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Accounting for Greenhouse Gas Emissions from Wood Bioenergy



Response to the U.S. Environmental Protection Agency's Call for Information,
Including Partial Review of the Manomet Center for Conservation Sciences'
Biomass Sustainability and Carbon Policy Study

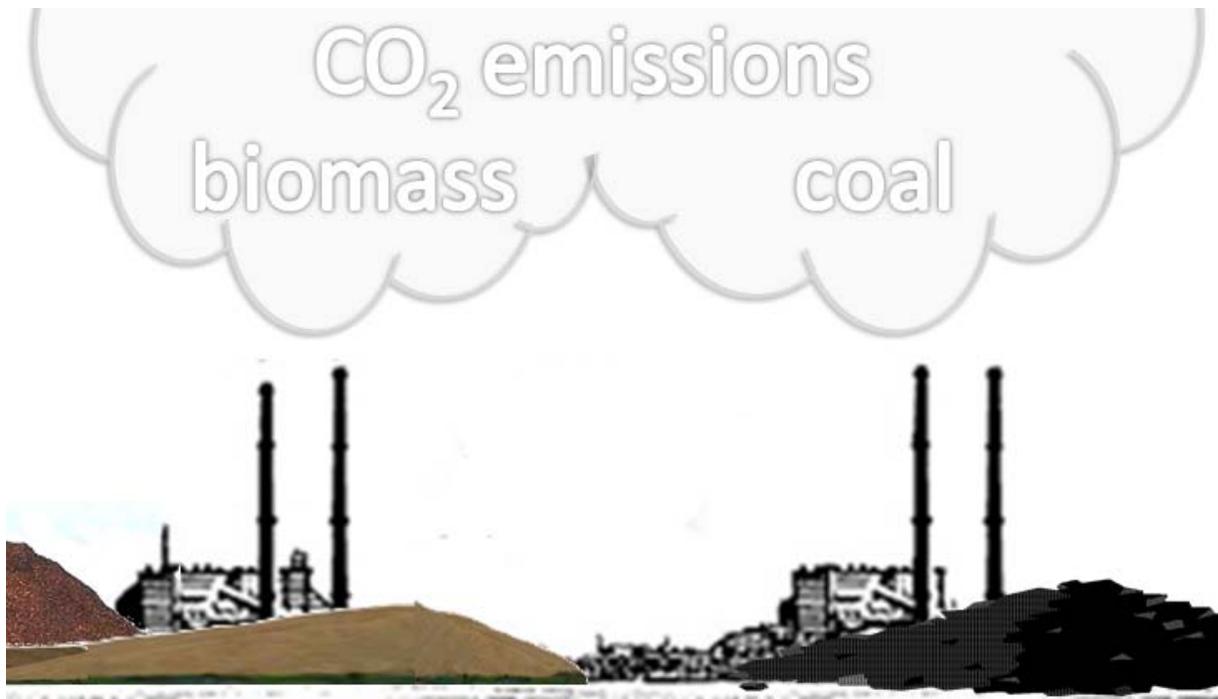
by

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The College of Natural Resources Policy Analysis Group (PAG) was established by the Idaho Legislature in 1989 to provide objective analysis of the impacts of natural resource proposals (see Idaho Code § 38-714).

The PAG is administered by Kurt Pregitzer, Dean, College of Natural Resources, University of Idaho.

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About the Policy Analysis Group (PAG)

Role and Mission. The Idaho Legislature created the Policy Analysis Group (or “PAG”) in 1989 as a way for the University of Idaho to provide timely, scientific and objective data and analysis, and analytical and information services, on resource and land use questions of general interest to the people of Idaho. The PAG is a unit of the College of Natural Resources Experiment Station, administered by William J. McLaughlin, Director, and Dean, College of Natural Resources.

PAG Reports. This is the thirty-first report of the Policy Analysis Group (see inside cover). The PAG is required by law to report the findings of all its work, whether tentative or conclusive, and make them freely available. PAG reports are primarily policy education documents, as one would expect from a state university program funded by legislative appropriation. The PAG identifies and analyzes scientific and institutional problems associated with natural resource policy issues. In keeping with the PAG’s mandate, several alternative policy options are developed and their potential benefits and detrimental effects are analyzed. As an operational policy the PAG does not recommend an alternative.

Advisory Committee. A standing Advisory Committee (see inside cover) has specific functions assigned by the PAG’s enabling legislation. The committee’s main charge is to review current issues and suggest topics for analysis. Based on those suggestions, the dean of the College of Natural Resources works closely with the PAG director to design analysis projects. The Advisory Committee has a responsibility to suggest the appropriate focus of the analysis. This is done iteratively, until an outline for the project is mutually agreed upon by the committee and the PAG. The outline is usually organized as a series of focus questions, and the PAG’s analytical tasks are to develop replies to the questions. The PAG uses the resources of the university and other public and private organizations as needed. When the PAG becomes active on a project, the Advisory Committee receives periodic oral progress reports. This process defines the scope of report content and provides freedom for the PAG to conduct unbiased analysis.

Technical Review. Peer review of PAG work is absolutely essential for ensuring not only technical accuracy but also impartiality and fairness. A technical advisory committee and technical reviewers are selected separately for each project by the dean and PAG director, sometimes upon recommendation of the Advisory Committee, to ensure that a wide range of expertise is reflected in the design and execution of PAG reports, and that no point of view is favored. Report review criteria used by the National Research Council of the National Academy of Sciences are the guidelines furnished to PAG reviewers.

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Table of Contents

Title page	i
About the Policy Analysis Group (PAG)	ii
Acknowledgements	iii
Table of Contents	iv
List of Figures and Tables	vi
Executive Summary.....	1
Introduction.....	2
Problem Analysis.....	3
1. Treatment of Biomass under the PSD/BACT	5
2. National-Scale Carbon Neutrality in IPCC Guidelines	6
2.1. International Policy	8
2.2. National Policy	8
2.2.1. U.S. Environmental Protection Agency (EPA)	8
2.2.2. U.S. Department of Energy (USDOE)	9
2.3. State Policy—Massachusetts	10
2.3.1. Discussion of Manomet Center's Carbon Policy Study conclusions	11
2.3.2. The Manomet Center on the "carbon neutral" issue	11
2.4. Conclusions	12
3. Smaller-Scale Accounting Approaches	13
4. Alternative Accounting Approaches	15
4.1. Time Interval for Accounting Purposes	15
4.1.1. Biomass carbon "debt-then-dividend" model	16
4.1.2. Explanation with revised graphics	16
4.1.3. Biomass "carbon debt" from whole-tree bioenergy harvest	18
4.1.4. "Debt" relative to fossil fuels, repayment and "dividend"	19
4.1.5. Critique: Discrete modeling of continuous process is problematic	20
4.1.6. Time scale issue	20
4.1.7. When does the carbon cycle begin and end?	20
4.1.8. Critique: Conclusions from the "debt-then-dividend" model	21
4.1.9. Conclusions	22
4.2. Appropriate Spatial/Geographic Scale for Accounting Purposes	23
4.2.1. Stand-level instead of landscape-level analysis	23
4.2.2. Why landscape-level analysis?	23
4.3. Life Cycle Analysis	26
4.3.1. Wood products carbon pool and avoided fossil fuel emissions	27
4.3.2. Forest management implications	29
4.3.3. Conclusions	31

Table of Contents (continued)

4.4. Forestry’s Role in Carbon Management	31
4.4.1. Carbon stocks and flows	32
4.3.2. Are U.S. forests a net source or sink?	33
4.3.3. Conclusions	33
4.5. Conclusion: A Comprehensive Approach to Biomass Emissions Accounting	34
5. Comparison with Fossil Energy	36
5.1. Why compare wood with coal?	36
5.2. Life cycle analysis	36
5.3. Fuel characteristics analysis	37
5.4. Electricity generation technology characteristics	40
5.5. Conclusions	40
6. Comparison among Bioenergy Sources	41
7. Renewable or Sustainable Feedstocks	42
8. Other Biogenic Sources of CO ₂	44
9. Additional Technical Information	45
9.1. Current and projected utilization of biomass feedstocks for energy	45
9.2. Economic, technological, and land management drivers for projected changes in biomass utilization rates	46
9.3. Current and projected levels of GHG emissions from bioenergy and other biogenic sources	46
9.4. Economic, technological and land management drivers for projected changes in emissions	46
9.5. Current and projected carbon sequestration rates in lands used to produce bioenergy feedstocks	46
9.6. Economic, technological and land management drivers for projected changes in sequestration rates	46
9.7. The types of processes that generate or are expected to generate emissions from bioenergy and other biogenic sources	47
9.8. The number of facilities that generate or are expected to generate such emissions	48
9.9. Emission factor information, particularly for the biogenic CO ₂ source categories of wastewater treatment, livestock management, and ethanol fermentation	48
9.10. Potential impacts on specific industries and particular facilities of various methods of accounting for biogenic GHG emissions	48
9.11. Potential impacts of GHG emissions from bioenergy and other biogenic sources on other resources such as water availability and site nutrient quality	48
9.12. Potential impacts of GHG emissions from bioenergy and other biogenic sources on other air pollutants (VOCs, criteria pollutants, and particulate matter)	48
Conclusions	49
References Cited	52

List of Boxes, Figures and Tables

Box 1. Some Things about Forest Carbon Accounting Policymakers Need to Know	4
Box 2. Two Frequently Asked Questions about Biomass Greenhouse Gas Emissions	8
Figure 1. Bioenergy zero net emissions increase conceptual model	7
Figure 2. CO ₂ emissions in U.S. by use sector and fuel source, 2008 and 2035.....	10
Figure 3. Total stand carbon sequestration profiles over time for a forest harvested in a Massachusetts “business as usual” (BAU 20) timber scenario, and the same forest harvest plus additional removal of whole-tree biomass (BAU 32) for energy	18
Figure 4. Total stand carbon recovery over time.....	19
Figure 5. Forestry and the carbon cycle.....	24
Figure 6. Behavior of carbon stores based on area expansion from increasing number of stands; fluctuation is a function of stand disturbances	25
Figure 7. Electricity production life-cycle analysis	26
Figure 8. Potential emission reductions from substituting wood for concrete and steel. Estimates are CO ₂ -equivalent emissions from constructing one kilometer of transmission line using poles made of either treated wood, concrete or tubular steel over a 60 year period, and include the impact of disposal	28
Figure 9. Total stand carbon for a Douglas-fir plantation under four management scenarios	29
Figure 10. Total stand carbon for a Douglas-fir plantation under a 45-year rotation management scenario with additional wood products carbon and avoided emissions from product substitution compared with a no-harvest scenario	30
Figure 11. Global carbon stocks and flows	32
Figure 12. Carbon balance in U.S. forests, 1700-2100	33
Figure 13. Wildfires in U.S., acres burned and number of fires, 1960-2007	47
Table 1. CO ₂ emissions from direct combustion of biomass and coal, based on carbon content and heat value of the fuel.....	39



Executive Summary

The utilization of woody biomass to produce energy is accompanied by concerns about sustainable forest management and greenhouse gas (GHG) emissions from burning biomass. The conversion, or potential conversion, of land from native forest to biofuel crops has led to reconsideration of emissions accounting practices. A novel approach is presented in the *Biomass Sustainability and Carbon Policy Study* commissioned by the Massachusetts Department of Energy Resources and conducted by the Manomet Center for Conservation Sciences (MCCS 2010a). It is based on the “carbon debt” concept presented in several articles appearing recently in *Science* magazine, and extended to a carbon “debt-then-dividend” model. This stretches the “debt” and its repayment into the future, but stops short of suggesting how decisions should be made today.

The “debt-then-dividend” model is flawed by time and space restrictions. The carbon cycle does not begin at the time a tree dies, rather it is continuous; wood utilization requires many, many stands sustained over a long period of time, not one stand over four decades as in the Manomet Center study report. The study report also purposely ignores wood products carbon pools and the benefit of avoided GHG emissions from substituting wood products for concrete and steel, which consume large amounts of fossil fuel energy in their production. The benefit of wood substitution is that fossil fuels stay in the ground, and their emissions are avoided.

Although the Manomet Center study report recognizes that “all bioenergy technologies—even biomass electric power compared to natural gas electric—look favorable when biomass ‘wastewood’ is compared to fossil fuel alternatives” (MCCS 2010a, p. 110), analysis focuses on whole-tree biomass harvesting. The report perplexingly claims that until trees regrow and recapture carbon from the atmosphere, coal is a better choice than wood for producing electricity. The study report also rejects the accepted convention that burning biomass to create energy results in a zero net GHG emissions increase; i.e., the rest of the world considers bioenergy is a low-carbon source of renewable energy, but the Manomet Center report does not.

This report is designed to provide analysis of these and other issues in response to a call for information by the U.S. Environmental Protection Agency. The agency is reconsidering how GHG emissions from biomass combustion should be treated under its regulatory responsibilities for GHG emissions. The policy choice is facilitating use of biomass produced continuously by the carbon cycle to substitute for fossil fuels, or encumber such use and continue to mine fossil fuels while forests are allowed to decay and burn.

The buildup of atmospheric carbon problem is a long-term problem, so a long-term sustainable approach is appropriate; a short-term measurement of stack emissions approach is not. A definitive life-cycle analysis would help identify environmental tradeoffs as policymakers sort through the alternatives for future energy production.

One approach is to have facilities that burn biomass to produce energy report how much biomass they burn, and where the biomass comes from. If it is from mill residues or forest residues (i.e., logging slash or pre-commercial thinnings with no value as wood products feedstocks) then there is no reason to “cap” these emissions as these biomass sources would otherwise release carbon into the atmosphere in the near future anyway.

Introduction

The U.S. Environmental Protection issued a “Call for Information” asking for technical and general comments, as well as data submissions, related to accounting for greenhouse gas (GHG) emissions from bioenergy (EPA 2010a). The request is for relevant information on the underlying science that should inform possible accounting approaches. The EPA invited interested parties to assist the agency by a) surveying and assessing science, and b) evaluating different accounting approaches and options via policy analysis. This report is a synthesis of published research related to an evaluation of accounting approaches, thus attempts to do both.

Each of the policy analysis reports we have produced over the past 20 years have been organized around a set of “focus questions” suggested by the Advisory Committee identified on the inside cover page herein. Then for each report we develop replies to the focus questions via science synthesis. For this report, the focus questions are posed by the EPA’s Call for Information (EPA 2010a), and the replies are developed via science synthesis designed to assist the agency with its task of determining how to account for GHG emissions from burning biomass to produce energy.

This policy analysis report is organized using the nine specific categories of information the EPA solicited. The desired information and viewpoints include, but are not limited, to the numbered topics in the **Table of Contents**. These form the outline of this report. Each numbered section is followed by the exact language in the Call for Information (EPA 2010a), and then a science synthesis. Some of the topics suggested by the EPA are dealt with in more detail than others, and some are not discussed at all. Two topics form the bulk of the report: **2. National-scale carbon neutrality in IPCC guidelines**, and **4. Alternative accounting approaches**.

The latter topic, alternative accounting approaches, is analyzed in considerable detail. It is about determining the net impact on the atmosphere of carbon dioxide (CO₂) emissions associated with bioenergy; and specifically the time interval, including the concept of “carbon debt” and length of time for forest regrowth to “pay back” the carbon emissions from burning biomass to produce energy (Section **4.1**) as well as the appropriate spatial/geographic scale for conducting this determination (Section **4.2**). This information consists primarily of a review of one of the three objectives of the *Biomass Sustainability and Carbon Policy Study* conducted by the Manomet Center for Conservation Sciences for the Massachusetts Department of Energy Resources (MCCS 2010a). In addition, considerable attention is given to **5. Comparison with fossil energy** and especially coal. The wood/coal comparison is also a major feature of the Manomet Center study report.

The discussion begins below with a **Problem Analysis**—such things are the core of a study conducted by members of the Society of Policy Scientists (see SPS 2010). After proceeding through the numbered list of topics of interest to the EPA, some **Conclusions** are drawn. As at the bottom of this page, a graphic element is added to partially fill blank space.



Problem Analysis

The primary issue addressed herein is whether burning biomass for energy should be regulated the same way as fossil fuels. Whether biomass combustion is “carbon neutral” is high on the list of related concerns and is treated in Section 2. By way of introduction to the more specific topics of interest to the EPA, this section provides a brief background on the situation.

