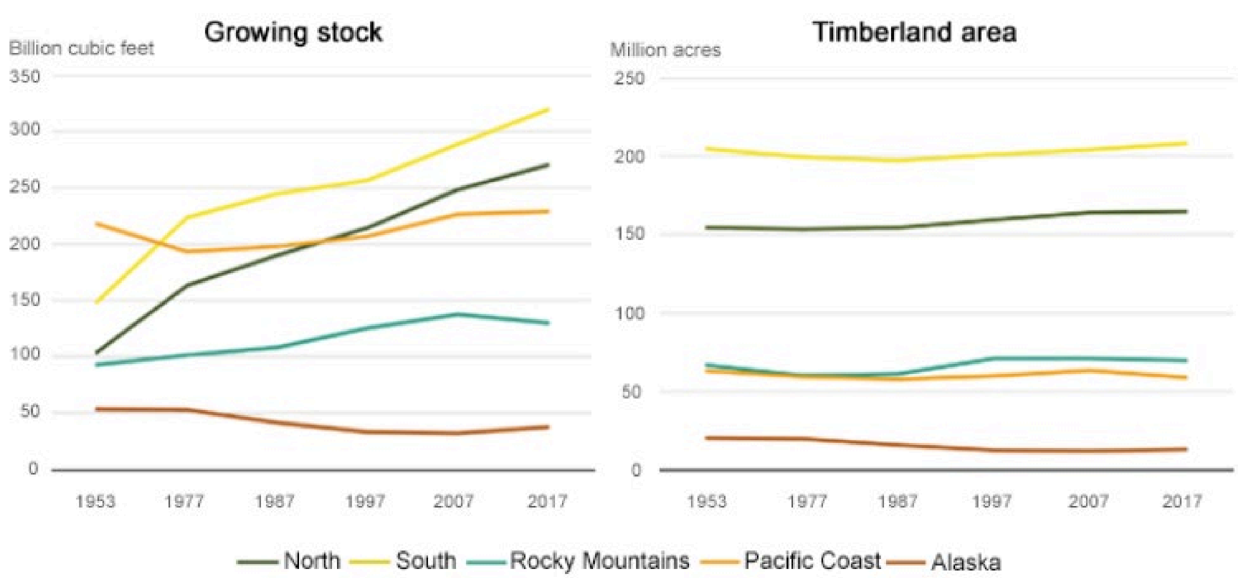
A significant conclusion contained in the IPCC Fourth Assessment Report[44] is that:

> "In the long term, a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fiber, or energy from the forest, will generate the largest sustained mitigation benefit. Most mitigation activities require up-front investment with benefits and co-benefits typically accruing for many years to decades." (IPCC 2007)

a. **Explain current growth, mortality, and removal rates and trends in forest growth**

U.S. timberland growing stock volume increased by 60 percent during the period 1953-2017, from 615 billion to 985 billion cubic feet. U.S timberland area increased by 1 percent over this time.[45] These trends are shown in Figure 2.

Figure 2. U.S. Growing Stock and Timberland Area by Region (1953 – 2017)[44]



[43] Baral, A. and Malins, C. 2014. Comprehensive Carbon Accounting for Identification of Sustainable Biomass Feedstocks. Washington D.C.: International Council on Clean Transportation. (http://www.theicct.org/sites/default/files/publications/ICCT_carbonaccounting-biomass_20140123.pdf)
[44] IPCC. 2007. Climate Change 2007: Working Group III: Mitigation of Climate Change. (https://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf)
[45] Forestland definitions and trends in the US. (https://usforests.maps.arcgis.com/apps/MapJournal/index.html?appid=26e99e39d258419ea3c15dc80a1570ae)

Most regions in the conterminous United States have seen this upward trend, with the sharpest increase, 160 percent, in the North. In Alaska, however, both timberland growing stock and timberland area have decreased, by 30 percent and 36 percent, respectively, between 1953 and 2017. Most of Alaska's timberland area loss is due to reclassification of these lands to protected categories (national park, state park, preserve, and wildlife refuge) that exclude commercial use. In the Rocky Mountain region, the 5 percent loss of timberland growing stock between 2007 and 2017 is mostly due to outbreaks of pine beetle infestations and severe wildfires.

b. **Address scale of use of woody biomass relative to current net growth**

Annual net growth (defined as growth minus mortality) on U.S. timberland reached 25 billion cubic feet in 2016, almost twice the annual net growth in 1952. At the same time, hardwoods in the North and South experienced a decline in annual net growth, of 14 and 20 percent, respectively. Mortality increased by 29 percent in the North and 2 percent in the South. Removals decreased by 14 and 35 percent, respectively. However, southern softwoods' annual net growth increased 21 percent because of an 11 percent decrease in mortality and an 11 percent decrease in timber removals. The 2007–2009 Great Recession led to many mill closures in the South, and much softwood timber remained uncut. In 2016, the volume of timber harvested (called removals) was 13 billion cubic feet, half the volume of timberland net growth.

States with harvest rates below 25 percent of net growth include Hawaii, North Dakota, Rhode Island, Kansas, Connecticut, Massachusetts, New Jersey, Nevada, New Mexico, Alaska, New York, Iowa and Delaware. In South Dakota, Montana, and Nebraska, removals have recently exceeded net growth. In Wyoming, Colorado, and Utah, mortality has been higher than net growth in recent years, accounting for negative percentages of net growth harvested.

The volume harvested from the nation's timberland in 2016 represented 1.3 percent of the total timber volume available for harvesting. Georgia, Louisiana, Florida, Alabama, Texas, and South Carolina harvested the highest percentage of growing stock, 3 percent. Hawaii, Utah North Dakota, Colorado, New Mexico, Nevada, Alaska, and Arizona harvested the lowest, less than 0.1 percent.

Since 1953, U.S. annual net growth of forests has exceeded annual harvest, while the total volume of growing stock on U.S. timberlands has increased by 60 percent. Three exceptions happened over this period. In 1976, removals exceeded net growth, by almost 1 billion cubic feet, in the Pacific Coast's softwood timberlands. In 1996, removals exceeded net growth, by almost half billion cubic feet, in the South's softwood timberlands. And in 2016, removals exceeded net growth, by 200 million cubic feet, in the Rocky Mountains softwood timberlands due to the high tree mortality in the region. Annual mortality of softwoods exceeded annual growth in Wyoming (158 million cubic feet), Colorado (154 million cubic feet), Utah (55 million cubic feet) and Nebraska (6 million cubic feet) in that same year.[46]

About 70 to 77 percent of all the trees removed in U.S. forests are harvested to produce industrial timber products (most of the rest are cut for silvicultural treatments and development). The primary timber products are sawlogs (for lumber), veneer logs, pulpwood (for paper and paperboard), and composites (for plywood and other wood panels). The volume of trees removed to produce timber

---

[46] Growth, harvesting, and reforestation in US forests (https://usforests.maps.arcgis.com/apps/MapJournal/index.html?appid=ec04704969514f20b1eb63280275c34c)

products reached a peak in 1986, at 13.4 billion cubic feet; the harvest for all wood products (both timber and nontimber) was 17 billion cubic feet. By 2016, the harvest for timber forest products was 11.5 billion cubic feet, and the total harvest for all wood products was 13.9 billion cubic feet.[47]

In 2016, the production of bioenergy (wood pellets, biomass power, and liquid biofuels) consumed more than 20 million dry short tons of wood fiber and produced more than 43 billion kilowatt-hours of electricity. The fuel used to generate more than two thirds of this electricity was wood and forest product companies' wood residues (mostly the by-products of wood that was chemically processed to make paper). The rest came from stand-alone biomass power plants.

c. Explain interaction with forest health, growth rates, and incentives to retain forest cover

Mortality is associated with reductions in harvested volume. Since 1996, nationwide in U.S. forests, tree mortality has increased by 90 percent as removals fell by 20 percent. All regions of the country experienced the same trend. The Rocky Mountains had the highest mortality increase, 900 percent, and the highest decrease in removals, 30 percent. Although the North had a large mortality increase in hardwoods, as noted earlier, this region overall had the lowest mortality increase, 16 percent, and the lowest removals decrease, 10 percent.[48]

The U.S. Forest Service measures forest inventory each year and publishes the data through the Forest Inventory and Analysis (FIA) Program. In the Southeast U.S., a major biomass energy producing region, the forest inventory measurements have found annual forest carbon increases. The ratio of growth to harvest in this region is 1.9, meaning that for every ton of wood removed from the forest for products each year, 1.9 tons are grown in the same period. Just as forest harvest rates that exceed rates of forest growth are not sustainable over the long term, an imbalance favoring a build-up of forest biomass is also not sustainable over the long term. Research shows that forest markets provide an important economic incentive to maintain forest equilibrium, improve forest health, and retain forest cover.[49]

3. What are the carbon impacts of woody biomass energy?

The carbon impacts of woody biomass energy depend upon several factors including the raw material being utilized and the energy production technology. In general, use of residues, waste materials, low-value materials, or biomass from sustainably managed forests in highly efficient or combined heat and power systems provide the greatest carbon benefits in comparison to non-renewable, fossil-fuel based systems. Recent technology innovations that include carbon dioxide capturing technologies in conjunction with electricity production from biomass energy are an emerging strategy for improving the carbon performance of these systems. Studies of carbon payback periods[50] often predicate a "pulse" of carbon due to inefficient combustion of biomass versus fossil fuel that would have been

---

[47] Forest Products and Services: (https://usforests.maps.arcgis.com/apps/Cascade/index.html?appid=6d3076faddfb4b8c8b6933cfcf4963cb)
[48] Growth, harvesting, and reforestation in US forests: (https://usforests.maps.arcgis.com/apps/MapJournal/index.html?appid=ec04704969514f20b1eb63280275c34c)
[49] Historical Perspective on the Relationship between Demand and Forest Productivity in the US South. 2017. (https://www.forest2market.com/hubfs/2016_Website/Documents/20170726_Forest2Market_Historical_Perspective_US_South.pdf)
[50] See Box 4 for discussion of payback period and carbon debt concepts

burned in the alternative scenario. However, there are many examples of modern biomass units having better efficiencies than the fossil fuel units they replace.

The International Energy Agency's (IEA) Bioenergy Task 38, the Intergovernmental Panel on Climate Change (IPCC, 2007), and a large number of scientists have concluded that biomass from sustainably managed forests is carbon neutral or a low-carbon fuel at the point of combustion (after accounting for emissions linked to harvesting and transport). Further, there is broad agreement within the scientific community that there are clear benefits to bioenergy versus fossil fuel alternatives if forests are managed sustainably. This view is shared by many of the researchers who accept the carbon debt concept. Agreement on this issue is based on an extensive body of research, dating at least to the mid-1990s[51,52], and reinforced by many more recent studies and reviews. In fact, the Manomet study[53], which has been widely reported as making an argument against bioenergy, also concluded that "After the point at which the debt is paid off, biomass begins yielding carbon dividends in the form of atmospheric greenhouse gas levels that are lower than would have occurred from the use of fossil fuels to produce the same amount of energy." This was further supported in the conclusion from the IPCC Fourth Assessment Report (page 16)[54].

Further, studies at the National Renewable Energy Lab (NREL), the U.S. Environmental Protection Agency (EPA) and the National Council for Air and Stream Improvement (NCASI) among others, have shown that co-firing biomass alongside coal at utility power plants reduces the emissions of pollutants that are linked to negative environmental and human health impacts, such as mercury, smog-forming nitrogen oxides (NOx), and acid rain-forming sulfur oxides (SO_x). Woody biomass also has lower concentrations of trace metals relative to coal, including arsenic, beryllium, cadmium, and lead.[55]

a. Address short (1-2 year) and long (2-20+ year) timeframes

The period it takes to realize the carbon benefits of utilizing woody biomass energy will depend upon the design of the system, including the raw materials being utilized and the energy production technologies. One way to think of this is that the sooner an energy system transitions to renewable biomass energy, the sooner the carbon benefits will be realized. There are many national and international examples of bioenergy systems that contribute to sustainable development and climate change mitigation goals in short and long timeframes.[56]

[51] Schlamadinger, B. and Marland, G. 1996. The Role of Forest and Bioenergy Strategies in the Global Carbon Cycle. Biomass and Bioenergy 10(5-6): 275-300. (http://www.sciencedirect.com/science/article/pii/0961953495001131)
[52] Marland, G. and Schlamadinger, B. 1997. Forests for Carbon Sequestration or Fossil Fuel Substitution? A Sensitivity Analysis. Biomass and Bioenergy 13(6): 389-397. (http://www.sciencedirect.com/science/article/pii/S0961953497000275)
[53] Walker T, et al. 2013. Carbon Accounting for Woody Biomass from Massachusetts (USA) Managed Forests: A Framework for Determining the Temporal Impacts of Wood Biomass Energy on Atmospheric Greenhouse Gas Levels. Journal of Sustainable Forestry, 32, 130–158. (http://www.tandfonline.com/doi/abs/10.1080/10549811.2011.652019?journalCode=wjsf20)
[54] IPCC. 2007. Climate Change 2007: Working Group III: Mitigation of Climate Change. (https://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf)
[55] Mann, M., & Spath, P. 2003. The Environmental Benefits of Cofiring Biomass and Coal. Golden, CO: National Renewable Energy Laboratory, p.8. (https://bioenergykdf.net/system/files/1/KC_091102094518.pdf)
[56] Gomez San Juan, M., et al. 2019. Towards sustainable bioeconomy - Lessons learned from case studies. Rome, FAO. 132 pp. Licence: CC BY-NC-SA 3.0 IGO (http://www.fao.org/3/ca4352en/ca4352en.pdf)

Lamers and Juninger state in their conclusions that "Using small residual biomass. . . offers (almost) immediate net carbon benefits."[57] In a study from the International Council on Clean Transportation, authors found the payback period for harvest of forest residues for biomass energy to be zero (i.e., immediate). Use of thinnings was found to have a 15-year carbon payback period.[58]

Box 4. Carbon Debt and Payback Time[59]

Disturbance of natural decay of dead biomass when used for energy affects the carbon dynamics of forest ecosystems. These perturbations of forest ecosystems are summarized under the concept of carbon debt and its payback time. Narrative reviews demonstrate that the payback time of apparently comparable forest bioenergy supply scenarios vary by up to 200 years allowing amble room for confusion and dispute about the climate benefits of forest bioenergy. A meta-analysis confirmed that the outcome of carbon debt studies lies in the assumptions and find that methodological rather than ecosystem and management related assumptions determine the findings. The current development of carbon debt methodologies and their lack of consensus implies that the concept is inadequate for informing and guiding policy development. At the management level the carbon debt concept may information be useful in directing management principles in more climate benign directions.