According to the Intergovernmental Panel on Climate Change,

Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level. . . . Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases. . . . Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations (IPCC 2007).

There is more carbon dioxide (CO₂) in the atmosphere today than at any time in the past 400,000 years (Rohde 2008, citing four ice core studies and recent atmospheric observations from Mauna Loa Observatory). The CO₂ increase is due primarily to the combustion of long-buried non-circulating fossil fuel carbon. Biomass carbon, by contrast, is part of the carbon cycle and as long as new biomass is regrown, biomass combustion does not result in a significant net increase of atmospheric CO₂ (Palstra and Meijer 2010).

If policymakers set a single-purpose goal to reduce CO₂ emissions, then the source of emissions matters little, as one molecule of CO₂ is exactly like any other. However, in another respect it matters a great deal. Biomass carbon is part of an ongoing recycling process. This gives biomass its renewable energy resource characteristics, and also recognizes the innate ability of plants to absorb CO₂ from the atmosphere.

As a result of the Supreme Court decision in *Massachusetts v. Environmental Protection Agency* (549 U.S. 497 (2007)) the EPA has a responsibility to regulate GHG emissions, which began in December 2009 when the agency declared that GHG emissions were harmful to public health (EPA 2010b). The “tailoring rule” was finalized on May 13, 2010. It is about prioritizing the regulation of emissions sources by trimming smaller sources out of the early process in order to focus on large, stationary sources. Although it is only one step in phasing in GHG regulations, the “tailoring rule” has become shorthand for the Clean Air Act permitting processes that will be the main regulatory tools for limiting GHG emissions. Beginning January 2, 2011, the EPA plans to regulate the GHGs that facilities like coal-fired power plants and oil refineries release into the atmosphere (EPA 2010c).

According to an Associated Press story (Barnard 2010), the biomass power industry, and some members of Congress, are worried that biomass may be treated like fossil fuels. The Biomass Power Association, representing 80 facilities in 20 states that employ 18,000 people, is concerned that the EPA could decide biomass is not “carbon neutral” and therefore must pay a penalty for the carbon released by biomass combustion to produce electricity. The extra cost could eliminate profitability for the industry, along with the jobs, renewable energy and forest benefits that come with it. Association CEO Bob Cleaves said, “The industry would be stopped in its tracks if it is regulated like a coal plant.” The EPA said their GHG accounting approach

has not reversed the agency's position that biomass combustion is carbon neutral, but the agency has begun a process to gather information on the issue and decide whether that position is still justified (Barnard 2010).

Box 1 identifies points that policymakers should keep in front of them while considering what to do about bioenergy emissions.

Box 1

Some Things about Forest Carbon Accounting Policymakers Need to Know

1. Trees and other plants absorb (uptake) CO₂ from the atmosphere.
2. Young trees grow faster and uptake CO₂ more rapidly than old trees.
3. Old trees store more carbon than young trees, simply because they are larger.
4. Trees die and return stored carbon to the atmosphere.
5. Wood products store carbon for some period of time, and many displace concrete and steel products that in manufacturing require large quantities of fossil fuels.
6. Bioenergy is a renewable substitute for fossil fuels that also can help improve forest conditions and provide employment in rural communities.

In 2008, the Massachusetts *Woody Biomass Energy* report stated that "Burning fossil fuels releases 'new' carbon into the atmosphere that has been stored underground for millions of years. Burning biomass releases carbon that was recently absorbed from the atmosphere by a growing plant" (Urquart and Boyce 2008). In 2010, the *Biomass Sustainability and Carbon Policy Study* report conducted by the Manomet Center for Conservation Sciences (MCCS 2010a) for the Massachusetts Department of Energy Resources tried to develop a new way of thinking about wood bioenergy and the carbon cycle by analyzing a single forest stand over a period of decades, which is considerably less than the life of a tree. The Manomet Center's contribution is a biomass carbon "debt-then-dividend" model. Their approach overlooks items 2, 4 and 5 in **Box 1**, and builds a case against item number 6, using wood bioenergy to substitute for fossil fuels because of short-term effects.

The problem of accounting for forest carbon is selecting the appropriate time framework. Wood is produced by a continuous cycling of carbon between terrestrial ecosystems and the atmosphere, and choosing a short time period is problematic. As one reviewer of this report noted, policy for wood bioenergy needs to consider the long term as well as the short (R. Sedjo, review comments; Sedjo 2010). As another reviewer wrote, "The Manomet Center's approach over-complicates a relatively simple truth, which is that a forest can be thought of as a storage device for solar energy. Over a long cycle, the energy can be realized in various ways, such as a forest fire, biological deterioration, or by harvesting the biomass and burning it in a furnace. Regardless, over a long period, the storage device will alternatively store energy and give up energy again and again. When we harvest and burn the biomass, we incur the cost of harvest and transport, but that is the only external energy component to an otherwise natural cycling process" (R. Harris, review comments). In essence, the Commonwealth of Massachusetts had it right in 2008, with the quotation beginning the paragraph immediately above. The Manomet Center's study report is being used to lead the Commonwealth down another path.

1. Treatment of Biomass Under the PSD/BACT

What criteria might be used to consider biomass fuels differently with regard to the Best Available Control Technology (BACT) review process under PSD? How could the process of determining BACT under the PSD program allow for adequate consideration of the impacts and benefits of using biomass fuels? (EPA 2010a)

The EPA is constrained by the Clean Air Act, and during this rulemaking phase (i.e., the “tailoring rule” (EPA 2010b,c), the agency must figure out how to rectify life cycle analysis of wood bioenergy emissions of CO₂ with traditional monitoring as measured by CO₂ out of the stack. Will the EPA incorporate the dividends of biomass harvesting into their approach? If the current regulatory framework will not allow that, it could be changed. If legislative change of the legal framework in which EPA is required to measure carbon, it may be useful to consider requiring use of life cycle analysis at a broad scale that could provide direction to the 10,000,000 private individuals who own forest land. To that end, the agency could endorse or make use of sustainability standards (certification, best management practices, state biomass harvest guidelines) as a way to minimize carbon release from land-use change in which biomass is removed and combusted without adequate planning for forest regeneration.

Furthermore, the crux of the issue with forest carbon accounting is the timeframe in which to do the analysis. This is the major focus of this report (see section **4.1**), and it is hoped that the EPA will carefully consider each of the points in **Box 1** above, all of which argue for a long timeframe, at least as long as the age of trees in the forest, otherwise the carbon cycle from which wood comes from will be ignored in the attempt to regulate emissions from the burning of wood to produce energy. A consistent timeframe and a carefully developed rationale for it are needed.

Similarly, establishment of appropriate and consistent spatial/geographic scales for analysis is needed. The rationale for such recommendations needs careful thought out. One option would be to scale the size of the minimum analysis area to the sustainable production of feedstocks based on the size of the biomass-using facility (see section **4.2**). For example, as a rule of thumb one megawatt of electricity requires approximately 8,000 to 12,000 green tons of biomass; a commonly-used figure is 10,000 green tons of woody biomass (O’Laughlin 2009).

There is general and widespread agreement in the literature, including the Manomet Center study report, that the use of “waste wood” to produce energy is desirable (see review in Section **7**). However, there is a lack of consistency on what might be considered to be waste wood. Mill residues and logging slash would probably find wide acceptance, especially if conditioned by a set of best management practices to leave some forest residues onsite for nutrient cycling, wildlife habitat, or to meet other objectives. Perhaps the most disagreement will arise over the thinning of whole trees to change stand conditions to improve tree growth or reduce hazardous fuels.

(Acknowledgment to D. Becker, review comments, for the above ideas.)

2. National-Scale Carbon Neutrality in IPCC Guidelines

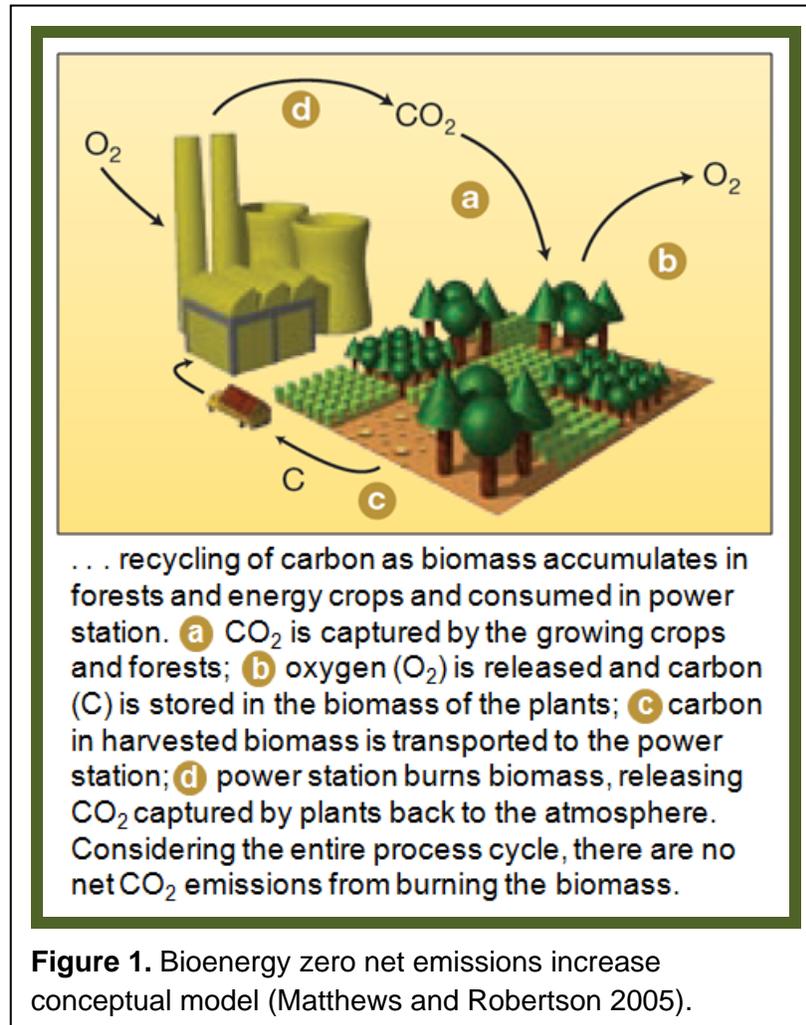
According to the Intergovernmental Panel on Climate Change (IPCC) Guidelines, CO₂ emissions from biomass combustion “. . . should not be included in national CO₂ emissions from fuel combustion. If energy use, or any other factor, is causing a long term decline in the total carbon embodied in standing biomass (e.g. forests), this net release of carbon should be evident in the calculation of CO₂ emissions described in the Land Use Change and Forestry (LUCF) chapter.” (IPCC 1996, Vol. 3, p. 1.10)

In the IPCC accounting approach described above, at the national scale emissions from combustion for bioenergy are included in the LUCF Sector rather than the Energy Sector. To what extent does this approach suggest that biomass consumption for energy is “neutral” with respect to net fluxes of CO₂? (EPA 2010a)

Concerns about atmospheric carbon dioxide (CO₂) bring attention to forestry’s role in carbon management. Current discussions revolve around the international accounting system in which greenhouse gas (GHG) emissions from biomass combustion are considered as zero in the energy sector to avoid double counting. Activities that change land-use or the amount of biomass in existing stocks are to be tallied in a land-use account. Both the U.S. Department of Energy (USDOE), through the U.S. Energy Information Administration (EIA), and the Environmental Protection Agency (EPA) currently report CO₂ emissions from combustion of biomass for bioenergy as information items. The EPA is reconsidering its previous stance that biomass combustion for energy is “carbon neutral”—a catch phrase for zero net GHG emissions increase. Concepts needing consideration are forests’ ability to reduce CO₂ already in the atmosphere, inevitable tree mortality and return of carbon to the atmosphere, and life-cycle analysis of wood products substitution for fossil fuel-intensive products as well as bioenergy substitution for fossil fuel energy.

A fuel that results in a zero net GHG emissions increase is often referred to as “carbon neutral.” In the case of biomass this term is misleading because collecting, transporting and processing biomass into energy consumes some fossil fuels. For each unit of fossil fuel used, somewhere between 20 and 50 units of bioenergy are produced (Matthews and Robertson 2005, citing five sources; Jones et al. 2010). Rather than “carbon neutral” it is more accurate to say that biomass can be a low-carbon source of renewable energy. The GHG emissions from transportation would be reported in that sector in order to avoid double counting.

The question whether burning biomass for energy is “carbon neutral” is currently being debated, with parties offering different interpretations of what the term might mean and then what they think it should mean. As indicated by quotations in the USDOE section below, “carbon neutral” is actually a catch phrase for zero net CO₂ emissions increase from biomass combustion. **Figure 1** offers perhaps the clearest explanation of the concept (Matthews and Robertson 2005). In addition, this conceptual model of carbon recycling through biomass energy utilization illustrates that a large land area is necessary to support a facility. At any given time the vegetation characteristics of different land management units will vary, as blocks of forest land will have different age classes. This is a key issue and discussed in Section **4.4**.



The combustion of woody biomass for energy production is not strictly “carbon neutral” because the harvesting, transporting and processing of woody biomass into thermal energy to heat buildings, dry lumber, or make electricity involves some expenditure of fossil fuels. Recent research in Montana’s Bitterroot Valley showed that for every unit of fossil fuel consumed in woody biomass processing to heat schools and other public buildings, 21 units of bioenergy were generated (Jones et al. 2010). Other research has shown returns on the order of 25 to 50 units of bioenergy for each unit of fossil fuel energy (Matthews and Robertson 2005, citing 5 studies). Forest bioenergy is not “*carbon neutral*” but can be a *low-carbon* source of renewable energy. Other than that, one can say that burning biomass produces CO₂ but it was CO₂ previously removed from the atmosphere as part of the carbon cycle, and if the vegetation is sustainably managed, it will again uptake the released CO₂.

Policy analysis for bioenergy should keep indirect emissions from land-use change separate from direct emissions from fuel combustion (Lynch and von Lampe 2010). This is consistent with the IPCC guidelines for GHG accounting whereby there is one account for Energy and another for Land-Use Change and Forestry (LUCF). Emissions from combustion of biomass are assumed to be zero, but emissions resulting from land-use change to produce bioenergy feedstocks are to be detailed in the LUCF account. Accounting for human-induced changes in

all forest carbon and wood product pools may be difficult, and some accounting and measurement issues remain unresolved (Birdsey et al. 2006).

2.1. International Policy

The United Nations Framework Convention on Climate Change (UNFCCC) and its IPCC has taken the position since 1996 that CO₂ emissions from the combustion of biomass for energy are reported as zero in the account for Energy (**Box 2**). Indirect net CO₂ emissions from land management to support a bioenergy operation are to be reported in an account for Land Use. The IPCC also recognizes the term “carbon neutral” and that it does not hold because some fossil fuels will be used in the transport and processing of biomass to energy (**Box 2**).

Box 2

Two Frequently Asked Questions about Biomass Greenhouse Gas Emissions

Q: How can we calculate the change in emissions from burning biomass residues for energy instead of using fossil fuels?

A: The IPCC methodologies are intended to estimate national, anthropogenic emissions and removals rather than life cycle emissions and removals. However the IPCC Guidelines can be used, with care for different purposes. For calculating emissions from substitutions, all the changes in emissions and removals must be accounted for.

Q: Can we consider CO₂ produced by biomass burning for energy to be “CO₂ neutral” or “carbon neutral”?

A: Biomass burning for energy cannot be automatically considered carbon neutral even if the biomass is harvested sustainably, there still may be significant emissions from processing and transportation etc. of the biomass. While CO₂ emissions from biomass burnt for energy are reported as zero in the Energy Sector, the net CO₂ emissions are covered in the Land Use Sector.

Source: IPCC website (undated)

2.2. National Policy

According to U.S. climate scientists, “biomass fuels are considered carbon neutral because return of the biomass carbon to the atmosphere completes a cycle that began with carbon uptake from the atmosphere by vegetation” (CSSP 2007, p. 88). The stance of the federal agencies towards the carbon-neutral question of biomass burning is uncertain at this time. Until recently, both the USDOE and the EPA took a stance that emissions from combustion of biomass for energy were zero or “carbon neutral” because biomass is part of the natural carbon cycle.

2.2.1. U.S. Environmental Protection Agency (EPA). Until recently, the EPA agreed that because biomass is part of the natural carbon cycle, emissions from biomass combustion added zero net emissions increase to the atmosphere. At this writing the agency is reconsidering this as part of the “tailoring rule” for commencing the regulation of GHG emissions from large stationary sources such as power plants beginning in January 2011 (EPA 2010c). The EPA may or may not decide to treat biomass combustion emissions the same as fossil fuel emissions.

The recently stated stance of the EPA (2010c) is: “Although the burning of biomass produces carbon dioxide, the primary greenhouse gas, it is considered to be part of the natural carbon cycle of the earth. The plants take up carbon dioxide from the air while they are growing and then return it to the air when they are burned, thereby causing no net increase.”

In another document: “CO₂ emissions from the combustion or decomposition of biogenic materials (e.g., paper, wood products, and yard trimmings) grown on a sustainable basis are considered to mimic the closed loop of the natural carbon cycle – that is, they return to the atmosphere CO₂ that was originally removed by photosynthesis” (EPA 2010d, p. 8-5)

The “carbon neutrality” of biomass burning is undergoing reexamination through the EPA’s “tailoring rule” for Prevention of Significant Deterioration and Title V GHG emissions permit regulations under the Clean Air Act (EPA 2010c). This has triggered letters of protest as well as support from interest groups, and a call from the EPA for new information (EPA 2010a). After evaluating such information, including this report, the agency will decide if biomass emissions should continue to be treated differently than fossil fuel emissions.

2.2.2. U.S. Department of Energy (USDOE). The Oak Ridge National Laboratory is part of USDOE and maintains a website that says, “Burning biomass efficiently results in little or no net emission of carbon dioxide to the atmosphere, since the bioenergy crop plants actually took up an equal amount of carbon dioxide from the air when they grew.” (ORNL undated)

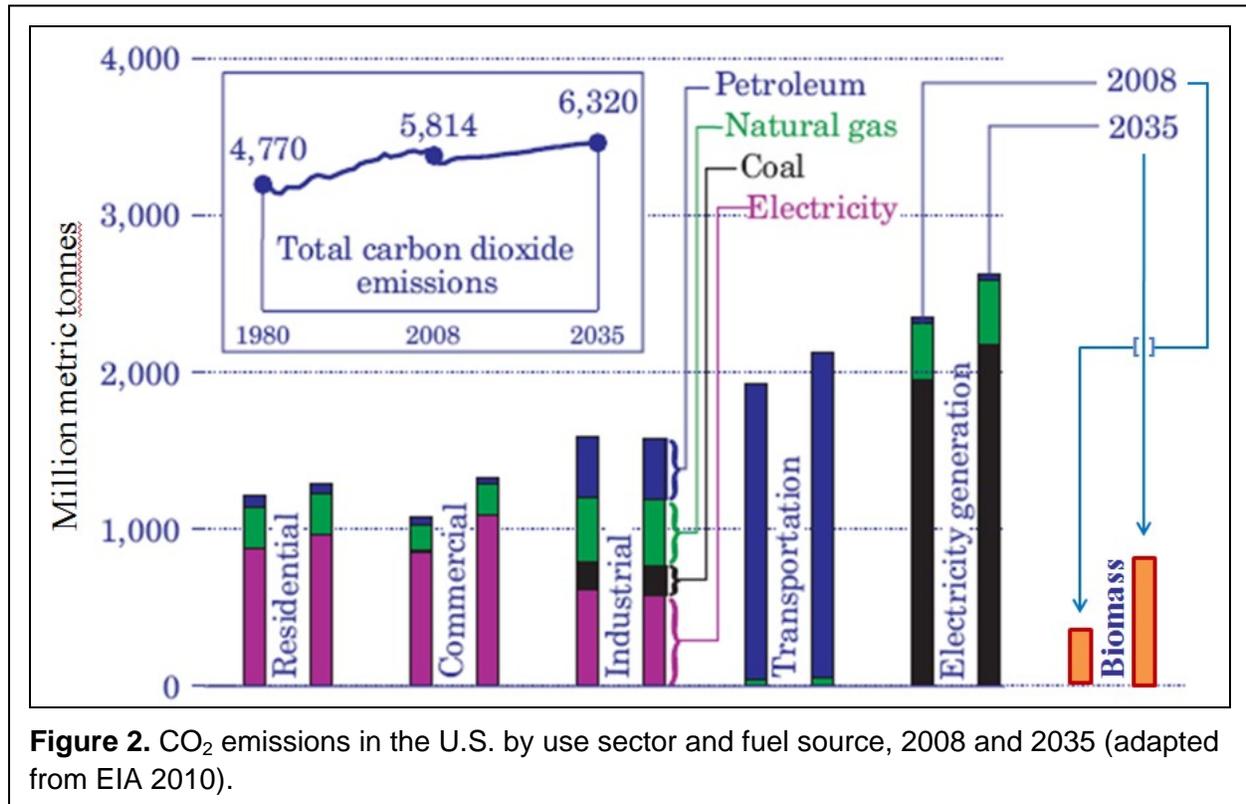
The U.S. Energy Information Administration, a part of USDOE, provides independent statistics and analysis related to energy use. The EIA (2010b) says CO₂ emissions from combusting biomass to produce energy are excluded from the energy-related CO₂ emissions, following current international convention of the IPCC. The agency reports CO₂ emissions from fossil fuels by use sector and fuel type. Biomass is an additional 6% of the total CO₂ emissions for 2008, and is projected to be almost 13% in 2035 (EIA 2010a). If in fact these emissions are all offset by biological sequestration, the net emissions would be zero as assumed in EIA’s totals (EIA 2010b).

The EIA (2010b, pp. 47-48) adds a caution regarding its biomass accounting approach:

This indirect accounting of CO₂ emissions from biomass can potentially lead to confusion in accounting for and understanding the flow of CO₂ emissions within energy and non-energy systems. In recognition of this issue, reporting of CO₂ emissions from biomass combustion alongside other energy-related CO₂ emissions offers an alternative accounting treatment. It is important, however, to avoid misinterpreting emissions from fossil energy and biomass energy sources as necessarily additive. Instead, the combined total of direct CO₂ emissions from biomass and energy-related CO₂ emissions implicitly assumes that none of the carbon emitted was previously or subsequently reabsorbed in terrestrial sinks or that other emissions sources offset any such sequestration.

Figure 2 illustrates what the EIA bar chart graphic would look like if biomass emissions were portrayed alongside fossil fuel emissions. The EIA treats emissions from burning biomass for energy differently than fossil fuel emissions and recognizes this as a key issue to focus on (EIA 2010b). In the future, EIA plans to report CO₂ emissions from biomass combustion alongside

other energy-related CO₂ emissions, but to exclude them from the total unless their inclusion is dictated by regulation (EIA 2010b).



2.3. State Policies—Massachusetts

Renewable portfolio standards (RPS) are policies that 36 states have adopted that require various changes in energy sources (DSIRE 2010). An RPS can increase pressure on utilities to consider biopower. Massachusetts is one such state, and its 2008 report on *Woody Biomass Energy* drew a distinction between fossil fuel emissions and biogenic emissions: “Burning fossil fuels releases ‘new’ carbon into the atmosphere that has been stored underground for millions of years. Burning biomass releases carbon that was recently absorbed from the atmosphere by a growing plant” (Urquart and Boyce 2008).

This is consistent with the zero net emissions increase viewpoint of the USDOE in Section 2.2.2 above. In addition, “Wood combustion recycles carbon that was already in the natural carbon cycle, the net effect being that no new CO₂ is added to the atmosphere as long as the forests from which the wood came are sustainably managed” (BERC 2010b). This is a noteworthy statement because two BERC staff members were on the Manomet Center study team. Despite their presence, the study report misinterpreted what “carbon neutral” actually means: “Policies encouraging the development of forest biomass energy have generally adopted a view of biomass as a carbon neutral energy source because the carbon emissions were considered part of a natural cycle in which growing forests over time would re-capture the carbon emitted by wood-burning energy facilities” (MCCS 2010a, p. 6). To the contrary, the USDOE, BERC and others take a position that biomass combustion results in zero net GHG emissions increase because no new carbon is added to the atmosphere, not because after some period of time forests will recapture CO₂. The latter statement is true, but is not the full story.

2.3.1. Discussion of Manomet Center's Carbon Policy Study conclusions. The Executive Summary of the Manomet Center study report makes two key points about the atmospheric GHG implications of shifting energy production from fossil fuels to biomass: 1) the "carbon neutral" issue of zero net emissions increase from burning biomass to create energy needs to be rethought, and 2) the biomass carbon "debt-then-dividend" model is a way to rethink the idea of accounting for GHG emissions from biomass combustion in the energy sector. Each point is discussed below, beginning with quotations from the report, followed by quotations from a statement by the Biomass Energy Resource Center (BERC 2010a). The BERC statements are included for clarification and because two BERC staff members served on the Manomet Center study team. A third section focuses on policy implications.

2.3.2. The Manomet Center on the "carbon neutral" issue. The Manomet Center study report concluded that "At the state, national, and international level, policies encouraging the development of forest biomass energy have generally adopted a view of biomass as a *carbon neutral* energy source because the carbon emissions were considered part of a natural cycle in which growing forests over time would re-capture the carbon emitted by wood-burning energy facilities. Beginning in the 1990s, however, researchers began conducting studies that reflect a more complex understanding of carbon cycle implications of biomass combustion. Our study, which is based on a comprehensive lifecycle carbon accounting framework, explores this more complex picture in the context of biomass energy development in Massachusetts" (MCCS 2010a, p. 6, italics in original).

To clarify, "It is not accurate to simply consider biomass energy 'carbon neutral.' The carbon implications and/or benefits of biomass energy depend entirely on several factors, including: where the wood comes from, applied forest management practices, how harvesting and management are distributed over the landscape and over time, and the types of technology used. The study clarifies that, when biomass is sustainably harvested and forest lands are well managed overtime, biomass can be a source of low carbon energy, especially when compared to fossil fuels" (BERC 2010a).

The Manomet Center study report misinterpreted what "carbon neutral" actually means with a statement that "... policies encouraging the development of forest biomass energy have generally adopted a view of biomass as a carbon neutral energy source because the carbon emissions were considered part of a natural cycle in which growing forests over time would re-capture the carbon emitted by wood-burning energy facilities" (MCCS 2010a, p. 6). To the contrary, the USDOE and EPA consider emissions from biomass to be zero because biomass combustion does not add new carbon to the atmosphere, not because after some period of time forests will recapture CO₂. Although that is true, it is only part of the story.



2.4. Conclusions

Whether biomass energy is “carbon neutral” remains an unsettled question that science can inform, but will be determined as a matter of policy. If the EPA decides to make the sole objective of carbon management policy one of reducing atmospheric CO₂ emissions at the source, then where the CO₂ came from would not matter, and biomass emissions would be treated like fossil fuels. If this is the policy approach the EPA decides to take, this will limit some of the eight ways Ryan et al. (2010) identified by which forests can help reduce GHG already in the atmosphere.

Furthermore, those studies all strongly support the use of waste materials as bioenergy feedstocks, and so does the Manomet Center study report. However, the study report mentions this as an afterthought and the analysis in the report focuses on whole-tree harvesting for bioenergy production.



3. Smaller-Scale Accounting Approaches

The Clear Air Act (CAA) provisions typically apply at the unit, process, or facility scale, whereas the IPCC Guidance on accounting for GHG emissions from bioenergy sources was written to be applicable at the national scale. EPA is interested in understanding the strengths and limitations of applying the national-scale IPCC approach to assess the net impact (i.e., accounting for both emissions and sequestration) on the atmosphere of GHG emissions from specific biogenic sources, facilities, fuels, or practices. To what extent is the accounting procedure in the IPCC Guidelines applicable or sufficient for such specific assessments? (EPA 2010a)

Bioenergy can provide much energy and help meet greenhouse caps, but correct accounting must provide the right incentives.

— Searchinger et al. (2009, p. 528)

Accounting is a bookkeeping exercise; incentives are a policy tool. Proper accounting helps inform policy makers. An effective forest carbon accounting system at the national level would identify the greenhouse gas (GHG) emissions from burning biomass to produce energy. Both the U.S. Department of Energy (USDOE) and the Environmental Protection Agency (EPA) currently do this. Keeping forest lands in forests provides opportunities for society to obtain the multiple forest benefits people desire. Some analysts warn that renewable energy incentives could encourage forest clearing and land conversion to biofuel crops (Fargione et al. 2008, Searchinger et al. 2008). Such incentives arise not from a GHG emissions accounting system but from policies that promote some types of renewable energy and discourage others. It is preferable that accounting methods facilitate the monitoring of policy outcomes irrespective of policy goals and means of attaining them.

Renewable energy policies need to address two key questions posed by Birdsey et al. (2006): 1) how to maintain forests as carbon sinks over the long term, and 2) how to optimize the production of forest biofuels and biomaterials that help reduce demand for fossil energy. The carbon sequestration potential of forests sets woody biomass apart from being considered as if GHG emissions from burning biomass for energy are the same as burning fossil fuels for energy. The USDOE is aware of the concerns raised by analysts, most notably the *Science* article by Searchinger et al. (2009), and proposes the system already in place that identifies biomass GHG emissions but does not lump them in with fossil fuel emissions (EIA 2010b). This accounting system does not create incentives for forest landowners to convert forests to biofuel crops, but other public policies could do so and should be considered separately from GHG emissions accounting policy. A life-cycle inventory analysis of various energy sources is needed. Kharecha et al. (2010) have synthesized such an analysis for electricity generation; findings are cited throughout this article.

The conclusion is that the USDOE has the forest carbon accounting issue in focus, and the preferred principle for accounting for biomass burning is, in USDOE's words, as follows:

The release of carbon from biomass combustion is assumed to be balanced by the uptake of carbon when the feedstock is grown, resulting in zero net emissions over some period of time. This is not to say that biomass energy is carbon-neutral. Energy inputs are required in order to grow, fertilize, and harvest the feedstock and to produce and process the biomass into fuels (EIA 2010b, p. 46).

The energy input/output relationship is that for each unit of fossil fuel used to harvest, transport and process biomass feedstocks into bioenergy, 20 to 50 units of bioenergy are produced (Matthews and Robertson 2005, citing five sources; Jones et al. 2010).

The USDOE is already keeping separate accounts for GHG emissions from biomass burning at the national level. The agency states that it will keep this accounting separately and not lumped in with fossil fuel emissions unless forced to by regulation (EIA 2010). The policy issue is whether biomass combustion emissions will be regulated the same way as fossil fuel burning emissions. The outcome of the issue will depend on how the carbon cycle is viewed: Is the carbon cycle a continuous process from which combusted biomass is assumed to have come from and will return to? Alternatively, does it make sense to break the carbon cycle into discrete time segments that can be regulated, and what role will certification of sustainable resource management play in such a scheme?

One approach the EPA could consider is to have facilities that burn biomass to produce energy report how much biomass they burn, and where the biomass comes from. If it is from mill residues or forest residues (i.e., logging slash or pre-commercial thinnings with no value as wood products feedstocks) then there is no reason to “cap” these emissions as these biomass sources would otherwise release carbon into the atmosphere in the near future anyway.



4. Alternative Accounting Approaches

Both a default assumption of carbon neutrality and a default assumption that the greenhouse gas impact of bioenergy is equivalent to that of fossil fuels may be insufficient because they oversimplify a complex issue. If this is the case, what alternative approaches or additional analytical tools are available for determining the net impact on the atmosphere of CO₂ emissions associated with bioenergy? Please comment specifically on how these approaches address:

- The time interval required for production and consumption of biological feedstocks and bioenergy products. For example, the concept of “carbon debt” has been proposed as the length of time required for a regrowing forest to “pay back” the carbon emitted to the atmosphere when biomass is burned for energy.
- The appropriate spatial/geographic scale for conducting this determination. For example, the question of spatial scale has legal complications under the CAA, but may be relevant for some of the suggested approaches. (EPA 2010a)

Many states are working out ways to use forests as a renewable energy resource. The Commonwealth of Massachusetts commissioned the Manomet Center for Conservation Sciences to research and publish the *Biomass Sustainability and Carbon Policy Study* (MCCS 2010a). When the study report was released on June 10, 2010, it was accompanied by a press release from the Manomet Center explaining the study and its results (MCCS 2010b) and another from a state office that said: “Electricity from biomass compares unfavorably with coal” (MEOEEA 2010). An Associated Press story on the same day bore the provocative headline: “Mass. Study: Wood power worse polluter than coal” (LeBlanc 2010). After its report became a lightning rod for controversy, the Manomet Center issued another press release on June 21 disavowing this headline (MCCS 2010c), and so did the Biomass Energy Resource Center (BERC 2010a), which is significant because two BERC staff members served on the Manomet Center study team.