Source: Bentsen, N. 2017. Carbon debt and payback time – Lost in the Forest. V. 73 pp 1211-1217. https://www.sciencedirect.com/science/article/abs/pii/S1364032117302034

Even when the carbon debt concept (see Box 4[59]) is embraced, not only does biomass yield 'carbon dividends' with greater climate benefits than would have occurred if fossil fuels are used, but that benefit continues through subsequent harvest cycles without any subsequent carbon 'debt.' This reality is acknowledged in the oft-cited Walker et al. (2010)[60] and other reports.

It is worth considering the findings of Sedjo (2011)[61]:

- Fossil fuels combustion releases incremental new carbon into the atmosphere (and therefore into the biosphere).
- Fossil emissions represent a release of stored carbon that has been sequestered for millennia, except for its liberation through combustion. This carbon cannot be returned to its solid fossil form on anything other than a geologic time scale. Therefore, the impact of fossil fuel emissions is immediate, permanent, and irreversible.
- There is an opportunity to capture carbon from the atmosphere and place it in the solid form of biomaterials or vegetation, but this sequestration potential has limits. Therefore, new

[57] Lamers, P. and Junginger, M. 2013. The "Debt" is in the Detail. Biofuels, Bioproducts and Biorefining 7(4): 373-385. (https://www.researchgate.net/ publication/259576449_The_'debt'_is_in_the_detail_A_synthesis_of_recent_temporal_forest_carbon_analyses_on_woody_biomass_for_energy)
[58] Baral, A. and Malins, C. 2014. Comprehensive Carbon Accounting for Identification of Sustainable Biomass Feedstocks. Washington D.C.: International Council on Clean Transportation. (http://www.theicct.org/sites/default/files/publications/ICCT_carbonaccounting-biomass_20140123.pdf)
[59] Bentsen, N. 2017. Carbon debt and payback time – Lost in the Forest. University of Copenhagen. Renewable and Sustainable Energy Reviews. June 2017. V. 73 pp 1211-1217. (https://www.sciencedirect.com/science/article/abs/pii/S1364032117302034)
[60] Walker, T., et al. 2010. Biomass Sustainability and Carbon Policy Study. (http://www.mass.gov/eea/docs/doer/renewables/biomass/manomet-biomass-report-full-hirez.pdf)
[61] Sedjo, R. 2011. Carbon Neutrality and Bioenergy: A Zero-Sum Game? Resources for the Future., Paper No. 11-15. (https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1808080)

additions to the biosphere through fossil fuel combustion represent cumulative additions of new carbon, and an irreversible flow to the biosphere.

- Carbon dioxide emissions due to combustion of biomass represent release of carbon sequestered from the atmosphere years or decades (not millennia) earlier, and do not add carbon to the biosphere and therefore do not increase the amount of carbon in circulation.
- The anticipated future use of wood for bioenergy can result in additional sequestration in advance of combustion, completely changing the concept of payback.

Therefore, if an impact from fossil fuel combustion that is immediate, permanent, and irreversible could be avoided, even a long payback period could be considered a benefit. Fortunately, instead of a 100-year payback (which can be avoided by not burning old-growth for energy), sustainable forestry can provide for a payback that is very short (immediate to 10 years) or even negative.

b. Identify circumstances that result in woody biomass being a carbon sink or source, identifying efficiencies of combined heat and power options compared to power only options

Activities or conditions that release carbon dioxide (CO_2) to the atmosphere are called carbon "sources", while processes that absorb and store CO_2 are called carbon "sinks". Through the carbon cycle, carbon is always moving through the environment via photosynthesis, plant respiration, combustion, decomposition, and other processes. The amount of carbon in the atmosphere depends on the balance that exists between the sinks and sources.

A forest functions as a sink when the rate of carbon sequestration is greater than net carbon losses. Regarding comparison of biomass energy vs alternatives, comparison of carbon emissions is useful in determining those systems that perform better than others from a GHG emissions standpoint. However, it does not make sense to use these comparisons to define whether a system is a sink or source. For instance, suppose that a forest biomass energy system results in net forest carbon loss, but still results in lower carbon emissions than a fossil fuel-based system. In this case, both systems may result in net carbon emissions and neither could be claimed to serve as a carbon sink.

Woody biomass and the associated production of biomass energy contribute to reductions in carbon sources when the emissions associated with its collection, processing, transport, and utilization are *less* than the carbon associated with the existing or alternative system (i.e., fossil fuel use). In general, combined heat and power systems have greater efficiencies than power only options.[62] However, recent technology innovations that include carbon dioxide capturing technologies in conjunction with electricity production from biomass energy are an emerging strategy for improving the carbon performance of biomass energy systems.[63]

[62] EPA. 2007. Biomass Combined Heat and Power Catalog of Technologies. (https://www.epa.gov/sites/production/files/2015-07/documents/biomass_combined_heat_and_power_catalog_of_technologies_v.1.1.pdf)

[63] Carbon dioxide now being captured in a first of its kind BECCS pilot. 7 February 2019. (https://www.drax.com/press_release/world-first-co2-beccs-ccus/)

The International Energy Agency[64] also commented on this topic:

> *"Land suitable for producing biomass for energy can also be used for the creation of biospheric carbon sinks. Several factors determine the relative attractiveness of these two options [i.e., creating sinks or producing biomass energy], in particular land productivity, including co-products, and fossil fuel replacement efficiency.... A further influencing factor is the time scale that is used for the evaluation of the carbon reduction potential: a short time scale tends to favor the sink option, while a longer time scale offers larger savings as biomass production is not limited by saturation but can repeatedly (from harvest to harvest) deliver GHG emission reductions by substituting for fossil fuels."*

According to the Biomass Energy Resource Center, "Used for heat or heat-led combined heat and power (CHP), biomass energy is approximately 75-80 percent efficient, while generation of electricity is only 20-25 percent efficient, and conversion to liquid fuels for transportation applications are even less efficient overall. This is true regardless of the type of fuel used—be it biomass, coal, or oil. "[65]

Gustavsson and Karlsson[66] examined emissions from various heating systems and fuel types, reporting emissions in each stage of the energy system. They found fossil carbon emissions from wood fuels to be only 1-6 percent of emissions from oil and 1-9 percent of emissions from natural gas. Renewable sources of thermal energy to heat homes, businesses, public buildings, and other facilities, are important strategies for reducing carbon emissions in regions with significant wintertime energy needs. Woody biomass for thermal energy, as well as combined heat and power systems, have been widely developed in other regions with cold winters, including parts of the northern Europe and the Northeastern U.S.

Homes, individual businesses and institutions, communities, and even large cities can be heated and cooled via district heating systems using a wide range of energy options. One option is wood in the form of forest biomass, mill residues, or wood pellets. Wood based district energy systems are relatively rare in the United States, but at the same time rather common in northern Europe. For example, 60% of all houses and residential units in Denmark are supplied with district heating of which 25% (or more than 600,000 houses) are heated by biomass-based district heating. Finland, on the other hand, is reportedly number one in the world in bioenergy use, and Sweden has over 400 wood-fired district heating plants that in 2007 supplied 29% of the energy delivered to the residential and service sectors; wood contributed nearly one-half of the feedstock nationwide for district heating.[67]

It is important to recognize that the magnitude of emissions is highly dependent upon the level of technology reflected in the combustion device. Dinca et al.[68] showed that on-site emissions of important pollutants are only one-sixth or less in modern wood boilers as compared to older ones, and

---

[64] Bauen, A., et al. 2009. Bioenergy – a Sustainable and Reliable Energy Source: A Review of Status and Prospects. IEA Bioenergy 2009-06. (http://www.ieabioenergy.com/wp- content/uploads/2013/10/MAIN-REPORT-Bioenergy-a-sustainable-and-reliable-energy-source.-A-review-of- status-and-prospects.pdf)

[65] Biomass Energy Resource Center. 2009. Biomass Energy: Efficiency, Scale, and Sustainability. (https://www.biomasscenter.org/policy-statements/FSE-Policy.pdf)

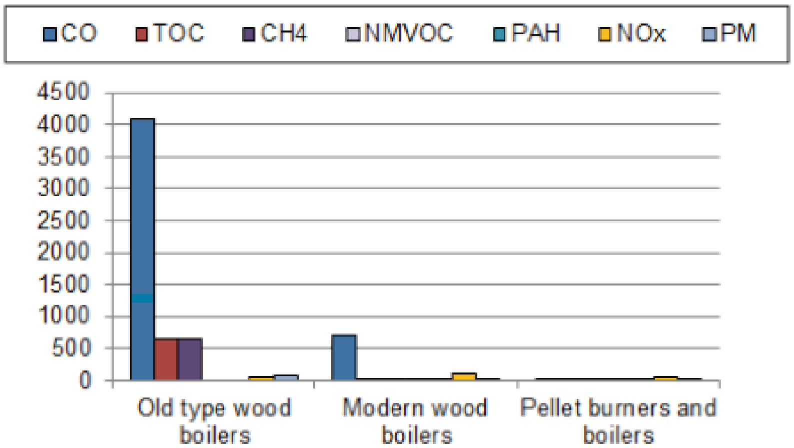
[66] Gustavsson, L. and Karlsson, Å. 2001. CO_2 Mitigation Cost: A System Perspective on the Heating of Detached Houses with Bioenergy or Fossil Fuels. Proceedings: Woody Biomass as an Energy Source – Challenges in Europe, pp. 95-114.

[67] Bratkovich, S. et al. 2009. Community-Based Bioenergy and District Heating: Benefits, Challenges, Opportunities and Recommendations for Woody Biomass. Dovetail Partners. 22 April 2009. (https://www.dovetailinc.org/upload/tmp/1582118974.pdf)

[68] Dinca, C., et al. 2009. Environmental Analysis of Biomass Combustion Process. Proceedings: 3rd World Scientific and Engineering Academy and Society (WSEAS) International Conference on Renewable Energy Resources, pp. 234-238.

far less than that in pellet burners and boilers (Figure 3). Johansson et al.[69] obtained the same results in extensive testing of wood combustion equipment in Sweden, concluding that emissions of non-methane volatile organics (NMVOC), total organic carbon (TOC), and particulate matter (PM) can be over 100 times higher from old low-efficiency residential wood stoves than from modern wood boilers and pellet burners.

Figure 3. Emissions from Various Types of Wood-Fueled Boilers (mg/MJ)[67]



There are a large number of case studies available illustrating the development and operational experiences of various community-scale facilities that employ biomass systems, including a large number of thermal energy systems associated with businesses, campuses, community or government facilities, institutions and schools.[70] These project examples illustrate diverse benefits associated with transitioning to woody biomass energy systems, including replacing old and expensive oil-fired heating systems, improving utilization of logging residues, enhancing forest health through thinning, reducing operating costs, cutting carbon emissions, and other benefits. Many of these examples are from communities in the Northeastern US and involve conditions that may be relevant to Maryland.

c. Summarize findings of life-cycle analysis of woody biomass

Several life-cycle assessments have evaluated the environmental impacts and carbon emissions associated with woody biomass in comparison with other energy systems. The results of these assessments vary widely based upon the assumptions being applied and other factors, yet there is wide agreement that energy generation from wood results in lower impacts, particularly in lower carbon emissions. Regarding carbon emissions from bioenergy vs. coal, a 2011 study, for instance, reported emissions from bio-electricity generation to be only 86% of those from electric generation using bituminous coal[71]. A study the following year found CO_2 emissions from combustion of anthracite, sub-bituminous, and lignite coal to be 3, 5 and 7% higher than CO_2 emissions resulting from using hardwood species to generate the same heat output.[72] Another study investigated the net

---

[69] Johansson, L. S., et al. 2004. Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Atmospheric Environment 38(2004):4183-4195.

[70] Biomass Energy Resource Center Case Study Library. (https://www.biomasscenter.org/resource-library/case-studies)

[71] Lippke, B., et al. 2011. Life-Cycle Impacts of Forest Management and Wood Utilization on Carbon Mitigation in the Forest and Wood Products: Knowns and Unknowns. Carbon Management 2(3):303-333.

[72] Strauss, W. and Schmidt, L. 2012. A Look at the Details of CO2 Emissions from Burning Wood vs. Coal. Future Metrics, January.

CO_2 exchange of forests to study net atmospheric impact of forest bioenergy production over a 90-year period and over the whole of the country of Finland. When expressed in terms of radiative forcing, the net atmospheric impact was on average 19% less for bioenergy production compared with that for coal energy over the whole simulation period.[73] Yet another study, which involved an LCA of the full life cycle including extraction, transportation, and power plant construction and operation, found electricity production from biomass to emit 8.5% lower CO_2e emissions than equivalent production from coal.[74] The conclusions of a 2011 staff working paper of the European Commission[75] were less specific, but included the observation that "While a number of knowledge gaps still exist, the vast majority of the biomass used today in the EU for heat and power is considered to provide significant GHG savings compared to fossil fuels." A more recent study of the European Commission[76], which involved an extensive review of scientific findings, reported that "most authors have found that forest bioenergy can present long-term reductions in atmospheric CO_2 emissions, with many pointing to the potential for increased sequestration at a landscape level yielding benefits over the long-term, as well as, the role of market forces that incentivize a planting response."

A study which did not employ life cycle assessment, but instead a comprehensive simulation model examined the GHG intensity of pellet-based electricity is 74% to 85% lower than that of coal-based electricity. This study also found that the GHG intensity of pellets produced using agricultural and forest biomass is 28% to 34% lower than that of pellets produced using forest biomass only.[77]

Generation of energy from all forms of fossil fuels requires more energy than is produced. Extraction, processing, and transport of non-renewable sources of energy requires energy, after which the energy stored within them is released in conversion to useful energy. No new energy is produced in the process or thereafter, with the result a net loss in fossil fuel stores. Biomass in contrast, is produced in growing plants (natural forests, tree plantations, agricultural fields) through photosynthesis using solar energy, creating in the process a new energy resource. As this material is converted to useful energy, plant regrowth replaces volumes used. Mann and Spath[78] succinctly summarized the net effect of this reality in a comparison of biomass and coal-derived energy:

> *"Results demonstrate significant differences between the biomass and coal systems. Per kWh of electricity produced, the amount of CO_2 emitted by the biomass system is only 4.5% of that emitted by the average coal power plant operating in the U.S. today. This is due to the absorption of CO2 from the power plant by the growing biomass. The life cycle energy balance of the coal systems is*

---

[73] Kilpeläinen, A., et al. 2012. Net Atmospheric Impacts of Forest Bioenergy Production and Utilization in Finnish Boreal Conditions. GCB Bioenergy 4(6): 811-817.

[74] Spath, P. and Mann, M. 1999. Coal Versus Biomass Electricity Generation – Comparing Environmental Implications Using Life Cycle Assessment. National Renewable Energy Laboratory.

[75] European Commission. 2011. State of Play on the Sustainability of Solid and Gaseous Biomass Used for Electricity, Heating and Cooling in the EU. Commission Staff Working Document. (http://ec.europa.eu/energy/sites/ener/files/2014_biomass_state_of_play_.pdf)

[76] Olesen, A., Bager, S., Kittler, B., Price, W. and Aguilar, F. 2015. Environmental Implications of Increased Reliance of the EU on Biomass from the South East US. European Commission. (http://www.aebiom.org/wp-content/uploads/2016/08/DG-ENVI-study-imports-from-US-Final-report-July-2016.pdf)

[77] Wang, W., et al. 2015. Carbon Savings with Transatlantic Trade in Pellets: Accounting for Market-Driven Effects. Environ. Res. Lett. 10(11).

[78] Mann, M. and Spath, P. 1999. A Life Cycle Comparison of Electricity from Biomass and Coal. American Council for an Energy Efficient Economy (ACEEE) Proceedings. (https://www.aceee.org/files/proceedings/1999/data/papers/SS99_Panel1_Paper48.pdf)

significantly lower than the biomass system because of the consumption of a non-renewable resource. For each unit of energy consumed by the biomass system, almost 16 units of electricity are produced; the average coal system produces only 0.3 units of electricity per unit of energy consumed. Not counting the coal consumed, the net energy produced is still lower than that of the biomass system because of energy used in processes related to flue gas clean-up."

d. Identify carbon balance for high-efficiency, clean-burning technology currently in use in some countries

Greenhouse gas emission balances for a wide range of biomass technologies to produce electricity and heat were determined by Elsayed, Matthews and Mortimer.[79] The analysis encompassed the entire system from fuel production to end-use. Some biomass systems were shown to have net GHG emissions savings of more than 40% of the substituted fossil alternatives, while others provided a 4% emissions savings (Figure 4).

Based on these results and others, it has been shown that the magnitude of environmental benefits from biomass energy is variable and the result will depend on the situation, including the technology and the scale of the application. It is worth noting that the total GHG emissions from waste-derived biomass fuels (non-tradables in Figure 4) are set at 0, since these fuels are generated because of existing operations. The emissions associated with their production are allocated to the primary products that are produced and from which the non-tradable biomass is generated as a waste byproduct.

e. Quantify contribution of carbon emissions from woody biomass processing and transport and relation to overall carbon balance

Available methods to address the quantification of carbon emissions from woody biomass, including processing and transport emissions, include utilizing international carbon accounting systems (Box 5) and certification programs that require carbon accounting for biomass producers.

The certification program of the Sustainable Biomass Partnership (SBP) requires the collection and analysis of energy and carbon data throughout the biomass supply chain. Certification requirements enable the calculation of energy and carbon savings achieved by burning biomass in place of fossil fuel sources. Data on biomass flows resulting from the analysis completed by SBP certified biomass producers is made available in aggregated form. Information on the supply base evaluation of each certified biomass producer is publicly available.[80]

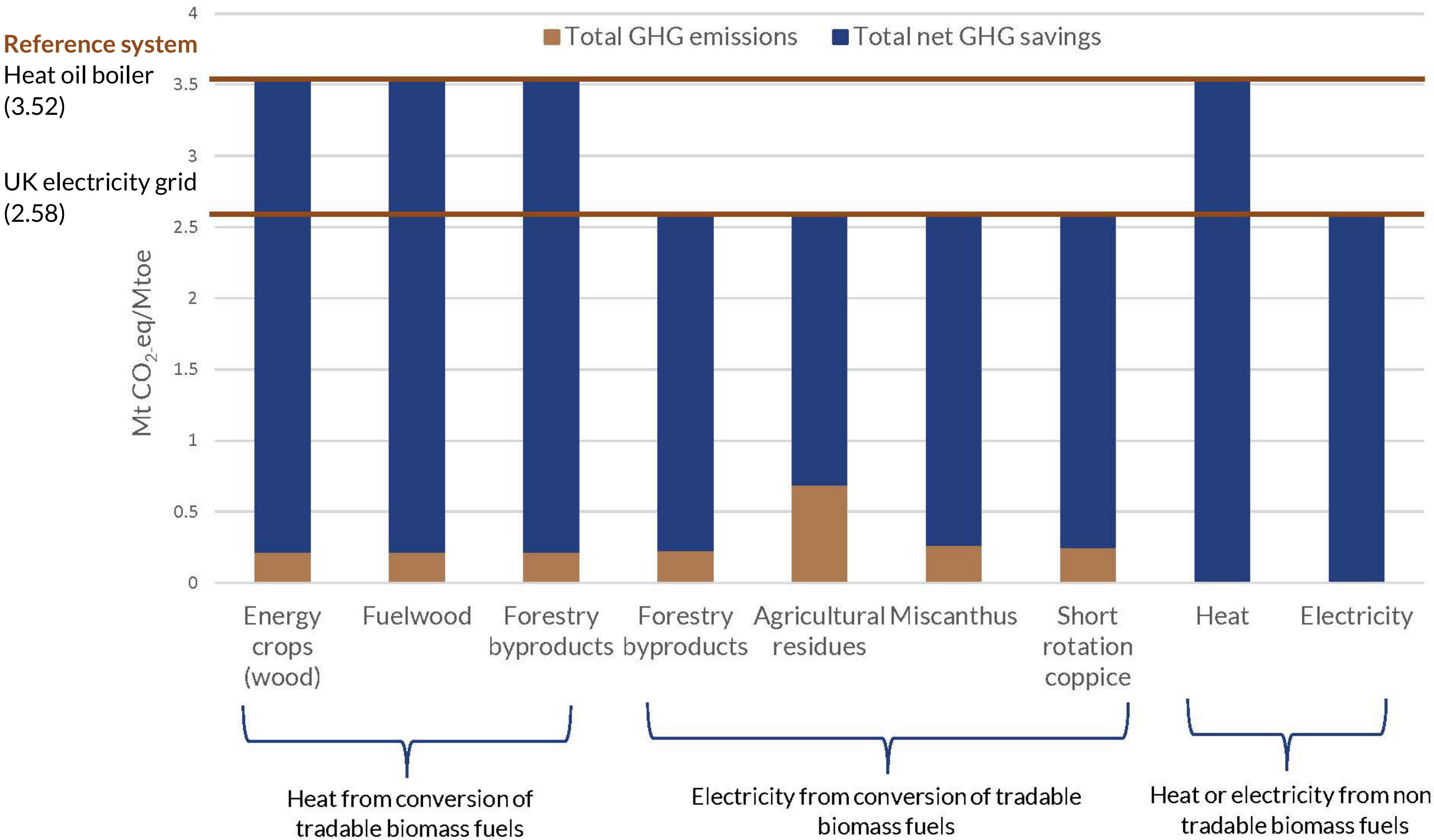
Through the SBP system, biomass end-users (i.e., bioenergy producers) use verified energy data and greenhouse gas emission calculations to address their respective regulatory requirements which differ from country to country. Using this process, Drax Power Station, a major bioenergy producer in the UK[81], reported that in 2019 their biomass provided GHG savings of over 85% when compared

[79] Elsayed, M. A., et al. 2003. Carbon and Energy Balances for a Range of Biofuels Options Project No. B/B6/00784/REP, URN 03/836 for the Sustainable Energy Programmes of the Department of Trade and Industry, Resources Research Unit, Sheffield Hallam University, Sheffield, United Kingdom.

[80] Sustainable Biomass Program. (https://sbp-cert.org/accreditations-and-certifications/certificate-holders/)

[81] Drax Power Station first started generating electricity using coal in the 1970s. The facility was expanded in the 1980s and became the largest power station in the U.K., with capacity to generate electricity for 6 million households. During the last decade, Drax has converted four of the station's six generating units to biomass.

Figure 4. GHG Savings for Select Technologies of Biomass Fuel Produced Electricity and Heat[79]



to the use of coal. Similarly, Ørsted, a bioenergy producer in Denmark reported that converting their combined heat and power plants to sustainable biomass allowed them to almost fully retire coal over the past decade, and in 2019, their use of biomass delivered an 89% saving in carbon emissions compared to burning fossil fuel.[82] The SBP standard has recognized the importance of carbon accounting, data collection and the energy and carbon balance calculations that are necessary to build a useful understanding of feedstock characteristics. Similarly, in the U.S., carbon accounting for woody biomass that includes an examination of forest carbon stocks as well as emissions associated with production and supply chains have found that the GHG intensity of pellet based electricity is 74% to 85% lower than that of coal-based electricity.[83] A study in 2014 that examined 930 different scenarios for producing wood pellets in the U.S. included the carbon impacts of delivering pellets to the UK and found the relative savings in GHG emissions (in comparison to a unit of electricity derived from fossil fuels) ranged between 50% and 68% depending upon power plant capacity and forest stand rotation age.[84] The following figure (Figure 5) from this study shows the relative contribution (%) of different steps within the supply chain toward total GHG emissions, including wood production, wood transportation, wood pellet production, wood pellet rail transport in the U.S. (i.e., to port), wood pellet transport across the Atlantic Ocean, wood pellet transport in the UK, and wood pellet use in the UK. As illustrated, wood pellet production (i.e., the manufacturing process) makes the greatest contribution to the GHG emissions.

Box 5. What is carbon accounting?

Carbon accounting is the process of quantifying greenhouse gas emissions, also referred to as a carbon or GHG inventory. Internationally accepted methodologies have been developed by the Intergovernmental Panel on Climate Change's (IPCC's) Task Force on National Greenhouse Gas Inventories. Countries around the world employ this methodology to accurately prepare national GHG inventory reports to meet the reporting obligations as Parties to the UN Framework Convention on Climate Change (UNFCCC).

The IPCC has established specific methodology for carbon accounting from forest land in the Agriculture, Forestry, and Other Land Use (AFOLU) sector, and accounts for the carbon exchange between land and atmosphere by measuring the difference between what is grown and harvested (or otherwise is cleared or dies) from the managed forest. When carbon sequestration (forest growth) exceeds emissions, forest carbon will increase; likewise, if emissions exceed growth, forest carbon will decline.

Following the IPCC's approach to carbon accounting, emissions and sequestration associated with forest products are counted in the AFOLU sector for a country's inventory. Information for the U.S. is calculated and reported by the U.S. Forest Service. When wood pellets are used for energy, it is *not* appropriate to also count the stack emissions in the energy sector. To do so would be double counting because the net atmospheric impact from harvest for that forest product is already and appropriately counted in the land sector.