The heart of the Manomet Center study report is the biomass carbon “debt-then-dividend” conceptual model, explained in Section 4.1. The study report analyzed three questions being asked as Massachusetts develops policies for forest biomass use. The first question is the focal point of this review: “What are the atmospheric GHG implications of shifting energy production from fossil fuel sources to forest biomass?” The other two questions are more specific to forest management policy in Massachusetts (see MCCS 2010a, p. 6) and are not reviewed herein.

4.1. Time Interval for Accounting Purposes

Time present and time past
Are both perhaps present in time future,
And time future contained in time past.

— T.S. Eliot (1935, *Four Quartets. Burnt Norton, I*)

The net carbon effects of harvesting wood for bioenergy use depend on how emissions are valued over time (Searchinger et al. 2009). What period of time is appropriate to conduct analysis of such effects? The carbon cycle takes place over the entire earth and is a continuous process. According to the *State of the Carbon Cycle Report* prepared for the U.S. Climate Change Science Program, “Biomass fuels are considered carbon neutral because return of the biomass

carbon to the atmosphere completes a cycle that began with carbon uptake from the atmosphere by vegetation” (CSSP 2007, p. 88, boxed pull-quote). Isolating discrete time periods, as in the Manomet Center study report, is problematic.

The choice of the time period and area over which forest carbon pool accounts are being tallied is the crux of the current debate. Some analysts, including the Manomet Center study team, use a small land area and short time period – “short” meaning less than the life-span of a tree – in what then amounts to partial analyses that are unsatisfactory to support either a forest carbon accounting system or forest carbon management policy.

4.1.1. Biomass carbon “debt-then-dividend” model. The EPA (2010a) has called for information on the “carbon debt” accounting concept. A number of studies have demonstrated that land-use change can “make footprints highly carbon positive” (Johnson 2009), meaning that clearing forests to cultivate biofuel crops may result in a “carbon debt” by releasing more CO₂ than the annual greenhouse gas (GHG) reductions that these biofuels would provide by displacing fossil fuels (Fargione et al. 2008, Searchinger et al. 2008). The Manomet Center study report (MCCS 2010a) cited these two articles to underpin its “carbon debt-then-dividend” concept, even though land-use change from forests to agricultural crops is not being proposed in Massachusetts. The change there is from a “business as usual” timber harvesting practice to increasing timber removals for hypothetical whole-tree processing into biopower feedstocks.

A key finding of the Manomet Center study report concerns timing. Over the next forty years, electricity produced from burning biomass would result in a 3 percent increase in carbon emissions compared to burning coal (MCCS 2010a). The Center says, “Using wood for energy can lead to lower atmospheric greenhouse gas levels than fossil fuels, but only after the point in time when the carbon debt is paid off” (MCCS 2010b). More precisely, “the use of sustainably harvested biomass to . . . make electricity takes about 42 years to begin to create a net dividend compared to coal” (BERC 2010a).

To comprehend the Manomet Center study report’s findings, it is necessary to understand how the study team arrived at its conclusions. The novel biomass carbon “debt-then-dividend” model is fundamental to this task.

4.1.2. Explanation with revised graphics. Several studies have demonstrated that land-use change can “make footprints highly carbon positive” (Johnson 2009), including two in *Science* expressing concern that clearing forests to cultivate biofuel crops may result in a “carbon debt” by releasing more carbon dioxide (CO₂) than the annual greenhouse gas (GHG) reductions that these biofuels would provide by displacing fossil fuels (Fargione et al. 2008, Searchinger et al. 2008). The Manomet Center study report cited these two articles to underpin the biomass carbon “debt” portion of the model, even though land-use change from forests to biofuel crops is not being proposed in Massachusetts. Instead the report focuses on a change in forest management from a “business as usual” timber harvesting practice to increasing forest removals via whole-tree harvesting for biopower feedstocks.

According to the Manomet Center,

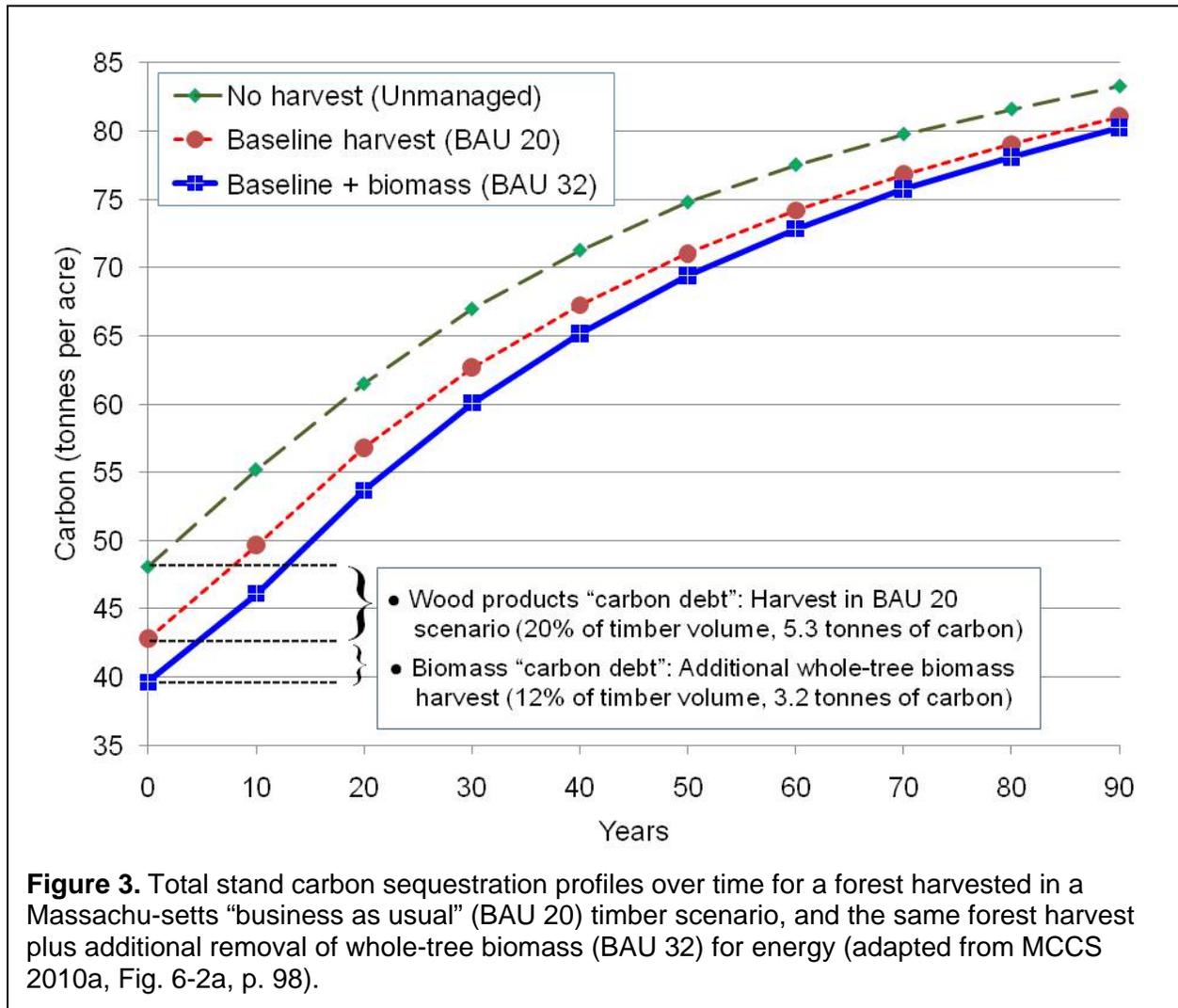
The most innovative and policy-relevant finding in the report is the ‘debt-then-dividend’ model that shows using forest biomass for energy can increase GHGs for a period of time before it reduces them (MCCS 2010b). Forest biomass

generally emits more GHGs than fossil fuels per unit of energy produced. We define these excess emissions as the biomass *carbon debt*. 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. The full recovery of the biomass *carbon debt* and the magnitude of the *carbon dividend* benefits also depend on future forest management actions and natural disturbance events allowing that recovery to occur (MCCS 2010a, p. 6, emphasis in original).

The “debt-then-dividend” conceptual model consists of two parts. Each is explained below and illustrated with revised graphics that use the whole-tree biomass harvest data developed for Massachusetts in the Manomet Center study report. The report itself used hypothetical data to develop the graphic illustrations that were used to explain the model. This not only made the presentation more confusing than it need have been, it substantially overstated the carbon “debt” relative to burning coal or wood to generate electricity.



4.1.3. Biomass carbon "debt" from whole-tree bioenergy harvest The first part of the model (**Figure 3**) is determining the "biomass carbon debt." The baseline for this is the "business as usual" (BAU) timber harvest scenario in Massachusetts in which 20 percent of the timber volume is removed periodically, every 70-100 years. This baseline BAU 20 harvest removes 5.3 metric tonnes per acre (tpa) of total stand carbon, reducing it from 48.1 to 42.8 tpa at the time of harvest (time zero).

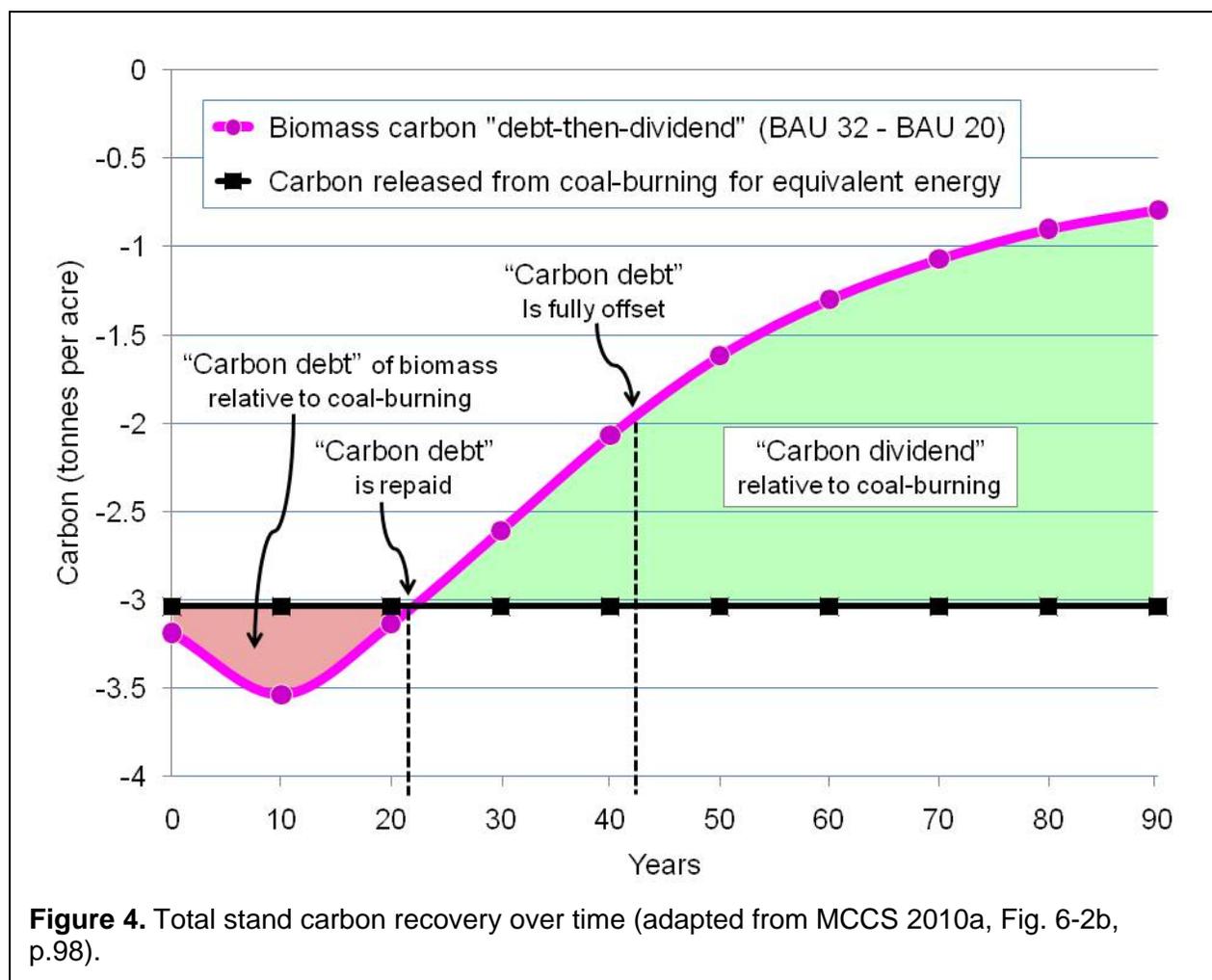


The BAU 32 harvest removes an additional 12 percent of timber volume as a whole-tree biomass harvest for energy production, removing an additional 3.2 tpa of stand carbon at time zero. Subtracting the stand carbon volume remaining after the BAU 20 harvest from that remaining after the BAU 32 harvest results in a negative number (−3.19 tpa) identified as the "biomass carbon debt" from harvesting additional whole-tree biomass to be used for energy production in comparison to the baseline BAU 20 harvest.

The stand carbon change of −5.3 tpa from harvesting timber in the BAU 20 scenario creates a wood products "carbon debt" that is not part of the analysis, but should be. Evaluating the use of biomass for energy needs to consider the full spectrum of impacts (Kharecha et al. 2010), including carbon stored in wood products that if ignored can lead to invalid conclusions

(Lippke et al. 2010) primarily due to avoided GHG emissions from using wood products instead of energy-intensive products such as concrete and steel (Perez-Garcia et al. 2005, Ryan et al. 2010; see Section 4.3).

4.1.4. "Debt" relative to fossil fuels, repayment and "dividend." The second part of the model (Figure 4) only works if CO₂ emissions from biomass combustion exceed CO₂ emissions from fossil fuel combustion for an equivalent amount of energy produced. The model is constructed by placing the previously determined "biomass carbon debt" (-3.19 tpa) on the vertical axis. This is the starting point for carbon recapture associated with tree regrowth. Above that point is a horizontal line at -3.04 tonnes indicating the amount of carbon released from an equivalent amount of energy from burning coal. This is calculated from data in the report in which combustion of biomass produces 5 percent more emissions than coal (MCCS 2010a, Appendix 2-B, p. 129).



The "biomass carbon debt" relative to fossil fuel (-0.15 tpa at time zero) is the difference between the carbon released from burning coal (-3.04 tonnes) and the "biomass carbon debt" (-3.19 tpa) from harvested biomass. The "debt-then-dividend" curve illustrates how the "debt" is repaid as over time trees recapture CO₂. At 21 years from now the "debt-then-dividend" curve crosses the coal emissions line. At this point the "debt" is repaid and the "dividend" begins and continues to accumulate from the annual increment of tree growth. According to the

Manomet Center study report, the “cumulative dividend” net of “debt” remains negative until about 42 years. At that point in time the report says biomass replacement of coal “fully offsets the carbon debt and lowers GHG levels compared to what would have been the case if [coal] had been used over the same period” (MCCS 2010a, p. 7). The report does not explain how the study team analysts determined that 42 years is when “full offset” happens.

4.1.5. Critique: Discrete modeling of continuous process is problematic. The carbon “debt-then-dividend” conceptual model is not an easy thing to grasp, due in part to inappropriate choice of time and space scales. In essence, the model takes the continuous process of carbon cycling over the entire earth and reduces it to one stand of trees over a discrete period of time that is relatively short (40-90 years) considering the life of a tree. As the scientists who recently synthesized forest carbon science put it in their report published by Ecological Society of America, “Management actions should be examined for large areas and long time periods” (Ryan et al. 2010, p. 4). The time and space issues are identified below, with further explanation of the time scale issue in the remainder of Section 4.1 and the spatial scale in Section 4.2.