For more information: https://www.ipcc.ch

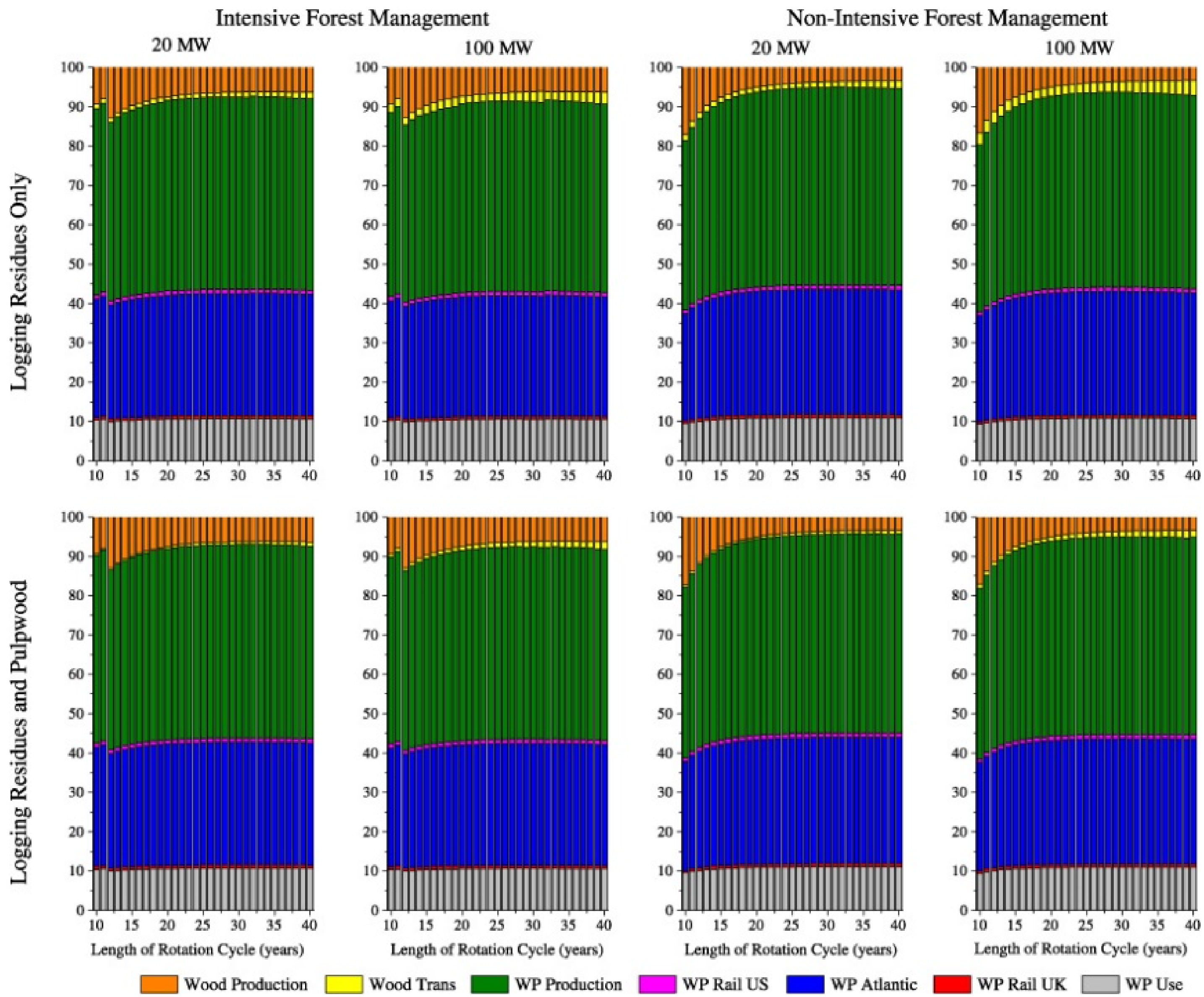
---

[82] Sustainable Biomass Partnership, Annual Report, 2019. (https://sbp-cert.org/wp-content/uploads/2020/04/SBP_AR2019_FINAL.pdf)

[83] Wang, W., et al. 2015. Carbon savings with transatlantic trade in pellets: accounting for market-driven effects. Environmental Research Letters. V. 10 No. 11. 16 Nov 2015. (https://iopscience.iop.org/article/10.1088/1748-9326/10/11/114019/pdf)

[84] Dwivedi, P., et al. 2014. Potential greenhouse gas benefits of transatlantic wood pellet trade. Environmental Research Letters. Vol 9. No. 2. 18 Feb 2014. (https://iopscience.iop.org/article/10.1088/1748-9326/9/2/024007/pdf)

Figure 5. Relative GHG emission contribution (percentage) from different steps present within the supply chain of transatlantic wood pellet trade[84]



4. What are the carbon impacts of other reuse options for small-diameter wood?

The carbon storage impact of different wood products is largely dependent upon the useful lifespan of each product. The amount of carbon sequestered in products depends on how much wood is harvested, what products are made from the harvested wood, losses in conversion of raw wood to finished product, and the half-life of wood in these products.[85]

When determining carbon storage from wood products, consideration is given to the wood products in use as well as wood products that are disposed of in landfills. Because landfills significantly decrease the rate of decay, they can result in significant carbon storage. The characterization of carbon in harvested wood includes four categories: products in use, in landfills, and emitted through combustion with energy capture, and without energy capture (Table 1). These categories and evaluations of production and consumption patterns are used to estimate the fraction of each primary product remains in use of in landfills after a given number of years. The results of this analysis are shown in Table 2 for several wood products and represent U.S. national averages.

Table 1. Categories for disposition of carbon in harvested wood[85] (Smith, et al., 2005)

Categories for disposition of carbon in harvested wood	
Products in use	End-use products that have not been discarded or otherwise destroyed, examples include residential and non-residential construction, wooden containers, and paper products
Landfills	Discarded wood and paper placed in landfills where most carbon is stored long-term and only a small portion of the material is assumed to degrade, at a slow rate
Emitted with energy capture	Combustion of wood products with concomitant energy capture as carbon is emitted to the atmosphere
Emitted without energy capture	Carbon in harvested wood emitted to the atmosphere through combustion or decay without concomitant energy recapture

The data in Table 2 indicate the fraction of each primary product remaining in an end use product for up to 100 years after harvest and processing. For example, the data indicates that after 15 years, 69.8 percent of softwood lumber remains in an end-use product (i.e., residential or other construction, furniture, and wood containers). The analysis estimates that by year 31 paper products no longer remain in an end use; however, these materials may continue to store carbon if they are disposed of in a landfill where decomposition is avoided or they may provide carbon benefits if they are combusted for energy production and as a substitute for fossil fuels.

a. Address carbon balance for mulch and compost

Mulch and compost products are readily and rapidly decomposed with most of the carbon released as a result. Some proportion of the carbon from these products may be incorporated into soil carbon storage which can be a long-term carbon storage strategy. It is likely that at best the carbon storage in mulch and compost products is comparable to the estimates for miscellaneous products shown in Table 2, recognizing this may be an overestimate.

[85] Smith, James E. et al. 2005. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. USDA Forest Service, North Eastern Research Station, General Technical Report NE-343. (https://www.nrs.fs.fed.us/pubs/8192)

Table 2.—Fraction of carbon in primary wood products remaining in end uses up to 100 years after production (year 0 indicates fraction at time of production, with fraction for year 1 the allocation after 1 year)[85]

Year After Production	Softwood lumber	Hardwood lumber	Softwood plywood	Oriented strand-board	Non-structural panels	Misc. Products	Paper
0	1	1	1	1	1	1	1
1	0.973	0.938	0.976	0.983	0.969	0.944	0.845
15	0.698	0.456	0.724	0.799	0.647	0.420	0.040
25	0.579	0.316	0.609	0.705	0.505	0.236	0.002
50	0.402	0.163	0.426	0.541	0.301	0.056	0.000
75	0.301	0.098	0.318	0.431	0.198	0.013	0.000
100	0.234	0.064	0.245	0.349	0.138	0.003	0.000

b. Address viability and carbon balance for engineered wood/mass timber products

Longer-lived wood products will store carbon for a longer period (Table 2). Wood is approximately 50% carbon by weight and this carbon remains largely stored as long as the wood is intact. Building products such as cross-laminated timber (CLT) and other durable goods such as furniture can remain in use and intact for many decades and even centuries. Even common shorter-lived products like paper can remain in long-term storage within books and other materials that are retained for long periods of time.

Estimates for 2005 place the rate of CO_2 sequestration in U.S. forests at 595 million metric tons annually, a quantity 17 percent greater than five years earlier and equivalent to about 10 percent of total carbon emissions nationally.[86] The rate of carbon accumulation within wood products in use and in landfills was estimated at about 103 million metric tons annually. This accumulation rate was 17 percent of the rate of sequestration within forests.[87] The same source reported carbon in harvested wood products in use in the United States to be roughly equivalent to 9 percent of the mass of carbon in standing trees and to about 3.4 percent of the mass of carbon contained within forest systems.[88] Carbon within harvested wood products that occupy landfills was equivalent to another 6+ percent of standing tree carbon. When considered together, the USDA estimate indicated that the carbon

[86] Skog, K. 2008. Sequestration of carbon in harvested wood products for the United States. Forest Products Jour. 58(6): 56-72. (http://www.fpl.fs.fed.us/documnts/pdf2008/fpl_2008_skog001.pdf)
U.S. Department of Agriculture. 2008. Carbon Stocks & Stock Changes in U.S. Forests. In: U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005. Technical Bulletin 1921. (http://www.usda.gov/oce/climate_change/AFGG_Inventory/4_Forest.pdf)
[87] "forests" include above and below-ground biomass, deadwood, litter, and soil organic carbon
[88] "forest systems" include standing trees, litter, below ground biomass and soil organic carbon

contained within harvested wood products in use and in landfills was about 15 percent of that contained within standing trees and about 6 percent of that in forest systems.[89,90,91]

In the U.S, it is common to build homes with wood as the main material. About 80 percent of housing units are primarily built of wood, providing millions of tons of carbon benefit, including both carbon stored in wood itself and emissions avoided. The current inventory of wood structures in the U.S. is estimated to store 1.5 billion metric tons of carbon equivalent to 5.4 billion metric tons of CO_2. Increasing the use of wood in construction could enhance carbon storage in the nation's building stock. For example, increasing wood use to the maximum extent feasible in multi-family housing, low-rise nonresidential construction, and remodeling could result in a carbon benefit equal to about 21 million metric tons of CO_2 annually; this would be equivalent to taking 4.4 million automobiles off the road indefinitely.[92]

5. If biomass energy is created by burning wood waste, what incentives or mechanisms exist in Maryland to replant or replace trees?

The Maryland Seed Tree Law, guidelines for woody biomass harvest, the Forest Conservation Act, and the Sustainable Forestry Act all provide incentives and mechanisms for ensuring an increase in demand for biomass energy from wood waste occurs within the practice of sustainable forestry and with emphasis on important forest values and functions, including replanting, replacement, and regeneration of trees and forests. For additional details about Maryland tree planting programs, see Appendix B.

Various forest product markets have existed for many generations in the U.S., including markets for firewood and wood energy uses, and people continue to replant and replace trees throughout rural and urban areas of the country. Research indicates that strong markets for forest products can lead to increased forest growth and tree planting.

Furthermore, it is worth repeating that rarely trees are cut for the sake of generating biomass for energy production. That biomass, more often, is a byproduct of other harvesting or forest improvement activities.

a. Address market and legal constraints

The strongest markets for woody biomass energy are in the EU and are the results of policy actions. In 2018, European Union Directive 2018/2001 set new renewable energy targets for meeting commitments made in the Paris Agreement on climate change and outlined conditions for the sustainable procurement of forest biomass. Within North America, Canada's Clean Fuel Standard could spur the increased use of forest-based biofuels. U.S. federal agencies are working on the

[89] U.S. Department of Agriculture. 2008. Carbon Stocks & Stock Changes in U.S. Forests. In: U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005. Technical Bulletin 1921. (http://www.usda.gov/oce/climate_change/AFGG_Inventory/4_Forest.pdf)
[90] Skog, K. 2008. Sequestration of carbon in harvested wood products for the United States. Forest Products Jour. 58(6): 56-72. (http://www.fpl.fs.fed.us/documnts/pdf2008/fpl_2008_skog001.pdf)
[91] Bowyer, J., et al. 2010. Recognition of Carbon Storage in Harvested Wood Products: A Post- Copenhagen Update. Dovetail Partners. (https://www.dovetailinc.org/portfoliodetail.php?id=5e454dacebc0f)
[92] Howe, J., et al. Building with Wood: Proactive Climate Protection. 2015. Dovetail Partners. (https://www.dovetailinc.org/portfoliodetail.php?id=5e2b289fcc05c)

adoption of consistent federal policies to promote the use of forest biomass as a carbon-neutral form of bioenergy.[93]

Maryland's current renewable energy policy emphasizes solar and wind with limited opportunity offered for biomass energy. The Greenhouse Gas Reduction Act (GGRA) mentions the use of wood for thermal energy but is not being strongly pursued. Barriers to the use of wood resources to meet renewable energy and climate change mitigation goals could be reduced through policy changes that balance the incentives associated with diverse sources of renewable energy and by emphasizing opportunities to use wood in thermal energy applications to displace fossil fuel consumption.

b. Identify Maryland programs and policies to address tree replacement

Maryland has implemented a no net loss of forest policy with the intention of ensuring at least 40% of the land in the state is covered by forest.[94] The programs and initiatives associated with this policy provide an important basis for addressing tree replacement, including the commitment to monitoring forest cover in the state.

Maryland also provides programs for state and federal cost-share to support tree planting and mitigation programs that favor trees. Maryland is one of a few remaining states with a seedling nursery program, and therefore provides a local supply of high quality, low cost seedlings. A variety of local smaller scale programs operating throughout Maryland cumulatively create significant tree planting gains (e.g., Backyard Buffers, Tree-Mendous, etc.).

---

[93] UNECE/FAO, Forest Products Annual Market Review, 2018-2019

[94] No Net Loss Final Report. 2012. (https://dnr.state.md.us/forests/Documents/nonetlossfinalreport.pdf)

Complete List of References

Abt, K., Abt, R., Galik, C. and Skog, K. 2014. Effect of Policies on Pellet Production and Forests in the U.S. South. USDA-Forest Service. (https://www.srs.fs.usda.gov/pubs/47281)

Alig, R., Stewart, S., Wear, D., Stein, S. and Nowak, D. 2011. Conversions of Forest Land: Trends, Determinants, Projections, and Policy Considerations. In: USDA- Forest Service, General Technical Report PNW-GTR-802. (https://www.fs.fed.us/pnw/pubs/gtr802/Vol1/pnw_gtr802vol1_alig.pdf)

Baral, A. and Malins, C. 2014. Comprehensive Carbon Accounting for Identification of Sustainable Biomass Feedstocks. Washington D.C.: International Council on Clean Transportation. (http://www.theicct.org/sites/default/files/publications/ICCT_carbonaccounting-biomass_20140123.pdf)

Bauen, A., Berndes, G., Junginger, M., Londo, M. and Vuille, F. 2009. Bioenergy – a Sustainable and Reliable Energy Source: A Review of Status and Prospects. IEA Bioenergy 2009-06. (http://www.ieabioenergy.com/wp- content/uploads/2013/10/MAIN-REPORT-Bioenergy-a-sustainable-and-reliable-energy-source.-A-review-of- status-and-prospects.pdf)

Bentsen, N. 2017. Carbon debt and payback time – Lost in the Forest. University of Copenhagen. Renewable and Sustainable Energy Reviews. June 2017. V. 73 pp 1211-1217. (https://www.sciencedirect.com/science/article/abs/pii/S1364032117302034)

Biomass Energy Resource Center. 2009. Biomass Energy: Efficiency, Scale, and Sustainability. (https://www.biomasscenter.org/policy-statements/FSE-Policy.pdf)

Biomass Energy Resource Center Case Study Library. (https://www.biomasscenter.org/resource-library/case-studies)

Bowyer, J., et al. 2011. Managing Forests for Carbon Mitigation. Dovetail Partners. (https://www.dovetailinc.org/portfoliodetail.php?id=5e46270598c21)

Bowyer, J., et al. 2010. Recognition of Carbon Storage in Harvested Wood Products: A Post-Copenhagen Update. Dovetail Partners, (https://www.dovetailinc.org/portfoliodetail.php?id=5e454dacebc0f)

Bratkovich, S. et al. 2009. Community-Based Bioenergy and District Heating: Benefits, Challenges, Opportuniites and Recommendations for Woody Biomass. Dovetail Partners. 22 April 2009. (https://www.dovetailinc.org/upload/tmp/1582118974.pdf)

Dinca, C., Badea, A., Marculescu, C., and Gheorghe, C. 2009. Environmental Analysis of Biomass Combustion Process. Proceedings: 3rd World Scientific and Engineering Academy and Society (WSEAS) International Conference on Renewable Energy Resources, pp. 234-238.

Dwivedi, P., Khanna, M., Bailis, R., and A. Ghilardi. 2014. Potential greenhouse gas benefits of transatlantic wood pellet trade. Environmental Research Letters. Vol 9. No. 2. 18 Feb 2014. (https://iopscience.iop.org/article/10.1088/1748-9326/9/2/024007/pdf)

Elsayed, M. A., Matthews, R., and Mortimer, N. D., 2003 Carbon and Energy Balances for a Range of Biofuels Options Project No. B/B6/00784/REP, URN 03/836 for the Sustainable Energy

Programmes of the Department of Trade and Industry, Resources Research Unit, Sheffield Hallam University, Sheffield, United Kingdom.

EPA. 2007. Biomass Combined Heat and Power Catalog of Technologies. (https://www.epa.gov/sites/production/files/2015-07/documents/biomass_combined_heat_and_power_catalog_of_technologies_v.1.1.pdf)

European Commission. 2011. State of Play on the Sustainability of Solid and Gaseous Biomass Used for Electricity, Heating and Cooling in the EU. Commission Staff Working Document. (http://ec.europa.eu/energy/sites/ener/files/2014_biomass_state_of_play_.pdf)

Favero, A., Daigneault, A., and B. Sohngen. 2020. Forests: Carbon sequestration, biomass energy, or both? Sci. Adv. 2020; 6 : eaay6792 25 March 2020

Forest2Market. 2015. Wood Supply Market Trends in the U.S. South 1995-2015. (http://www.forest2market.com/uploads/Forest2Market/documents/US-South-Wood-Supply-Trends.pdf)

A Guide to Forest Biomass Harvesting and Retention in Maryland (http://www.pinchot.org/uploads/download?fileId=915)

Gomez San Juan, M., Bogdanski, A. & Dubois, O. 2019. Towards sustainable bioeconomy - Lessons learned from case studies. Rome, FAO. 132 pp. Licence: CC BY-NC-SA 3.0 IGO. (http://www.fao.org/3/ca4352en/ca4352en.pdf)

Gustavsson, L. and Karlsson, Å. 2001. CO2 Mitigation Cost: A System Perspective on the Heating of Detached Houses with Bioenergy or Fossil Fuels. Proceedings: Woody Biomass as an Energy Source – Challenges in Europe, pp. 95-114.

Harrington, T. 2001. Silvicultural Basis for Thinning Southern Pines: Concepts and Expected Responses. Georgia Forestry Commission. (http://www.gfc.state.ga.us/resources/publications/SilviculturalBasis.pdf)

Howe, J., et al. Building with Wood: Proactive Climate Protection. 2015. Dovetail Partners. (https://www.dovetailinc.org/portfoliodetail.php?id=5e2b289fcc05c)

Ince, P. 2010. Global Sustainable Timber Supply and Demand. In: Sustainable Development in the Forest Products Industry, Chapter 2. Porto, Portugal; Universidade Fernando Pessoa, pp. 29-41. (https://www.fpl.fs.fed.us/documnts/pdf2010/fpl_2010_ince001.pdf)

IPCC. 2007. Climate Change 2007: Working Group III: Mitigation of Climate Change. (https://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter4.pdf)

Jefferies, H. and Leslie, T. 2017. Historical Perspective on the Relationship Between Demand and Forest Productivity in the U.S. South. Forest2Market, July 26. (https://www.forest2market.com/hubfs/2016_Website/Documents/20170726_Forest2Market_Historical_Perspective_US_South.pdf)

Johansson, L. S., Leckner, B., Gustavsson, L., Cooper, D., Tullin, C., and Potter, A. 2004. Emission characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Atmospheric Environment 38(2004):4183-4195.

Kingsley, E. 2012. Importance of Biomass Energy Markets to Forestry: New England's Two Decades of Biomass Energy Experience. University of Georgia Warnell School of Forestry. (https://plumcreek.app.box.com/s/92duinawd1zd82z0sjmcvpn5bx9r2uts)

Kilpeläinen, A., Kellomäki, S. and Strandman, H. 2012. Net Atmospheric Impacts of Forest Bioenergy Production and Utilization in Finnish Boreal Conditions. GCB Bioenergy 4(6): 811-817.

Kittler, J. 2013. Forest Bioenergy and Biodiversity: Commitment to Sustainable Sourcing. Pinchot Institute for Conservation. (http://www.pinchot.org/doc/510)

Kolb, T.E., Wagner, M.R., and W.W. Covington. 1995. Forest Health from Different Perspectives. (https://www.fs.fed.us/rm/pubs_rm/rm_gtr267/rm_gtr267_005_013.pdf)

Lamers, P. and Junginger, M. 2013. The "Debt" is in the Detail. Biofuels, Bioproducts and Biorefining 7(4): 373-385. (https://www.researchgate.net/publication/259576449_The_'debt'_is_in_the_detail_A_synthesis_of_recent_temporal_forest_carbon_analyses_on_woody_biomass_for_energy)

Li, Y. and Zhang, D. 2007. A Spatial Panel Data Analysis of Tree Planting in the US South. Southern Journal of Applied Forestry 31(4): 192-198. (http://www.auburn.edu/~zhangd1/RefereedPub/SJAF2007.pdf)

Lippke, B., Oneil, E., Harrison, R., Skog, K., Gustavsson, L. and Sathre, R. 2011. Life-Cycle Impacts of Forest Management and Wood Utilization on Carbon Mitigation in the Forest and Wood Products: Knowns and Unknowns. Carbon Management 2(3):303-333.

Mann, M., & Spath, P. 2003. The Environmental Benefits of Cofiring Biomass and Coal. Golden, CO: National Renewable Energy Laboratory, p.8. (https://bioenergykdf.net/system/files/1/KC_091102094518.pdf)

Mann, M. and Spath, P. 1999. A Life Cycle Comparison of Electricity from Coal. American Council for an Energy Efficient Economy (ACEEE) (https://www.aceee.org/files/proceedings/1999/data/papers/SS99_Panel1_Paper48.pdf)

Mantgem, P., Stephenson, N., Byrne, J., Daniels, L., Franklin, J., Fule, P., Harmon, M., Larson, A., Smith, J., Taylor, A. and Veblem, T. 2009. Widespread Increase of Tree Mortality Rates in the Western United States. Science. 23 Jan 2009: 521-524 (http://science.sciencemag.org/content/323/5913)

Marland, G. and Schlamadinger, B. 1997. Forests for Carbon Sequestration or Fossil Fuel Substitution? A Sensitivity Analysis. Biomass and Bioenergy 13(6): 389-397. (http://www.sciencedirect.com/science/article/pii/S0961953497000275)

Maryland Seed Tree Law. (https://dnr.maryland.gov/forests/Pages/programapps/treelaw.aspx)

Miner, R., Abt, R., Bowyer, J., Buford, M., Malmsheimer, R., O'Laughlin, J., Oneil, E., Sedjo, R. and Skog, K. 2014. Forest Carbon Accounting Considerations in US Bioenergy Policy. J. For. 112(6):591–606. (https://www.fpl.fs.fed.us/documnts/pdf2014/fpl_2014_miner001.pdf)

Natural Resources Article 5-1601 - 1613, Forest Conservation Act, enacted in 1991 (https://dnr.maryland.gov/forests/Pages/programapps/newfca.aspx)

No Net Loss Final Report. 2012. (https://dnr.state.md.us/forests/Documents/nonetlossfinalreport.pdf)

Olesen, A., Bager, S., Kittler, B., Price, W. and Aguilar, F. 2015. Environmental Implications of Increased Reliance of the EU on Biomass from the South East US. European Commission. (http://www.aebiom.org/wp-content/uploads/2016/08/DG-ENVI-study-imports-from-US-Final-report-July-2016.pdf)

Oswalt, S., Smith, W. B., Miles, P. and Pugh, S. 2014. Forest Resources of the United States, 2012: a Technical Document Supporting the Forest Service 2015 Update of the RPA Assessment. Gen. Tech. Rep. WO-91. Washington, DC: U.S. Department of Agriculture, Forest Service, Washington Office. 218 p. (https://www.srs.fs.usda.gov/pubs/gtr/gtr_wo091.pdf)

Parker,B., and Bennett, N. n.d. Reducing Hazardous Fuels on Woodland properties: Thinning. Oregon State University. (http://oregonforests.org/sites/default/files/publications/pdf/Haz_Fuels_Thinning_LR.pdf)

RISI. 2015. (http://www.risiinfo.com/risi-store/do/product/detail/us-southern-pulpwood-study.html)

Russell, M., Woodall, C., Fraver, S., D'Amato, A., Domke, G., and Skog, K. 2014. Scientific Journal. Ecosystems. 17(5): 765-777. (https://www.srs.fs.usda.gov/pubs/46089)

Ryan, M.G., M.E. Harmon, R.A. Birdsey, C.P. Giardina, L.S. Heath, R.A. Houghton, R.B. Jackson, D.C. McKinley, J.F. Morrison, B.C. Murray, D.E. Pataki and K.E. Skog. 2010. A Synthesis of the science on forest and carbon for U.S. Forests. Issues in Ecology 13:1-16.

Schlamadinger, B. and Marland, G. 1996. The Role of Forest and Bioenergy Strategies in the Global Carbon Cycle. Biomass and Bioenergy 10(5-6): 275-300. (http://www.sciencedirect.com/science/article/pii/0961953495001131)

Sedjo, R. 2011. Carbon Neutrality and Bioenergy: A Zero-Sum Game? Resources for the Future., Paper No. 11-15. (https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1808080)

Skog, K. 2008. Sequestration of carbon in harvested wood products for the United States. Forest Products Jour. 58(6): 56-72. (http://www.fpl.fs.fed.us/documnts/pdf2008/fpl_2008_skog001.pdf)

Smith, James E. et al. (2005). Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. USDA Forest Service, North Eastern Research Station, General Technical Report NE-343. (https://www.nrs.fs.fed.us/pubs/8192)

Spath, P. and Mann, M. 1999. Coal versus Biomass Electricity Generation – Comparing Environmental Implications Using Life Cycle Assessment. National Renewable Energy Laboratory.

Stewart, P. 2015. Wood Supply Trends in the South. Forest2Market. (http://nafoalliance.org/images/issues/pellets/Forest2Market_USSouthWoodSupplyTrends.pdf)

Strauss, W. and Schmidt, L. 2012. A Look at the Details of CO2 Emissions from Burning Wood vs. Coal. Future Metrics, January.