4.1.6. Time scale issue. The Manomet Center’s press release issued with the report stated that “using forest biomass for energy can increase GHGs for a period of time before it reduces them” (MCCS 2010b). The press release defined “debt” and “dividend” and then attempted to explain the time scale effect more clearly. The Manomet Center said, “After the carbon debt is paid off, if the forest continues to grow, a carbon dividend is realized and the use of wood for energy then becomes increasingly beneficial for GHG mitigation” (MCCS 2010b). What does this statement imply for using wood for energy today? Manomet Center President John M. Hagan responded to *Boston Globe* journalist Beth Daley: “Do you want to wait 10, 20, 30 years just to get to the point (wood-burning) is as good as coal? That is a real social question. Do we as a society want to make the climate worse before it gets better?” (Daley 2010). The Manomet Center study report leaves it to policymakers to address such questions. They in turn might want to ask: How on earth can coal-burning be better than wood-burning today and wood be better than coal in the future?

4.1.7. When does the carbon cycle begin and end? For GHG emissions accounting purposes the choice of when the carbon cycle begins and ends is the crux of the issue, and one of the keys to determining whether a “biomass carbon debt” exists. There are three viewpoints in the literature regarding carbon cycle timing and biomass combustion emissions accounting. These are described in the next three bulleted paragraphs, then a conclusion is drawn.

■ **Zero net emissions for all biomass.** The position of the USDOE is that combustion of biomass from sustainable sources produces zero net emissions because it releases carbon that previously was stored in the atmosphere and then transferred to vegetation through photosynthesis and CO₂ uptake before its release (EIA 2010, ORNL undated). According to a current EPA website, “Although the burning of biomass produces carbon dioxide, the primary greenhouse gas, it is considered to be part of the natural carbon cycle of the earth. The plants take up carbon dioxide from the air while they are growing and then return it to the air when they are burned, thereby causing no net increase” (EPA 2010d). The carbon cycle is a continuous process, with photosynthesis, respiration, and plant growth, death, and regrowth constantly moving carbon between terrestrial ecosystems and the atmosphere:

The cycling of carbon from the atmosphere to organic compounds and back again not only involves life but also involves the atmosphere. The carbon cycle describes the pathway that carbon takes as it is transferred from plant to animal to atmosphere to ocean and so on. There is no start or end point (USDOE 2004).

- **Zero net emissions for some biomass.** An emerging viewpoint in Europe is that annual crops grown for bioenergy purposes have zero net emissions increase because the vegetation grows back relatively quickly. For woody biomass, forest residues used for bioenergy immediately improve GHG emissions; so does wood from land converted from low carbon stocks to plantations, but these sources are not “carbon neutral” (Zanchi et al. 2010).
- **“Carbon debt” for all biomass.** The Manomet Center study report takes a standpoint that a “biomass carbon debt” exists for any reduction of existing forest carbon stock pools resulting from bioenergy combustion, including forest residues. This “debt” is not recovered or paid back until such time as forest growth recaptures the carbon released by biomass combustion.
- **Conclusion.** Carbon cycling between terrestrial ecosystems and the atmosphere occurs continuously over the entire earth. The choice of a discrete time period within which to begin and end counting carbon stocks and flows is the crux of the issue. Selecting the time a forest is harvested to begin counting carbon is arbitrary. It could just as easily begin when the trees were born rather than when they die.

4.1.8. Critique: Conclusions from the biomass carbon “debt-then-dividend” model. The Manomet Center study report concluded that “Forest biomass generally emits more greenhouse gases than fossil fuels per unit of energy produced. We define these excess emissions as the biomass *carbon debt*. Over time, however, re-growth of the harvested forest removes this carbon from the atmosphere, reducing the carbon debt. 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 (Figure 4 [as modified herein]).” (MCCS 2010a, p. 6, emphasis in original).

Furthermore, “The time needed to pay off the carbon debt and begin accruing the benefits of biomass energy . . . for biomass replacement of coal-fired electric capacity begins at approximately 20 years . . . [and] the net cumulative emissions in 2050 are approximately equal to what they would have been burning coal.” (MCCS 2010a, p. 7).

To clarify, “There is a carbon ‘debt’ when biomass is burned for energy, i.e., burning carbon often releases more carbon at the time of combustion than an equivalent amount of fossil fuel and it takes a certain amount of time (specific to both the type of fuel used and the energy technology) to ‘recover’ that debt by re-sequestering that additional carbon. Beyond this point, the continued sequestration of carbon makes the combustion of biomass carbon-beneficial as compared to fossil fuels. . . . The use of biomass to make electricity takes about 42 years to begin to create a net dividend compared to coal, but with a positive carbon dividend of 19 percent by the year 2100” (BERC 2010a).

The BERC quotation above refers to a biomass carbon “debt” relative to fossil fuels. The Manomet Center study report has two different ways of looking at the biomass carbon “debt.” First, there is a debt from forest management practices that remove biomass for energy production, but not for timber production. This is inconsistent and inappropriate as a basis for

an accounting system. The BEREC clarifying communication is referring to the second type of carbon “debt” from biomass removal, which is derived by comparison to using fossil fuel to produce the same amount of energy.

4.1.9. Conclusions. The choice of the time period and area over which forest carbon pool accounts are being tallied is the crux of the current debate. Some analysts, including the Manomet Center study team, use a small land area and short time period – “short” meaning less than the life-span of a tree – in what then amounts to a partial analysis that is unsatisfactory to support either a forest carbon accounting system or forest carbon management policy. The studies cited in the study report that are said to “reflect a more complex understanding of carbon cycle implications of biomass combustion” are focused on the issue of clearing native forests for production of biofuel crops. This is not what is happening in Massachusetts. One reviewer of this report (R. Sedjo) has written that, “If forest biomass is also used to substitute for fossil fuel energy, U.S. forests can reduce the total carbon emissions of the entire energy system released into the atmosphere by both sequestering carbon and permanently reducing fossil fuel use. Thus, the relevant unit for analysis is the forest system, not a single site” (Sedjo 2010).

The Manomet Center quotations are first based on the idea that carbon released from the forest is a “debt” that must be repaid and offset by forest regrowth. This rejects the net zero emissions increase standpoint that many analysts, USDOE and BEREC among them, have accepted. Second, if combustion of the removed forest biomass produces more emissions than burning fossil fuels to attain the same amount of heat energy, a biomass “debt” relative to fossil fuel is created. Manomet Center President John M. Hagan has stated that society may be worse off by burning biomass until such time as the “debt” has been repaid by sequestering the released carbon, at which time a “dividend” from biomass burning begins, and after some time the cumulative dividend will reach a point where biomass burning is better than fossil fuels because of the net cumulative dividend (Daley 2010, MCCS 2010a). This is an overly complicated way of saying that as long as the woody biomass used to produce bioenergy comes from a sustainably managed source, biomass combustion today is better for the atmosphere than burning fossil fuels.

The basic idea presented in the Manomet Center study report is that the carbon released by biomass combustion must be recaptured before bioenergy can be considered beneficial for the atmosphere, and over time wood bioenergy will become increasingly beneficial. This stretches time like a rubber band from now into the future, but not from now into the past, as if the past does not matter. Given the continuous nature of the carbon cycle, this approach is not only arbitrary, but also makes the decisions about energy sources that are alternatives to fossil fuels more perplexing than they need to be. In addition, fossil fuels generate a debt that is never repaid nor expected to be repaid.

To sum up, the conclusion quoted above from the study report takes a viewpoint that carbon cycle analysis should begin at the present time, and does not recognize that the combusted biomass is part of a continuous cycle. The opposite point-of-view is stated succinctly by the Biomass Energy Resource Center on its website, current as of this writing: “Wood combustion recycles carbon that was already in the natural carbon cycle, the net effect being that no new CO₂ is added to the atmosphere as long as the forests from which the wood came are sustainably managed” (BERC 2010b).

4.2. Appropriate Spatial/Geographic Scale for Accounting Purposes

The “debt-then-dividend” model focuses on what happens in only one forest stand. In the real world a wood-based facility needs continual wood supplies between now and that point in the future when the “debt” from today’s use of wood from one small area has been recaptured by tree growth. Because of continuous supply needs, the “debt-then-dividend” scenario plays on continuously over a large area of land, and the carbon “dividend” some other areas are accruing today is repaying the carbon “debt” from harvesting created today. If the forest is sustainably managed, which by definition is long-term management (SAF 2008a), then carbon balance is maintained. Demonstration of sustainable forest management therefore may suffice to demonstrate that renewable energy production will not create a “carbon debt” from land-use change. Adherence to best management practices is a way to do that. If a landowner is also interested in obtaining payment for carbon credits, certification of sustainability is a necessary expense.

4.2.1. Stand-level instead of landscape-level analysis. Forestry for at least twenty years has been transitioning from sustained yield to sustainable forest management. In addition to planning with a perpetual time horizon and consideration of a full range of ecosystem services, foresters now emphasize the importance of spatial scale. As a practical matter that means thinking through the implications of how actions taken in the stand being managed will affect adjacent stands. In some respects the Manomet Center study report abandons this approach and only considers what happens in one stand, with no consideration for the surrounding area. Rejecting such an approach in a study by others, the rationale in the Manomet Center study report for stand-level management is that

[The] landscape approach to carbon neutrality is incomplete because it does not fully frame the issue with respect to the carbon sequestration attributes of the forested landscape in a “business as usual” scenario. In general, the carbon accounting model should be premised on some knowledge of how lands will be managed in the future absent biomass harvests, and this becomes a critical reference point for analyzing whether burning biomass for energy results in increased or decreased cumulative GHG emissions over time (MCCS 2010a, p. 99).

This explanation in the study report unsatisfactorily rationalizes the chosen spatial scale with a temporal scale explanation in the future. What about today? There are effects on the landscape from adjacent stands that are not captured by modeling one stand. Although the use of stand-level instead of landscape-level modeling helps simplify our understanding of carbon dynamics, this approach does not consider the spatial dimension of forest management involved in supporting industrial facilities, whether for wood products manufacturing or bioenergy production.

4.2.2. Why landscape-level analysis? Stand-level analysis is not capable of considering that harvests are scheduled over large areas and long time periods. In effect, other forest areas that have already been cut and are regrowing, as well as areas with established forests that will be cut in the future, help sustain resource supplies and maintain carbon balance in a mill woodshed at any given point in time.

Figure 1 illustrates the biomass zero net emissions increase concept. It works because while one area is harvested and biomass combustion emits carbon, many other areas simultaneously are

absorbing carbon from the atmosphere. This graphic depicts a variety of forest age classes intermingled with biomass energy crops. Although in one sense this is more complicated than the current situation in the U.S., where economics of biomass energy are such that dedicated biomass energy crops are not yet viable, in another sense it is oversimplified because it does not illustrate the U.S. situation in which biomass for energy production is a waste material from the manufacturing of wood products. **Figure 5** better depicts the flow of carbon on U.S. forest lands, but fails to capture the spatial extent of forests needed to sustain a wood-based facility.

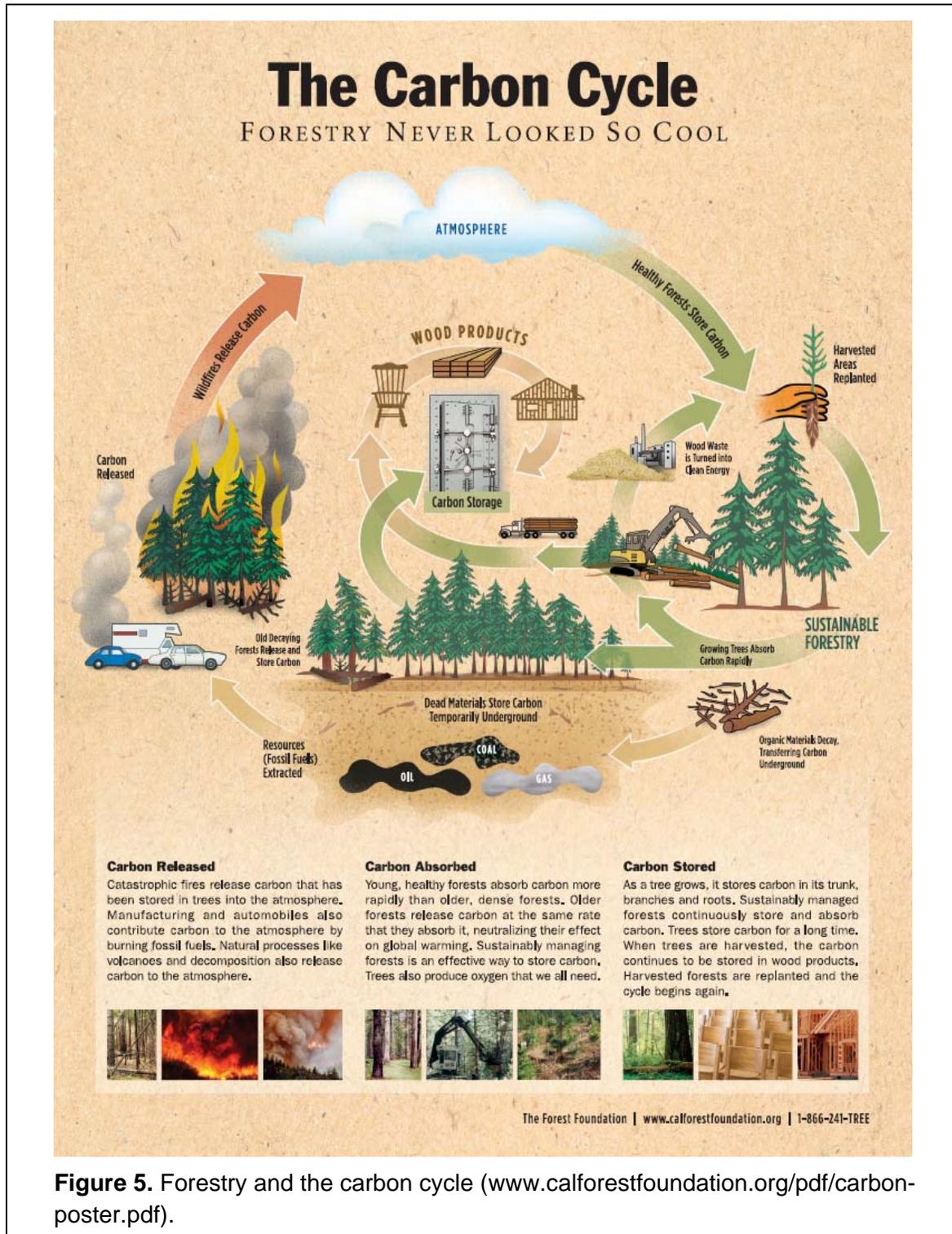
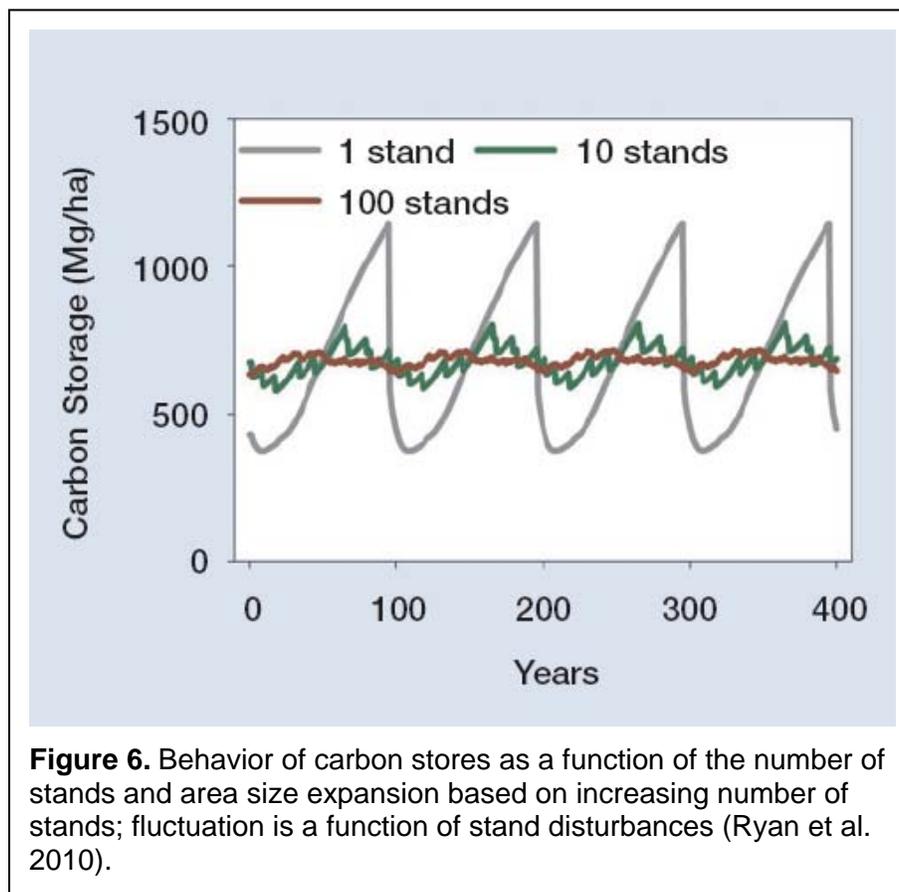


Figure 5. Forestry and the carbon cycle (www.calforestfoundation.org/pdf/carbon-poster.pdf).