Sustainable Forestry Act of 2009. (https://dnr.maryland.gov/forests/Pages/sfcouncil.aspx)

The State of America's Forests. Forest Products and Services. Accessed 2 April 2020. (https://usforests.maps.arcgis.com/apps/Cascade/index.html?appid=6d3076faddfb4b8c8b6933cfcf4963cb)

Sustainable Biomass Partnership, Annual Report, 2019. (https://sbp-cert.org/wp-content/uploads/2020/04/SBP_AR2019_FINAL.pdf)

UNECE/FAO, Forest Products Annual Market Review, 2018-2019

U.S. Department of Agriculture. 2008. Carbon Stocks & Stock Changes in U.S. Forests. In: U.S. Agriculture and Forestry Greenhouse Gas Inventory: 1990-2005. Technical Bulletin 1921. (http://www.usda.gov/oce/climate_change/AFGG_Inventory/4_Forest.pdf)

U.S. Environmental Protection Agency (USEPA). 2011. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2009. Washington DC: U.S. Environmental Protection Agency. EPA 430-R-11-005.

USDA Forest Service. 2012. Future of America's Forest and Rangelands: Forest Service 2010 Resources Planning Act assessment. USDA-Forest Service, Gen. Tech. Rep. WO-87, pp. 76-78 and Fig. 83. (https://www.fs.fed.us/research/publications/gtr/gtr_wo87.pdf)

Verschuyl, J.,Riffell, S., Miller, D. and Wigley, T.B. 2011. Biodiversity Response to Intensive Biomass Production from Forest Thinning in North American Forests – A Meta-analysis. Forest Ecology and Management 261(2011): 221-232.

Walker T, Cardellichio P, Gunn J., Saah D. and Hagan J. 2013. Carbon Accounting for Woody Biomass from Massachusetts (USA) Managed Forests: A Framework for Determining the Temporal Impacts of Wood Biomass Energy on Atmospheric Greenhouse Gas Levels. Journal of Sustainable Forestry, 32, 130–158. (http://www.tandfonline.com/doi/abs/10.1080/10549811.2011.652019?journalCode=wjsf20)

Walker, T., Cardellichio, P., Colnes, A., Gunn, J., Kittler, B., Perschel, B., Recchia, C. and Saah, D. 2010. Biomass Sustainability and Carbon Policy Study. (http://www.mass.gov/eea/docs/doer/renewables/biomass/manomet-biomass-report-full-hirez.pdf)

Wang, W., Dwivedi, P., Abt, R. and Khanna, M. 2015. Carbon Savings with Transatlantic Trade in Pellets: Accounting for Market-Driven Effects. Environ. Res. Lett. 10(11). (http://iopscience.iop.org/article/10.1088/1748-9326/10/11/114019)

Wear, D. 2013. Projected Land Use Change in the South. In: Wear, D. and Greis, J. 2013. The Southern Forest Futures Project: Technical Report. USDA-Forest Service Gen. Tech. Rep. SRS-GTR-178, Asheville, NC, Chapter 4. Findings from the Southern Forest Futures Project. USDA-Forest Service, Southern Research Station. (https://www.srs.fs.usda.gov/futures/technical-report/04.html)

Wear, D. 2013. Forecasts of Land Uses. In: Wear, D. and Greis, J. Southern Forest Futures Technical Report. USDA- Forest Service, Gen. Tech. Rep. SRS-GTR-178, pp. 45-72. (http://www.srs.fs.fed.us/pubs/gtr/gtr_srs178.pdf)

Appendix A. Glossary of Terms

Afforestation Establishing a forest on land not previously forested or not forested for a long period of time (i.e. 50 years).

Baseline Generally, the reference against which program or project activities are measured.

Best Management Practices (BMPs) Guidelines that help foresters, loggers, and others who work in the woods protect soil and water quality. These are typically defined at the state level and may or not be mandatory.

Bioenergy heat or electricity produced from biomass energy systems.

Biomass any organic matter that can be burned for energy.

Btu British thermal unit. Standard unit of energy equal to the heat required to increase the temperature of one pound of water one degree Fahrenheit.

Cap-and-Trade A market-based approach to controlling pollution that allows corporations or national governments to trade emissions allowances under an overall cap, or limit, on those emissions.

Carbon Accounting Refers generally to processes undertaken to "measure" amounts of CO2e emitted by an entity.

Carbon Benefit The difference between a baseline and the results from management activities. This is a measurement of additionality.

Carbon Dioxide (CO_2) A naturally occurring molecular structure that holds most of the carbon in the atmosphere in its gas form. CO_2 is also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass and of land use changes and of industrial processes (e.g., cement production).

CO_2 is the principal anthropogenic GHG that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a GWP of 1. (IPCC)

Carbon Pools (or Stocks) A system that has the capacity to store or release carbon.

In forests, five main carbon pools or stocks are commonly recognized: above-ground biomass, below-ground biomass, dead wood, litter and soil organic matter.

Carbon Sequestration Any process by which CO2 is removed from the atmosphere and stored in solid or liquid form.

Carbon Sink A negative source of CO2 in the atmosphere (NEP>0) via absorption and storing of carbon in vegetation, the atmosphere, and the ocean.

Carbon Source A positive source of CO2 to the atmosphere (NEP < 0).

Carbon Storage The maintenance of sequestered carbon over time in a specific place – often referred to as a carbon pool (e.g. in wood products or in forests).

Certification A mechanism for forest monitoring, tracing and labeling timber, wood and pulp products, and non-timber forest products, where the quality of forest management is judged against a series of agreed standards. (WWF)

Chips a type of wood fuel. Clean chips are wood fiber processed by chipping, are free of contaminants like bark and needles, and generally include only the bolewood of a tree. Clean chips are suitable for residential and small industrial heating applications.

Co-firing combustion of two types of materials, e.g., biomass with coal.

Co-generation simultaneous production of heat and electricity from one or more fuels, also called combined heat and power (CHP).

Conversion A substantial and immediate reduction in forest carbon stock through cutting and clearing trees and the permanent change of land cover or use from forest with no plans to reforest.

Cord stack of round or split wood consisting of 128 cubic ft of wood, bark, and air space (measures 4ft x 4ft x 8 ft).

Disturbance Forest disturbances are events that cause change in the structure and composition of a forest ecosystem, beyond the growth and death of individual organisms. The sets and patterns of natural disturbances that characterize a particular area or ecosystem are referred to as the ecosystem's disturbance regime.

Disturbances, both human-induced and natural, shape forest systems by influencing their composition, structure, and functional processes. Climate change is impacting forests by altering the existing disturbance regimes.

Examples include fire, wind, harvest, disease, and pests. Climate change will largely impact forests by altering the existing disturbances and cycles of disturbance.

Double-counting The scenario under which a singular GHG emission reduction or removal is monetized separately by two different entities or where a GHG emission reduction or removal is sold to multiple buyers. (Verra)

Forest ecosystems are defined vertically from the top of the tree canopy to the "bottom" of the soil. While sediments and roots can extend for many meters, sampling is rarely done below 1m in depth.

Forest biomass the accumulated above- and belowground mass (bark, leaves, and wood) from living and dead woody shrubs and trees.

Forest Ecosystems A unit of biological organization made up of all of the organisms in a given forest area interacting with the physical environment so that a flow of energy leads to characteristic trophic structure and material cycles within the system. (Odum 1967)

Forest residues the aboveground material generated from logging during harvesting, e.g., leaves, bark, and tree tops (see also Slash)

Forest Stand An aggregation of trees or other growth occupying a specific area and sufficiently uniform in species composition, size, age, arrangement, and condition as to be distinguished from the forest or other growth on adjoining areas.

Harvested Wood Products (HWPs) Wood-based materials harvested from forests, which are used for products such as furniture, plywood, paper and paper-like products, or for energy. (UNECE)

Improved Forest Management (IFM) Activities to maintain or increase carbon stocks, such as:

- Increasing overall age of forest by increasing rotation ages
- Increasing the forest productivity by thinning diseased or suppressed trees or managing brush and other competing vegetation
- Improving harvest practices; and
- Maintaining stocks at a high level

Intergovernmental Panel on Climate Change (IPCC) A United Nations body founded in 1988, which evaluates climate change science.

The IPCC assesses research on climate change and releases it in major 'assessment' reports every 5–7 years. The fifth assessment report - referred to as AR5 – was published in 2014 (IPCC).

Inventory The systematic collection of data on the forestry resources within a given area. It allows assessment of the current status and lays the ground for analysis and planning, constituting the basis for sustainable forest management. (FAO)

Litter Undecomposed or only partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs, etc.). (USDA)

Mass Timber Construction A category of framing style typically characterized by the use of large solid wood panels for wall, floor, and roof construction. This term also includes innovative forms of sculptural buildings and non-building structures formed from solid wood panel or framing systems of six feet or more in width or depth.

Methane (CH4) A GHG with a GWP of 28-36 over 100 years.

CH4 is produced through anaerobic (without oxygen) decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion. (UNFCCC)

Mitigation Actions to minimize climate change by reducing sources of GHG emissions and enhancing carbon sequestration.

Old-Growth Forest Ecosystem distinguished by old trees and related structural attributes. Old growth encompasses the later stages of stand development that typically differ from earlier stages in a variety of characteristics which may include tree size, accumulations of large dead woody material, number of canopy layers, species composition, and ecosystem function. Definition specifics will vary by geography and forest type. (FAO)

Paris Agreement An agreement within the United Nations Framework Convention on Climate Change (UNFCCC) to address GHG emissions mitigation, adaptation, and finance. The agreement was negotiated by 196 state parties at the 21st Conference of the Parties of the UNFCCC in France and adopted by consensus in December 2015 to go into effect in 2020.

Pulpwood trees and wood suitable for manufacturing paper.

Rotation number of years required to establish and grow trees to a specified size, product, or condition of maturity.

Roundwood sawtimber, pulpwood, and other round sections cut from the tree.

Saw timber log or tree meeting minimum diameter and stem quality requirements to be sawed into lumber.

Slash tree-tops, branches, bark, or other residue left on the ground after forestry operations (see also Forest Residues).

Stumpage value or volume of uncut trees in the woods.

Thinning partial harvesting of a stand of trees to accelerate the growth of the trees left standing.

Timberland forested land capable of producing in excess of 20 cubic ft/acre per year of industrial wood crops under natural conditions.

Wildland-urban interface (WUI) forest areas with increased human influence and land use conversion.

Wood Pellets type of wood fuel made from compacted sawdust or pulverized wood chips. Premium pellets are made from sawdust and clean chips free of contaminants and are highly dense with low moisture content (below 10%) that are burned with greater combustion efficiency in residential and small industrial applications. Industrial grade pellets have higher ash content and are used in industrial applications with larger boilers and higher combustion temperatures than residential scale boilers.

Many of the above glossary terms were taken from the Michigan State University Forest Carbon and Climate Program's Forest Carbon Shortcourse: https://www.canr.msu.edu/fccp/

Additional definitions of terms available from:

https://www.biomasscenter.org/resource-library/glossary

https://www.energy.gov/eere/bioenergy/glossary

https://www.usabiomass.org/glossary-of-terms/

https://bioenergy-for-business.org/why-bioenergy/glossary-of-bioenergy-terms/

https://www.canr.msu.edu/fccp/FCCP-ORL/index

Appendix B. Maryland Tree Planting Program Briefs

TREE-Mendous

TREE-Mendous provides native trees and shrubs at a reduced cost each spring and fall for residents to plant at schools, parks and public community spaces statewide. This program's goal is to help Maryland residents have access to affordable trees to plant on their public lands. With permission from landowners, volunteers can plant trees at schools, in state and community parks, local open space, street trees and more.
https://dnr.maryland.gov/forests/Pages/treemendous/default.aspx

Marylanders Plant Trees

Marylanders Plant Trees is a coupon program that gives $25 off the purchase of a native tree with minimum retail value of $50 at 35 participating nurseries. The Maryland Forest Service covers $20 of the cost and the nurseries cover the remaining $5. A printable coupon, recommended native tree list and the participating nurseries can be found online at:
https://dnr.maryland.gov/forests/Pages/MarylandersPlantTrees/Introduction.aspx

Gift of Trees

Any citizen wanting to plant a tree in honor of family or friends can donate $40 to the Maryland Forest Service's Gift of Trees and this program will arrange for a tree to be planted in the county honoree resides in. Planting areas focused on include schoolyards, playgrounds, parks, towns and alongside streams. The person being honored will receive a certificate as well. Donating a grove of 10
trees at $400 allows the program participant to choose the planting location.
https://www.shopdnr.com/tree-mendousmarylandgiftoftrees.aspx

Backyard Buffers

Backyard Buffers is a seedling giveaway program for any Maryland residents who have a drainage ditch, stream, creek, or river flowing through their property or live adjacent to a waterway. Property owners can sign up typically in March to get a buffer bag, which includes 20-30 native tree and shrub bareroot seedlings, approximately 1 to 2 feet in height. Also included are fact sheets on the species included in bag, tree planting techniques and proper tree maintenance. A mix of various species, the seedlings are well suited to streamside conditions. Bags are made available for pickup at a designated local site and time for the spring planting season.
https://dnr.maryland.gov/forests/Pages/programs/Backyard-Buffer-Program.aspx

Woodland Incentive Program

Private, non-industrial woodland owners who manage their forest land may apply for financial assistance through the Maryland Forest Service's Woodland Incentive Program. Landowners who own 5 to 1,000 acres of woodland and agree to maintain the forestry practice for 15 years are eligible to apply. Some eligible cost-share practices include preparation of stewardship plans and reforestation of open land.
https://dnr.maryland.gov/forests/Pages/programapps/costshareprograms.aspx#wip

Forest Conservation Management Program

Under Maryland Forest Service's Forest Conservation Management Program, any resident who owns over 5 contiguous forested acres can get a forest management plan drawn up by a forester while getting a break on property taxes for at least 15 years. House sites, crop land and other non-forest open spaces are not eligible. Open land that was recently planted with tree seedlings can be included in the program after one growing season.
https://dnr.maryland.gov/forests/Pages/programapps/fcmp.aspx

Environmental Quality Incentive Program

Pairing with the U.S. Department of Agriculture Natural Resources Conservation Service, Maryland Forest Service staff act as technical service providers in helping implement the Environmental Quality Incentive Program. Farm and forestry producers are guided in how best to improve their agricultural and woodland practices while restoring their landscape and gaining environmental
benefits like improved wildlife habitat. There are up to 200 conservation practices included in program depending on location.
https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/

Conservation Reserve Enhancement Program

The Conservation Reserve Enhancement Program is led by USDA Farm Service Agency, with the Natural Resources Conservation Service, Soil Conservation Districts and the Maryland Forest Service as technical service providers. This program supports forest buffers and wetlands on working farmland to protect and restore water quality and wildlife by offering cost-share and technical assistance to farmers maximizing their agriculture land use.
https://dnr.maryland.gov/wildlife/Pages/habitat/milo.aspx

Healthy Forests Healthy Waters

The Chesapeake Bay Trust-funded Healthy Forests Healthy Waters program is a partnership between Maryland Forest Service, Alliance for the Chesapeake Bay and the Maryland Forestry Foundation, with grant funding provided by the Department of Natural Resources Chesapeake and Coastal Bays Trust Fund. Healthy Forests Healthy Waters provides participating landowners with a free tree planting project of an acre or more on open land they want to convert into a forest, with supplies, labor and at least 3 years of maintenance and technical advice. Only requirement of the landowner is to maintain this newly planted forest for a minimum of 10 years.