Figure 6 furthers understanding of the spatial scale issue and illustrates why the Manomet Center's stand-level approach is inappropriate. The science synthesis report by the Ecological Society of America explains:

Management actions should be examined for large areas and long time periods. . . . Forests are biological systems that continually gain and lose carbon via processes such as photosynthesis, respiration, and combustion; whether forests show a net gain or loss of carbon depends on the balance of these processes. The observation that carbon is lost from forests has led to the notion that carbon cannot be permanently stored in forests. However, this view ignores the inevitable increase and eventual recovery of carbon that follows most disturbances. Thus over time, a single forest will vary dramatically in its ability to store carbon; however, when considering many different forests over a large area or landscape, such 'boom and bust' cycles may not be apparent because the landscape is composed of forest stands that are in different stages of recovery from disturbance or harvesting (Ryan et al. 2010).



4.3. Life Cycle Analysis

Life-cycle inventory analyses reveal that the lumber, wood panels, and other forest products used in construction store more carbon, emit less GHGs, and use less fossil energy than steel, concrete, brick, or vinyl, whose manufacture is energy intensive and produces substantial emissions (Malmsheimer et al. 2008). **Figure 7** depicts a synthesized electricity life-cycle analysis comparing fossil fuel GHG emissions with biomass and other renewables (Kharecha et al. 2010, citing ten sources). It shows biomass (in tree plantations) produces less CO₂ per unit of electricity than all other renewables except wind, and considerably less than fossil fuels, especially coal.

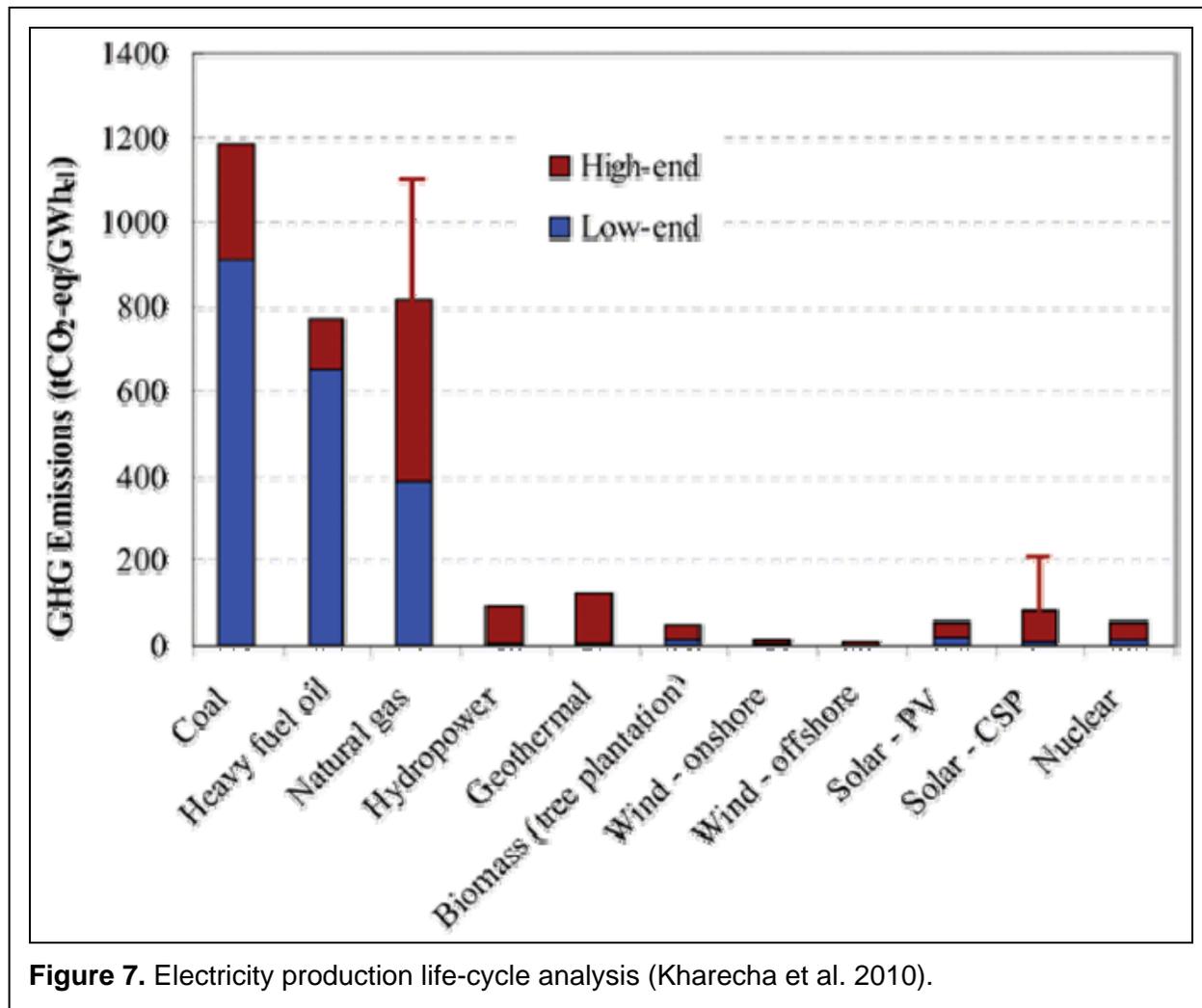


Figure 7. Electricity production life-cycle analysis (Kharecha et al. 2010).

In a footnote to **Figure 7** in the source article, Kharecha et al. (2010) cite Fargione et al. (2008) and Searchinger et al. (2008), and add a similar cautionary note to their life-cycle analysis: “Improperly designed biomass-based approaches could result in much higher emissions than shown here” (Kharecha et al. 2010). What a properly-designed approach to ensuring the sustainability of biopower feedstocks would be is debatable, but it is a debate worth having.

Because biomass has the ability to capture and store carbon dioxide from the atmosphere, “Biomass power offers an important option other renewables do not: the potential to

incorporate carbon capture and storage (CCS), thereby making biomass power substantially carbon-negative” (Kharecha et al. 2010). Life-cycle inventory accounting is necessary to reveal such opportunities.

4.3.1. Wood products carbon pool and avoided fossil fuel emissions. Wood products as a carbon pool represent about 2 percent of all carbon pool stocks in the U.S., and about 10 percent of carbon flux (Woodbury et al. 2007). Focusing on some forest-related carbon pools but omitting the carbon in wood products frequently results in invalid conclusions; comparison of various building materials shows that wood is more environmentally friendly than concrete and steel because of permanent avoidance of emissions from fossil fuel-intensive products (Lippke et al. 2010). Alternative strategies for wood products can increase carbon stocks, the amount depending on several factors: how long carbon is retained in use, how much wood is used for bioenergy, and substitution of wood for other materials that use more energy to produce (Birdsey et al. 2007). The contributions of the forestry and timber sector to mitigate climate change can be optimized when harvested wood is used as long-lived structural materials, with “waste wood” residues used to generate energy (Werner et al. 2010).

The Manomet Center study report purposely does not account for the wood products carbon pool: “Typically wood products would also be included as an important carbon pool but because we assume these products are produced in the same quantities in both the BAU 20 forest management and BAU 32 biomass scenarios, there would be no net change and thus there is not reason to track them explicitly” (MCCS 2010a, p. 96). As Kharecha et al. (2010) state, “. . . it is crucial to consider the full spectrum of climate as well as ecological and socioeconomic impacts in evaluating the use of biomass.”

By ignoring the wood products carbon pool, the Manomet Center study report overlooks the substitution of wood products for concrete or steel and the avoided fossil fuel emissions involved in their production. The science synthesis report by the Ecological Society of America explains why this is important:

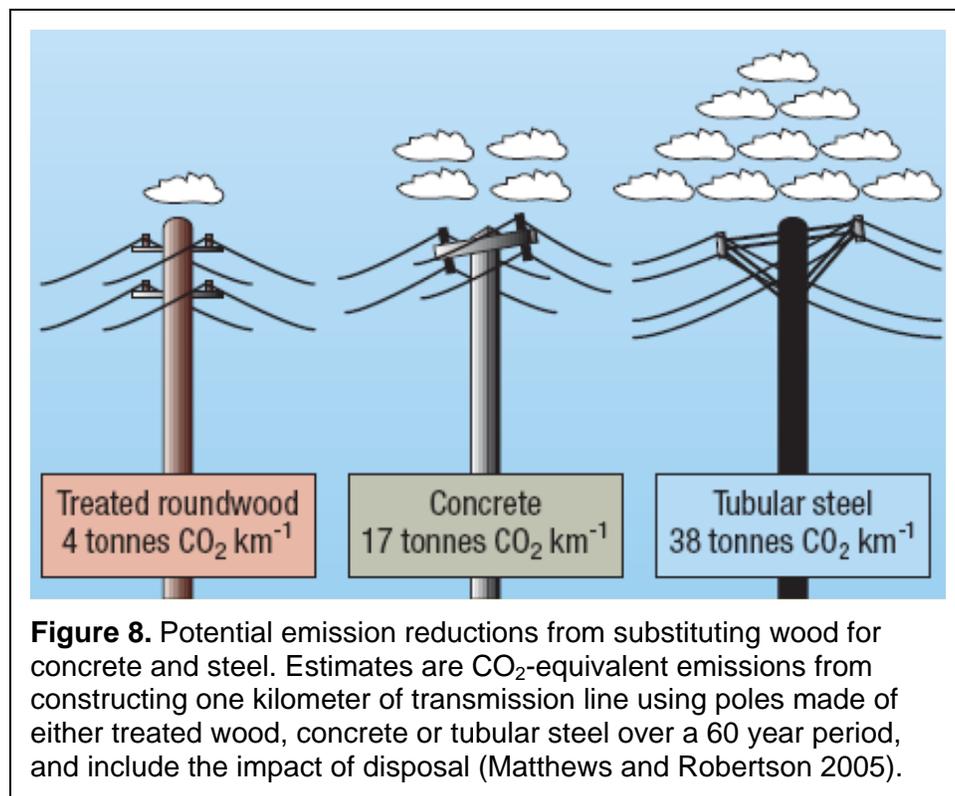
“Carbon emissions can be offset by substituting wood products for products such as steel and concrete, which generate more GHG emissions in their production. A review of studies suggests that if wood products containing one unit of carbon were used in buildings as a substitute for steel or concrete, fossil fuel emissions from manufacturing would be reduced by two units or more” (Ryan et al. 2010).

A displacement factor of two units of carbon emission reductions for every unit of wood used to replace concrete or steel is an average middle estimate derived from a range of product substitutions and analytical methods (Sathre and O’Connor 2008). It means that for each tonne of carbon in wood products substituted for non-wood products, a GHG emission reduction of approximately two tonnes of carbon can be expected. This value corresponds to roughly 3.7 tonnes of equivalent CO₂ emission reductions per tonne of dry wood used. For comparison, when wood is used as a bioenergy feedstock to replace fossil fuel instead of being used as a building material or other durable product, the displacement factor will range from less than 0.5 up to about 1.0, depending largely on the type of fossil fuel replaced and the relative combustion efficiencies (Sathre and O’Connor 2008).

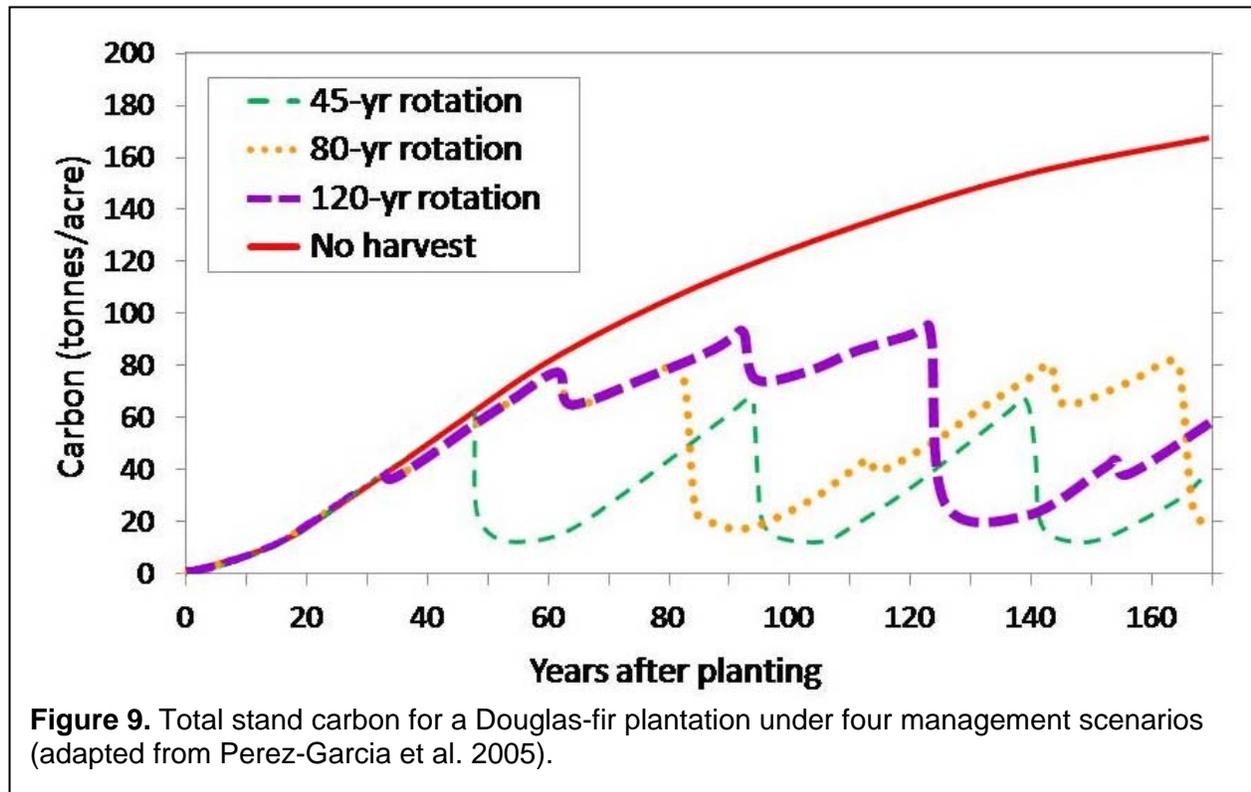
Because wood is a renewable and relatively energy-efficient source of material, using wood in place of more energy-intensive materials can reduce CO₂ emissions (GBFC 2010). For example,

an everyday kitchen spoon can be made from either wood, stainless steel or plastic. A wooden spoon requires about one-thirtieth of the energy needed to make a steel or plastic spoon. The associated GHG emissions from manufacturing are also lower. Making kitchen spoons out of wood rather than steel or plastic would cut GHG emissions by up to 95% per spoon. This illustrates the well known product substitution principle. There have been a number of life-cycle analysis case studies into the environmental impacts of building construction suggesting that where it is practical to do so, increasing the use of wood in place of other materials could cut GHG emissions by between 40% and 80% per building, depending on the type of building (GBFC 2010).

Figure 8 illustrates the products substitution benefit for wood replacing concrete utility poles is a four-fold reduction in GHG emissions, and a nine-fold reduction by replacing steel poles. Applying these findings, if all utility poles in the U.S. were made of steel instead of wood there would be an additional 163 million metric tonnes of CO₂ in the atmosphere. This is equivalent to about 2.8 percent of total U.S. emissions in one year (Sedjo 2002).