Lawn to Woodland

Lawn to Woodland helps Maryland residents who own 1-4 acres of land convert unused lawn to forest cover at no cost. Under guidance of the Maryland Forest Service, bare-root tree seedlings are planted and protected with tree shelters by a contractor. Weed mats are also included to help with weed control, and 3 years of maintenance and planting advice are provided. Can be limited to some counties based on available funding.

Appendix C. Maryland Forest Assessment Summary

Information provided by the Maryland Department of Natural Resources

Forests on reserved land (forestland that is withdrawn from timber harvesting through statute or administrative designation) in Maryland amounted to 284,000 acres in 2018, according to U.S. Forest Service estimates (figure 1). This makes up 41.9% of all public land in the state and includes all National Park and U.S. Fish and Wildlife Service land and one third of all state land. Of state land, 66,000 acres, or roughly 14% of state-owned land, are part of the Maryland Wildlands Preservation System. These areas are protected indefinitely by an act of the state legislature as wild, where motorized vehicle access is restricted, and tree harvesting is prohibited. Wildlands make up nearly 3% of Maryland's total forest cover.

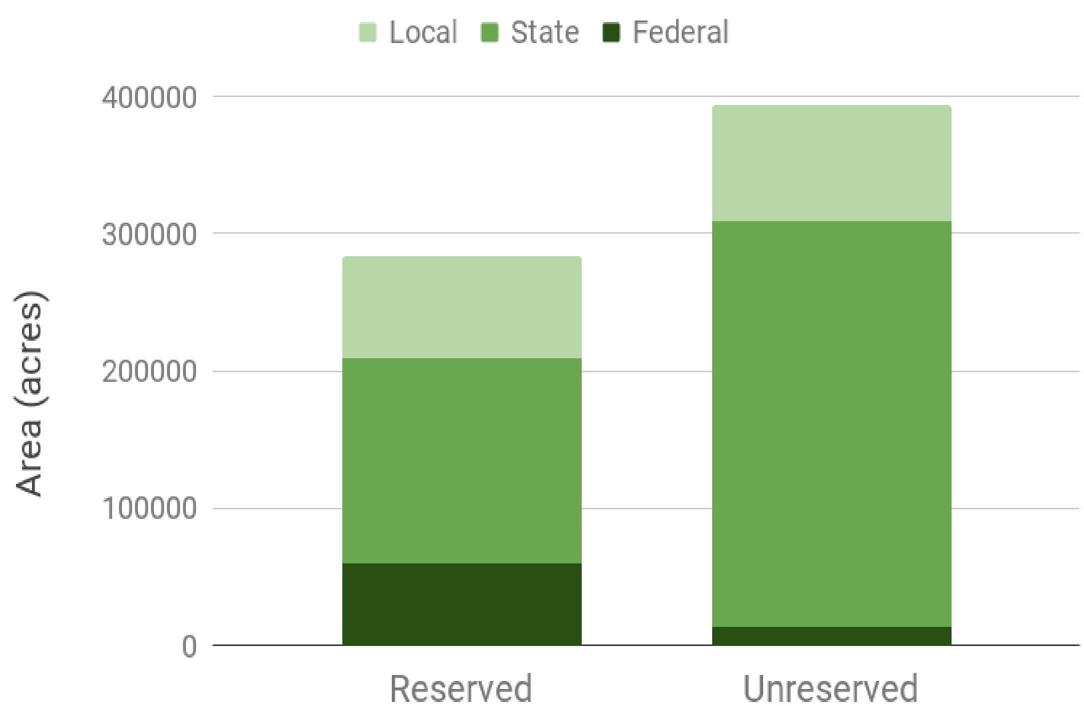


Figure 1 Area of public land in Maryland by reserve from timber harvest status and ownership

In Maryland, forest stands in which most of the stocking is in large trees have increased in acreage since the early 1970's. The U.S. Forest Service estimates that 78% of the State's forests are in the Mature/Large forest class, nearly 40% of forest is over 80 years of age (figure 2), and nearly all of which is in the oak/hickory forest type (Lister, 2018). This is indicative of a slowing of the forest products industry in Maryland over the last 40 years. Furthermore, the U.S. Forest Service reports that 10% of Maryland's timberland is at least 100 years old—more than any other state in the Northeastern Area. By contrast, only 8% of the state's timberland is younger than 20 years.

Although old growth forest was once a dominant feature throughout most of the Maryland landscape, only about 40 small, scattered remnants remain (MD DNR, unpublished data). The ongoing inventory for old growth forests on state lands has documented 1,981 acres of this important key wildlife habitat in western Maryland. This habitat is fragmented into small patches ranging in size from about 3 to 390 acres. Only five areas exceed 100 acres each. Most are considerably smaller (3-50 acres) and confined to isolated steep slopes, sheltered ravines or otherwise difficult to access areas where they were spared from indiscriminate logging and/or deforestation associated with agriculture.

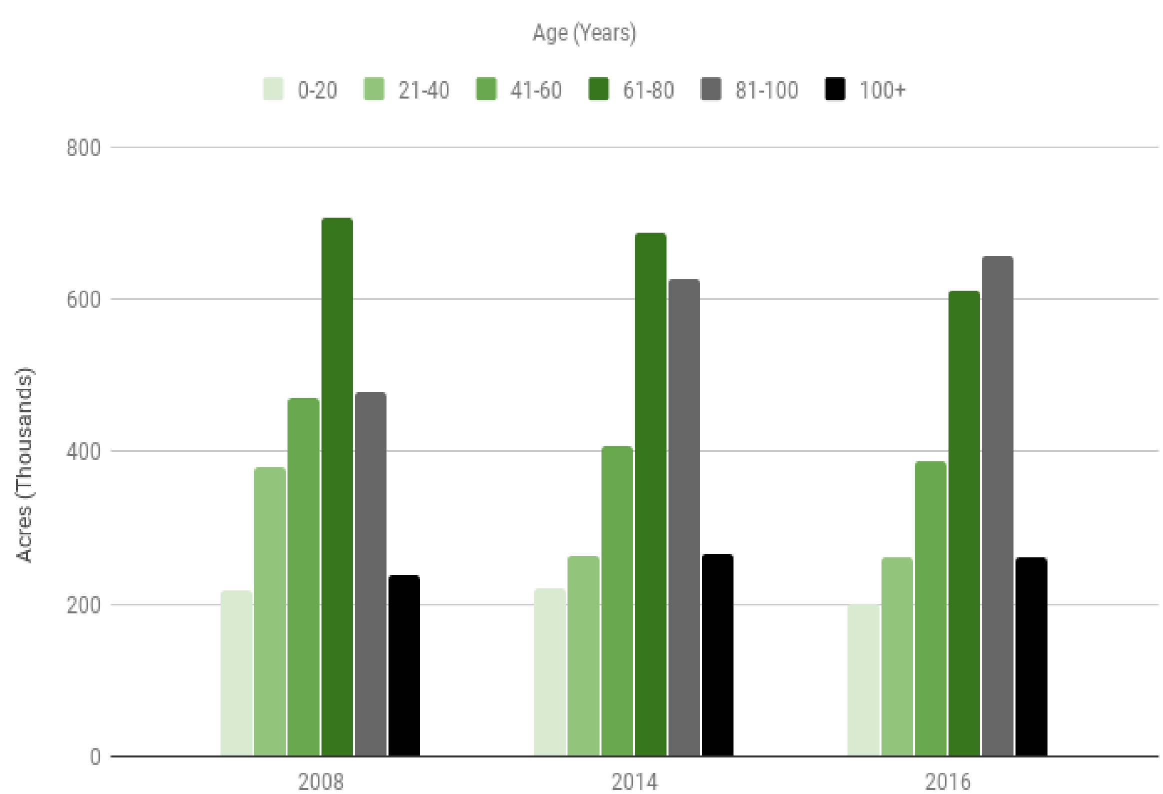


Figure 2 Forest age class by survey period

The average annual net growth of wood on timberland in Maryland has been declining over the past decade. According to FIA data, in 2008 the annual net growth of merchantable bole volume for growing stock trees was 178.8 million cubic feet. This decreased to 127.4 million cubic feet in 2013, and 109.9 million cubic feet in 2018 (figure 3). This could be because the average age of Maryland's forests has been increasing overtime, and older trees grow slower than younger ones. Removals for harvest stayed consistent from 2008 to 2013 at around 55 million cubic feet. However, this sharply declined to 27.8 million cubic feet in 2018. Mortality on timberland has stayed fairly consistent between 2008 and 2018.

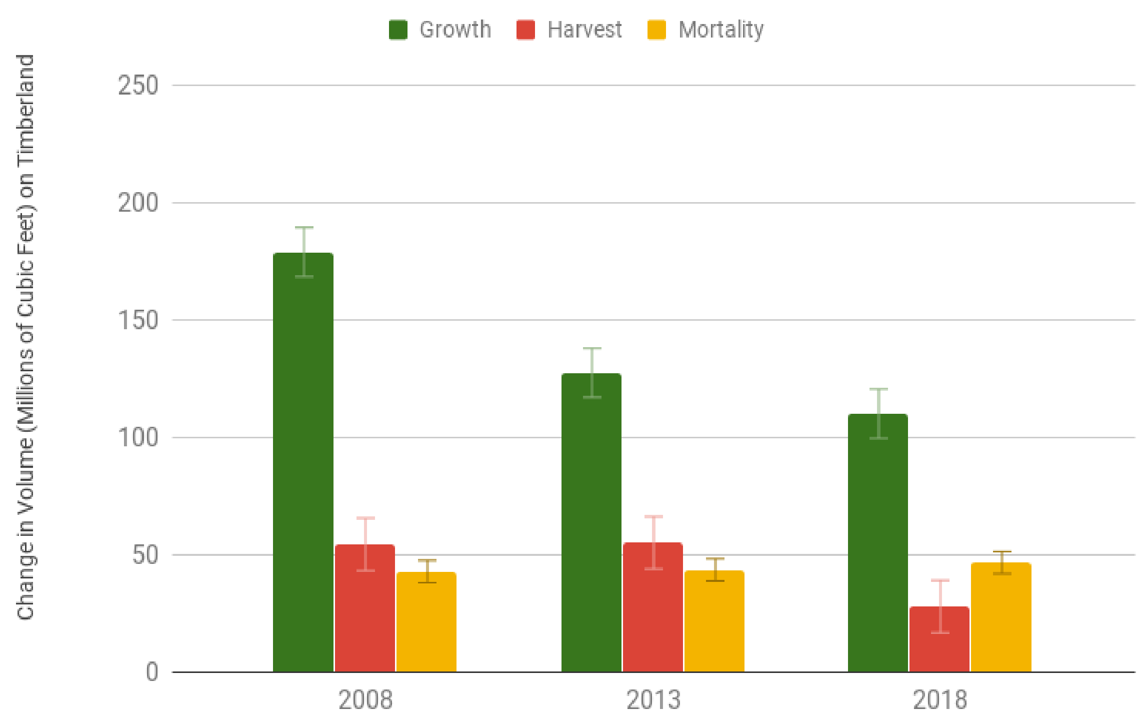


Figure 3 Annual growth rate, harvest, and mortality over time on timberland

Forest land saw similar patterns changes to annual growth rates and harvesting, but there was a noticeable increase in mortality rates in the last decade, going from 57 million cubic feet in 2008 to 73.1 million cubic feet in 2018 (figure 4).