4.3.2. Forest management implications. This section presents two interrelated figures demonstrating the forest management as well as GHG emissions implications of the carbon stored in wood products that substitutes for concrete and steel and thereby avoids fossil fuel emissions (**Figure 9** and **Figure 10**). The solid red line in **Figure 9** is a no-harvest or unmanaged scenario for newly planted Douglas-fir on an average site in the State of Washington. It is comparable to the same line in **Figure 3** for Massachusetts.

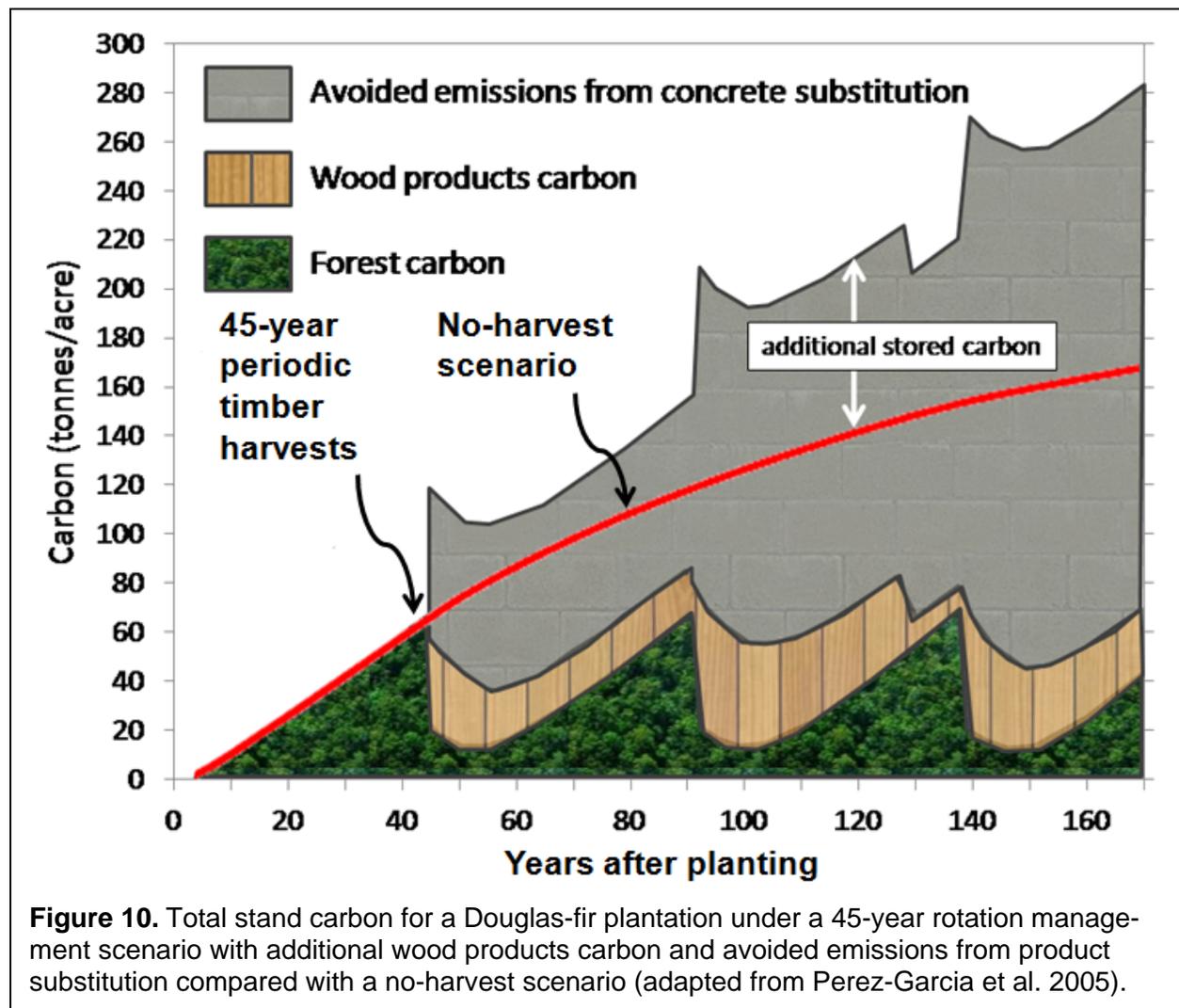


As **Figure 9** illustrates, there are several management scenarios ranging from no-harvest to a stand-replacement or clearcut harvest every 45 years, or 80 or 120 years with intermediate stand-improvement thinnings. It is evident that any scenario removing substantial amounts of timber will not allow the stand to attain the same amount of stored carbon as the no-harvest unmanaged stand, but this ignores the wood products carbon pool and avoided emissions from product substitution. The reason timber is harvested is for the manufacture of wood products. Wood building products can replace concrete or steel, both of which consume large amounts of fossil fuel energy in their production. Wood by contrast is created from solar energy. Although wood products do consume some fossil fuels during the process of collecting, transporting and processing wood from the forest into useful consumer products, from the standpoints of energy efficiency and GHG emissions wood products are superior to concrete and steel.

It is evident from **Figure 9** that harvest of timber creates a stand carbon “debt” compared to the no-harvest unmanaged scenario; this is the area under the solid red line and above any of the three broken lines that represent different timber harvest scenarios. Two reviewers of an earlier draft noted that the age-class distribution of the forest is critically important. The growth of a forest is not constant. While young forests grow rapidly and hence sequester substantial carbon, mature forests experience little net growth and therefore sequester little additional carbon. If the material from the mature forest is used as biomass and the mature forests are replaced by

dynamic young forests, the forest system can be managed to maximize its total capture of carbon. When partial harvest occurs, remaining trees respond with increased growth (R. Sedjo and J. Altemus, review comments).

Figure 10 builds upon **Figure 9** and demonstrates a life-cycle approach that includes two off-site effects overlooked by the Manomet Center study report: carbon stored in wood products and avoided emissions from substituting wood products for concrete or steel. The GHG implications of two forest management options are compared. One is a no-harvest scenario depicted by the solid red line, which is the same as **Figure 9** and represents forest carbon stored in the no-harvest scenario. The other is a stand of newly-planted Douglas-fir harvested in the 45th year to produce lumber, and every 45 years thereafter.



In **Figure 10**, approximately half of the wood in the raw timber product ends up stored in wood products. In this example lumber substitutes for above-grade concrete block walls in residential construction. When wood products carbon pools and avoided emissions from displacing fossil fuel energy are considered, the 45-year timber harvest rotation is a better carbon management choice than the no harvesting alternative when viewed only from a GHG emissions perspective. When avoided emissions are considered the 45-year rotation is superior to the other options

(**Figure 9**) as well as the no-harvest scenario (Perez-Garcia et al. 2005). The Manomet Center study report cited this work and recognized that when forest carbon is counted, a no-harvest scenario will store more carbon than the harvest scenarios depicted in **Figure 9**. However, the off-site effects were not considered, and the additional stored carbon from fossil fuels that remain underground is substantial (**Figure 10**).

Figure 10 may be used to illustrate the Manomet Center study report's error in not accounting for wood products carbon. According to the study report, wood combustion results in a "biomass carbon debt" of 5 percent in relation to coal (see Section 2.1.2 above). It is evident from **Figure 10** that at any time after 45 years the "debt" would be immediately "repaid" from the benefit of the additional stored carbon from product substitution resulting in avoided GHG emissions. This area above the solid red line at any point after 45 years would be substantially greater than 5 percent of the carbon stored in the unmanaged forest (i.e., the avoided "biomass carbon debt" by not harvesting trees). For example, at 65 years the benefit is at its lowest point, and is approximately 15 percent more than the stored forest carbon in the unmanaged forest, enough to completely repay the biomass carbon "debt" from harvesting trees immediately and begin to create a biomass "dividend" relative to fossil fuels.

4.3.3. Conclusions. This analysis illustrates why "... it is crucial to consider the full spectrum of climate as well as ecological and socioeconomic impacts in evaluating the use of biomass" (Kharecha et al. 2010). The Manomet Center study report results are flawed with a crucial failure of not considering wood products carbon storage and the avoided GHG emissions from product substitution that results from additional stored carbon. This is especially egregious because the study report cited the work by Perez-Garcia et al. (2005) from which **Figure 9** and **Figure 10** were derived.

To repeat the key point of this analysis, fossil fuels remain underground when wood products are substituted for concrete, steel or other materials that consume large amounts of fossil fuel in their production. As Marland and Schlamadinger (1997) stated the situation, when wood products substitute efficiently for fossil fuel energy-intensive products, such as concrete, a sequence of sustainable harvests produces greater net carbon benefits than does protection of standing forests. This benefit increases rapidly with increasing productivity. Carbon storage is very sensitive to the forest growth rate and to the efficiency with which wood products substitute for alternative products or fuels. When wood products are not used efficiently as substitutes, the greater carbon benefit is achieved through reforestation and protection of standing forests, and efforts to increase the rate of stand growth yield little gain (Marland and Schlamadinger 1997).

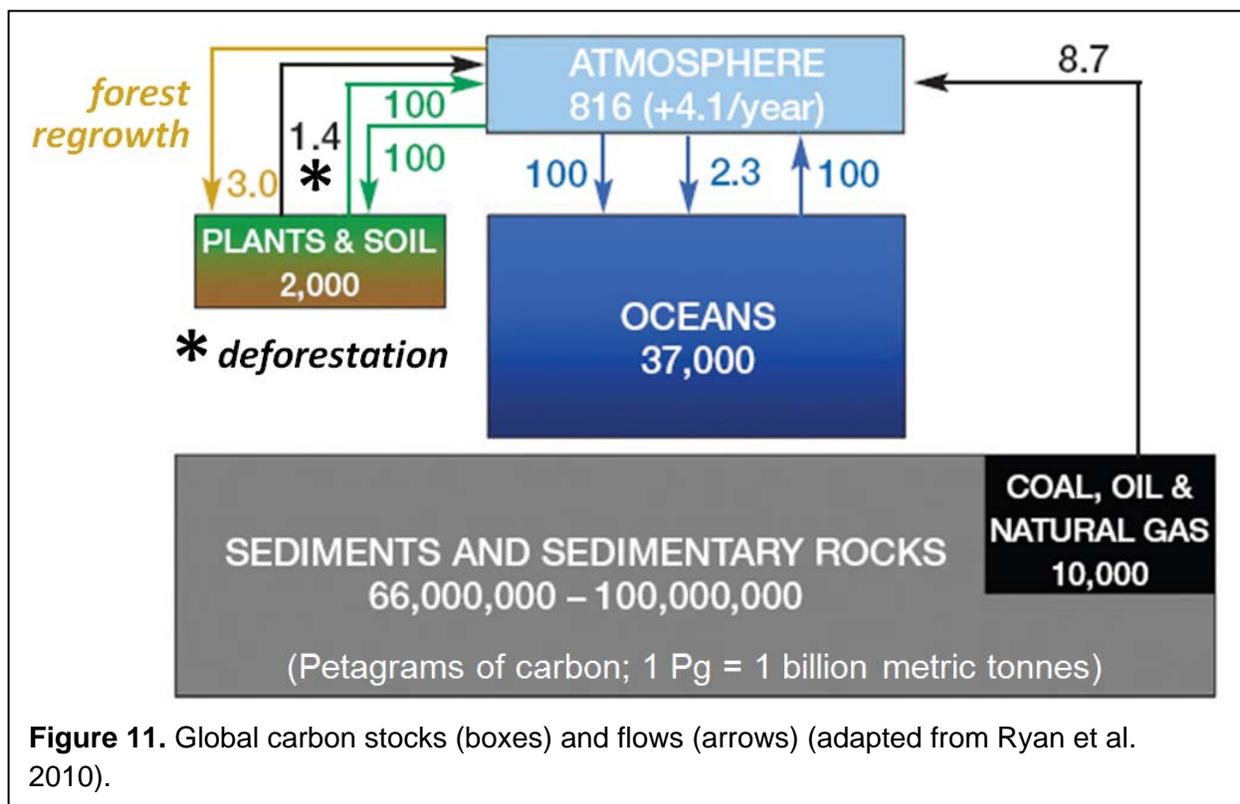
Using woody biomass as fuel may also be part of a carbon sequestration strategy and depends on site-specific parameters and the technical factors of energy substitution to help determine whether harvesting woody biomass for fossil fuel substitution should be preferred to on-site carbon sequestration strategies (Marland and Schlamadinger 1997). A comparison of wood and coal as fuel for electricity generation is provided in Section 5, and further discussion of and support for **Figure 9** and **Figure 10** is provided elsewhere (O'Laughlin 2008).

4.4. Forestry's Role in Carbon Management

The interconnected nature of energy production and the carbon cycle provides the appropriate context for considering forest carbon accounting methods. Forests are part of the carbon cycle,

in which carbon moves between land, sea and air. Forests can function as a “sink” for carbon as the trees absorb or “uptake” CO₂ from the atmosphere. Fire releases CO₂ back into the atmosphere and so does tree death from other causes and subsequent wood decay. Neither technology nor policy will alter that fact. Inevitable tree mortality therefore should be part of forest carbon accounting deliberations, but some analysts avoid it by selecting too-short time horizons, as if trees live and store carbon forever. If dead or harvested vegetation is replaced, then the net balance of carbon uptake and emissions in terrestrial ecosystems is zero. Using wood for manufactured products and the residual “waste wood” as energy feedstocks replaces what will happen in nature anyway: Trees die and return carbon to the atmosphere. The standpoint of many foresters is that a harvest of trees is the beginning of the next forest. This is different than the way most people view timber harvesting.

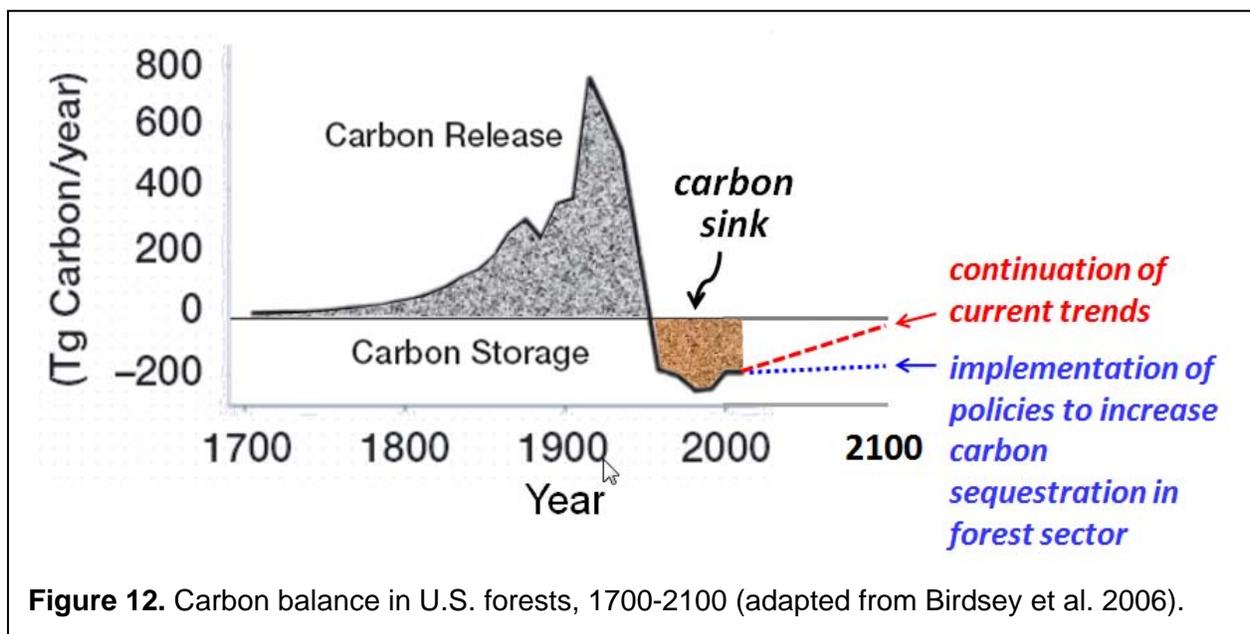
4.4.1. Carbon stocks and flows. Worldwide, fossil fuel combustion releases to the atmosphere at least 6 times more CO₂ than deforestation (**Figure 11**). For the record, deforestation means conversion of forest to some other land use, and this is not much of an issue in North America. It is evident from this diagram of carbon stocks and flows that terrestrial ecosystems store more than twice as much carbon as the atmosphere. The carbon cycling between the atmosphere and terrestrial ecosystems is roughly in balance. Forest regrowth is responsible for the uptake of twice as much CO₂ as that released from deforestation. Forest management obviously plays a large role in the global carbon balance.