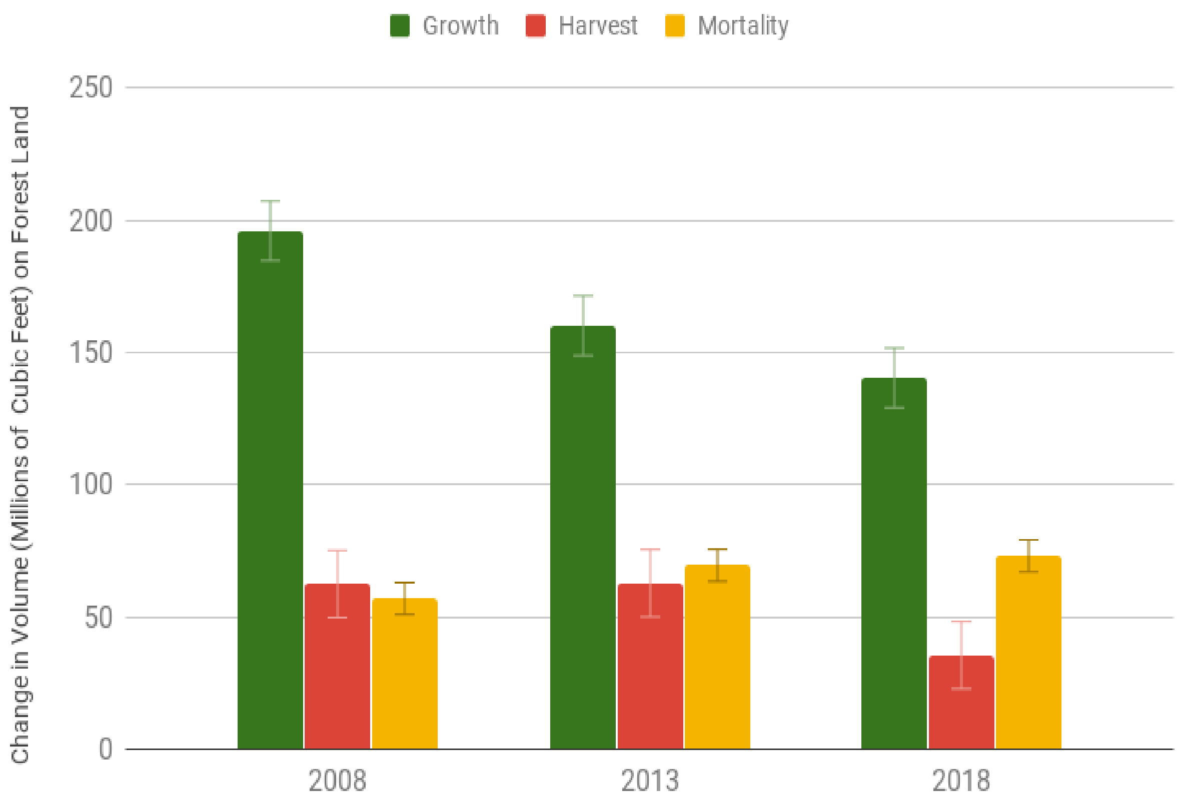


Figure 4 Annual growth rate, harvest, and mortality over time on forest land

Maryland's tree biomass has been steadily increasing over the past decade. According to data from the Forest Inventory and Analysis (FIA) the dry weight of aboveground tree biomass over 1 inch on forest land was 176.3 million tons in 2008 and 190.1 million tons in 2018, an 8% increase. Aboveground biomass followed a similar pattern on timberland, increasing from 158.9 million dry tons in 2008 to 166.0 million dry tons in 2018, a 4% increase. Density of above ground biomass on forest land increased from 70.4 dry tons per acres in 2008 to 77.8 dry tons per acre in 2018, a 10.5% increase (figure 5). Belowground biomass per acre of forest land showed a similar change, increasing 10% from 2008 to 2018.

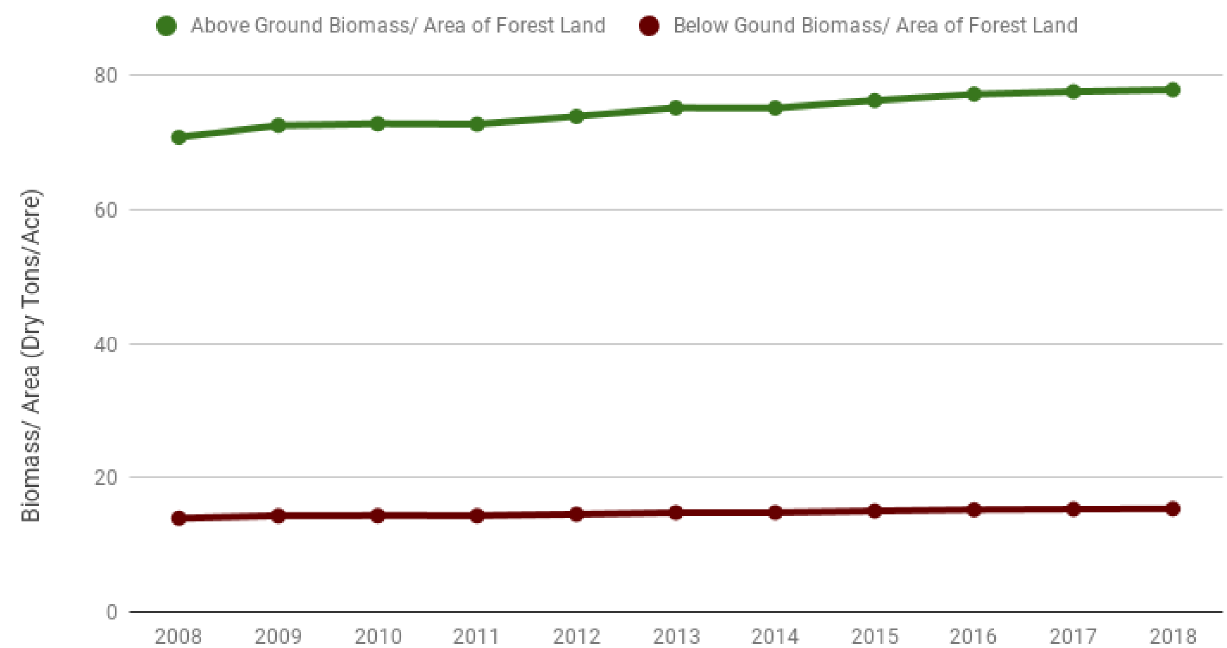


Figure 5 Above and below ground tree biomass per acre on forest land over time

Similarly, to biomass estimates, forest carbon pools in Maryland have slightly increased over the past decade. According to data from FIA, in 2008 there were 204.0 million tons of carbon on forest land (figure 6). This includes 105.6 million tons of carbon in live trees larger than 1 inch, 70.4 million tons of carbon in soil organic matter, and 28.0 million tons of carbon in other pools (dead trees, seedlings, shrubs, stumps, coarse roots, coarse woody debris, and litter). In 2018 total carbon on forestland was 212.8 million tons, with 113.8 million tons in live trees, 69.7 million tons in soil organic carbon, and 29.2 million tons in other stocks. This is a 4% increase in total forest carbon from 2008.

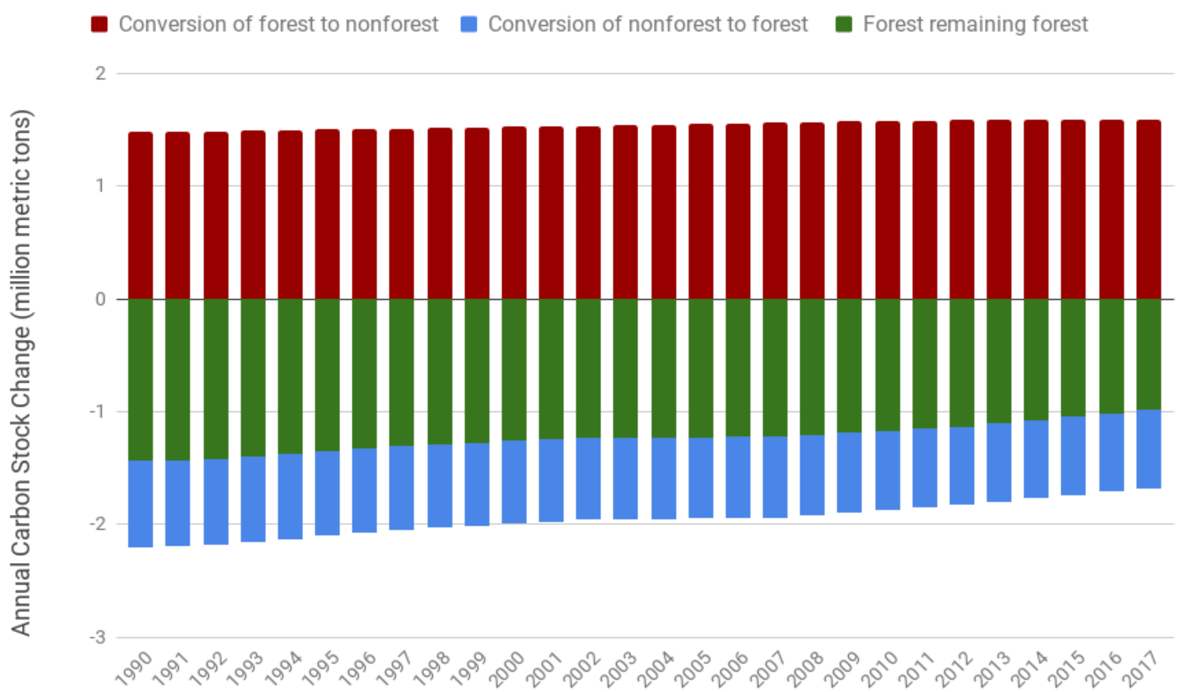


Figure 6 Annual carbon stock change of forest to nonforest, nonforest to forest, and forest to forest lands from 1990 to 2017. Positive values represent a release of carbon while negative values represent carbon sequestration.

While total biomass and carbon stocks have increased in the past decade, annual amounts of sequestration on forest land has decreased according to greenhouse gas estimations from the U.S. Forest Service (figure 7) (Domke et. al., 2019; U.S. EPA, 2019). The annual amount of carbon sequestered on forest lands (including forest remaining forest and nonforest land being converted to forest) has been decreasing over the last three decades. This is likely because the average age of Maryland's forest is getting older. While older forests store more carbon, their growth rate is slower than younger forests. Older forests are also a larger source of carbon emissions than younger forests as they have more mortality and respiration from the decomposition of dead organic material.

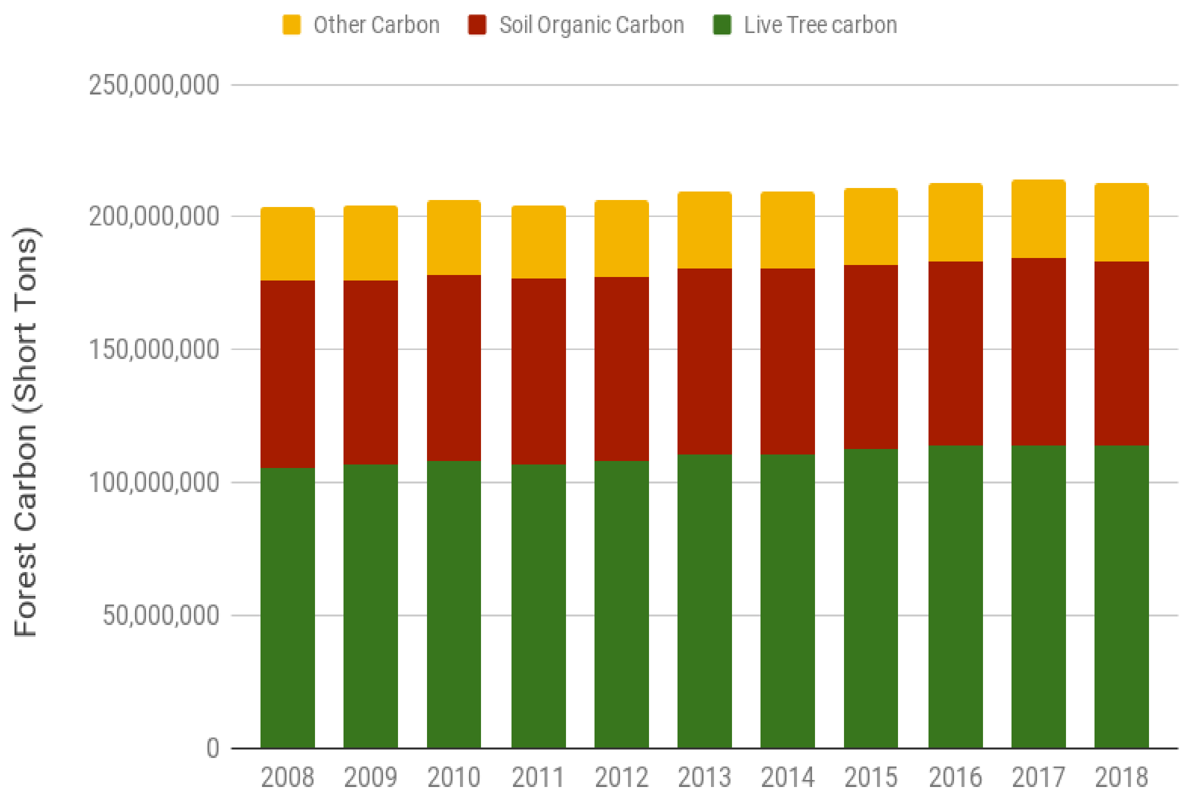


Figure 7 Stocks of live tree, soil organic, and other forest carbon over time

Report published by:

DOVETAIL PARTNERS

Your trusted source for environmental information.

www.dovetailinc.org