More than three-fourths of the terrestrial biomass consists of forests (EPA 2009), and approximately half the weight of a tree is carbon (Ryan et al. 2010). It may be possible to sequester additional carbon in forests, helping manage the atmospheric concentration of CO₂ by employing various forestry activities that can increase sequestration, reduce emissions, or both;

and particularly situations in which improved carbon management is compatible with other goals such as restoration of degraded forests or timber production (Birdsey et al. 2006). Some forests will be best managed as carbon sinks, and others for multiple products, including durable wood products that store carbon for a period of time, and bioenergy that substitutes for fossil fuel burning (Bauen et al. 2009). Sink forests will be those of low productivity or with characteristics that make biodiversity or wilderness and other aesthetic considerations the dominant-use objective for management.

4.4.2. Are U.S. forests a net source or sink? Forests in the U.S. have been functioning as a sink since the post-World War II era began, but before that functioned as a net GHG emissions source (**Figure 12**). With a continuation of current policies, forests are heading towards becoming a net source in about a century (Birdsey et al. 2006). According to the U.S. Dept. of Agriculture's GHG emissions inventory, forests in eight states function as net sources of emissions rather than sinks: Arizona, Connecticut, Idaho, Maryland, Michigan, Minnesota, Tennessee, and Vermont (USDA 2008).



Debate about “carbon neutrality” should bring attention to the two options portrayed in **Figure 12** and promote policy discussion aimed at managing forests to reduce atmospheric CO₂ rather than increase it. In such deliberations, as in dealing with alternative fuels, “. . . it is crucial to consider the full spectrum of climate as well as ecological and socioeconomic impacts in evaluating the use of biomass” (Kharecha et al. 2010). That means life-cycle analysis.

4.4.3. Conclusions. Management of multiple-product forests can help maintain and improve the overall carbon balance. Five types of carbon reservoirs are preferable to storing carbon in the atmosphere, and four of them involve forestry: new forestry plantations, new timber structures and other durable wood products, underground wood burial, biochar storage in soil reservoirs with co-produced bio-oil, and carbon capture and storage in deep geological strata or other locations (Read 2009).

A report from the IEA Bioenergy group frames the forest management question as whether a forest should be managed for multiple wood products utilization (including bioenergy) or as a sink. The sink option's lock-in feature is a disadvantage, and time-scale matters: "A short timeframe (a few decades) tends to favor the sink option, while a longer timeframe favors the bioenergy option. The reason is that the accumulation of carbon in forests and soils cannot continue endlessly—the forest eventually matures and reaches a steady state condition" (Bauen et al. 2009). And then, inevitably, trees die and release carbon to the atmosphere. With adequate management attention the forest can be regrown, and as that happens trees uptake CO₂. A question worth asking is, How can forest management help reduce atmospheric CO₂? The EPA and resource management agencies should be focused on developing a consistent and logical rationale. In some respects this question is more important than the "carbon neutral" question, because forests can help reduce the amount of CO₂ already in the atmosphere. Five forestry strategies can affect climate change. In order of their relative importance these are 1) reduce stand-replacing fires; 2) keep forestlands in forests; 3) afforestation and reforestation; 4) use wood products as substitutes for fossil fuel-intensive products; and 5) forest management and rotation length (Cloughesy 2006). Any effort to significantly reduce wildfires will generate large volumes of biomass and require the development of an additional workforce (USFS 2005).

A science synthesis report on forests and carbon by the Ecological Society of America identified eight strategies for managing forests to enhance their role in carbon management. Avoiding deforestation is at the top of the list. Biomass energy and use of wood products in place of concrete or steel are two viable strategies (Ryan et al. 2010). According to the scientists who wrote the forestry chapter in IPCC report on climate change mitigation strategies, "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, fibre or energy from the forest, will generate the largest sustained mitigation benefit" (Nabuurs et al. 2007, p. 543).

4.5. Conclusion: A Comprehensive Approach to Biomass Emissions Accounting

The "carbon debt-then-dividend" conceptual model used in the Manomet Center study report is problematic for four reasons:

- 1) the choice of today as the beginning time frame for carbon cycling instead of in the past when the existing forest began to uptake atmospheric CO₂;
- 2) use of stand-level instead of the landscape-level modeling—"management actions should be examined for large areas and long time periods" (Ryan et al. 2010, p. 4);
- 3) failing to use a life-cycle approach that includes emissions from transporting energy feedstocks; and
- 4) failing to include the carbon sequestered in wood products that result from the timber harvest "business as usual" scenario, and the avoided fossil fuel emissions from substitution for concrete and steel products in the analysis.

Whether it is worth trying to fix these problems with the "carbon debt-then-dividend" model as presented in the Manomet Center study report is a question worth asking, but only if the EPA decision regarding biomass emissions is that they must be counted at the stack. This in itself is problematic.

Researchers and governments generally accept that land-use change must be accounted in bioenergy footprints, and Johnson (2009) suggests that carbon accounting use a “carbon-stock change” line item. This provides for accounts that are more consistent with common sense, UNFCCC aims, and the “Marland branch” (e.g., Marland and Schlamadinger 1997) of existing literature (Johnson 2009). Carbon-stock change seems to be the approach that the USDOE and EPA have already taken.

Searchinger et al. (2009, p. 528) noted that “In theory, the accounting system would work if caps covered all land-use emissions and sinks. However, this approach is both technically and politically challenging as it is extremely hard to measure all land-use emissions or to distinguish human and natural causes of many emissions (e.g., fires).” Their proposed solution is not to track land-use change but instead “counting emissions from tailpipes and smokestacks whether from fossil energy or bioenergy” (Searchinger et al. 2009, p. 528). Although it is possible to separate out the two sources of carbon emissions at the pipe or stack by measuring carbon isotopes (Palstra and Meijer 2010), this approach may not be cost effective or particularly policy-relevant in the electric power generation sector.

With respect to bioenergy feedstocks, Kharecha et al. (2010) stated that “. . . a sound approach uses biomass waste products or low-input/high-diversity perennial plants grown on degraded or marginal lands.” This is consistent with strongly expressed support from Fargione et al. (2008) and Searchinger et al. (2008) for using waste materials as bioenergy feedstocks. Combustion of “waste wood” does not deplete the forest carbon stock, but agreement on what might be considered waste wood is lacking (Johnson 2009). The U.S. biopower industry uses sawmill and pulpmill waste products almost exclusively, and logging residues would likely qualify as waste wood as long as adequate material is left onsite to recycle nutrients.

It may be practical to have bioenergy facility operators document fuel source purchases. Similar to sustainable forest management certification protocols, something like a chain-of-custody approach tracing biomass to its source may be workable. Many wood-processing firms have adopted sustainability as a principle, including chain-of-custody certification (AF&PA 2010a). Another approach would be to develop a list of criteria indicating what “sustainable” bioenergy resources might be, such as specific definitions of waste wood. Voluntary biomass harvesting guidelines in the form of best practices might also work.



5. Comparison with Fossil Energy

EPA is interested in approaches for assessing the impact on the atmosphere of emissions from bioenergy relative to emissions from fossil fuels such as coal, oil, and gas. What bases or metrics are appropriate for such a comparison? (EPA 2010a)

One of the key features of the Manomet Center study report (MCCS 2010a) is the comparison of biomass used for energy production with fossil fuel alternatives. This section compares emissions from the combustion of wood and coal to produce electricity, and includes a discussion of GHG emissions implications from co-firing wood with biomass, the basic characteristics of the two fuels that are responsible for emissions, and the comparative inefficiencies of waste heat from electricity generation by combustion of fuel. In sum, based strictly on GHG emissions the difference between burning wood or coal to make electricity is not large, with coal having an advantage of perhaps 15 percent, which varies according to the types of wood and coal being combusted and the technology for conversion of heat from combustion into electricity.

5.1. Why compare wood to coal? There are good reasons for comparing GHG emissions from combustion of biomass to those from coal. To start with, coal combustion provides about half of the electricity consumed in the U.S. and projections show no diminishment in the foreseeable future (EIA 2009). A cover story in *The Economist* (2002) magazine recognized coal (**CO₂AL**) as “Environmental enemy No. 1” because of its CO₂ emissions.

Coal mining causes ecosystem damage, soil erosion, dust and air pollution from surface activities, landscape disruption from surface mining, interruption of streams and aquifers with impacts on water availability, acidified water, subsidence and land instability from underground mining, and emissions of methane and other greenhouse gases (Chan et al. 2010). If future extraction uses current technology and practice between now and 2020 to meet the business-as-usual demand projections in the U.S. (see EIA 2009), cumulative environmental damages by 2020 from coal mining will include 93.6 million acres of land-use change, 11,000 tonnes of soil erosion, 300 billion tonnes of acid in our waters, and emissions of 10 million tonnes of particulate matter, 5 million tonnes of nitrous oxides, 5 million tonnes of sulfur dioxide, and 561 million tonnes of CO₂ equivalent (Chan et al. 2010).



5.2. Life cycle analysis. From an energy perspective, life-cycle analysis shows that, the biomass to electricity pathway saves the largest amount of equivalent CO₂ emissions, more than thermal or transportation fuel uses (Zhang et al. 2009). Biomass can be used most cost-effectively to mitigate climate change in the energy sector by producing heat and power, especially if coal-burning is replaced (Bauen et al. 2009). Some scientists (Kharecha et al. 2010) see the global climate problem as manageable if coal use is phased out in the U.S. by 2030, and they identify technology options for doing so. Options include biomass utilization about which the scientists wrote, “. . . we suggest that bioelectricity used to supply base load power is likely

to provide the greatest [bioenergy] benefit, since it can offset demand for coal” (Kharecha et al. (2010).

The Kharecha et al. (2010) team of four scientists included James E. Hansen of the National Aeronautics and Space Administration (NASA). During a September 2008 interview with British journalist Geoffrey Lean, Hansen called for a back-to-the-future return to burning wood because he believes humankind has already exceeded the danger level for atmospheric CO₂. He said grow trees, which absorb the gas from the air as they grow, and burn them instead of fossil fuels to generate electricity. By capturing and storing the carbon produced in the process the greenhouse effect could be brought down to safe levels (Lean 2008). In December 2008, *Discover* magazine recognized Hansen as one of the 10 most influential people in science, those who move science from theory to action. The magazine noted that “Al Gore won a Nobel Peace Prize for explaining global warming to the world, but it was James Hansen who explained global warming to Al Gore” (Kruglinski and Long 2008).

5.3. Fuel characteristics analysis. Considering what the USDOE and other analysts have concluded about coal-burning emissions in a carbon-constrained world, the findings in the Manomet Center study report are astonishing. Analysis in the Manomet Center study report is built upon this statement: “Biomass generally produces greater quantities of GHG emissions than coal, oil or natural gas. If this were not the case, then substituting biomass for fossil fuels would immediately result in lower GHG emissions” (MCCS 2010, p. 96). That is, if fossil fuel burning generates greater quantities of GHG emissions than biomass, then there is no “biomass carbon debt” relative to fossil fuel.

A frequently cited *Science* article on bioenergy carbon accounting noted that “Each ton of wood consumed in a boiler instead of coal does not significantly alter combustion emissions” (Searchinger et al. 2009, on-line supporting material). The Manomet Center study report reproduced this quotation within its context, and the study built its conceptual model of the biomass carbon “debt-then-dividend” time line upon the forest management situation in Massachusetts. The study team determined that to attain the same energy output, wood combustion produces 5% more CO₂ emissions than coal combustion. This is verified herein.

A comparison of wood- and coal-burning emissions in Massachusetts and Montana illustrates that the difference in GHG emissions from wood and coal combustion is not large. Montana coal has a lower carbon and energy content than the bituminous coal that comprises nearly all of the coal burned in Massachusetts (MDOEP undated), which is mined in West Virginia (MCCS 2010a). If the average energy value of wood is assumed to be the same in both states, burning wood in Montana produces less CO₂ than coal for the same amount of energy produced, and there would not be a “biomass carbon debt.”

This warrants further analysis. The Manomet Center study report states that “Energy generation, whether from fossil fuel or biomass feedstocks, releases GHGs to the atmosphere. The GHG efficiency—i.e., the amount of lifecycle GHG emissions per unit of energy produced—varies based on both the *characteristics of the fuel* and the energy generation technology” (MCCS 2010a, p. 96, emphasis added). Fuel characteristics affecting CO₂ emissions are carbon content and energy value per unit of weight, often expressed as Btus (British thermal units) per pound of fuel. These two factors are plugged into formula [1] below to calculate CO₂ emissions. The Manomet Center study report used this formula (personal communication, Kamallesh

Doshi, Biomass Energy Resource Center, June 21, 2010). It is based on a U.S. Energy Information Administration (EIA) report explaining how to calculate coal emissions (Hong and Slatick 1994):

$$[1] \quad X \text{ lbCO}_2/\text{MMBtu} = C / E \times 3.667$$

where:

X = pounds (lb) of CO₂ emissions per Btu produced by fuel combustion, and multiplied by 10⁶ to get pounds of CO₂ emissions per million Btus (MMBtu) of heat produced;

C = carbon percent of fuel, in decimal format;

E = energy content of fuel, in Btus per pound;

3.667 is a constant for multiplying the weight of carbon (molecular weight = 12) to get the weight of carbon dioxide (molecular weight = 12+16+16=44); (44/12=3.667).

Table 1 provides a range of CO₂ emissions calculated for wood and coal combustion. Burning wood from birch, elm or poplar trees produces less CO₂ than the West Virginia coal burned by utilities in Massachusetts; ash wood produces about the same amount as coal; whereas maple, oak or white pine produces more emissions than coal. The Powder River coal burned in Montana has a lower carbon and heat content, and burning western red cedar or western larch produces less CO₂ than Montana coal, Douglas-fir about the same, and lodgepole pine more.

The source of the coal emissions datum of 205.3 lbCO₂ /MMBtu (pounds of CO₂ per million Btu) in the Manomet Center study report is a table in a GHG emissions report (EIA undated). By comparison, calculated emissions averaged 205.4 lbCO₂ /MMBtu based on the carbon and heat content of West Virginia coal samples (USGS 2004). The EIA (undated) datum for wood-burning emissions is 195.0 lbCO₂ /MMBtu which compared to 205.3 lbCO₂/MMBtu means there is no “biomass carbon debt” relative to coal. However, this datum is not verifiable in either the EIA source document or the analysis in this section,

According to Morris (2008), electricity production from biomass, as measured at the stack of a biomass power plant, produces more CO₂ than coal. The Manomet Center study team calculated wood-burning emissions to be 215.7 lbCO₂ /MMBtu (MCCS 2010a, Appendix Table 2-B, p. 129). Although the calculation method is not clear in the study report, the Manomet Center study team has explained it satisfactorily (personal communication, Kamallesh Doshi, Biomass Energy Resource Center, June 21, 2010). Carbon content of wood is generally accepted to be 50% and a generally accepted “average” heat value for wood is 8,500 Btu/lb (Marker 2004). Calculated emissions with formula [1] above are 215.7 lbCO₂ /MMBtu. Burning wood using an “average” heat value thus results in higher emissions than burning West Virginia coal to produce the same amount of energy. These data imply that wood combustion produces 5% more CO₂ emissions than coal combustion to produce the same amount of heat ((215.7–205.3)/205.3×100=5.07) or, stated another way, coal combustion produces 5% fewer CO₂ emissions than wood combustion ((215.7–205.3)/215.7×100=4.82).

Table 1. CO₂ emissions from direct combustion of biomass and coal, based on carbon content and heat value (British thermal unit, or Btu) of the fuel; data sources are footnoted.

Fuel	Carbon content (% x .01)	Btu per pound (average)	CO ₂ ^{1/} (pounds per million Btu)
Coal, Central Appalachian (West Virginia)	.7400 ^{2/}	13,210 ^{2/}	205.4
Coal, Powder River (Montana)	.4810 ^{2/}	8,097 ^{2/}	217.8
Wood (generally accepted average)	.5000 ^{3/}	8,500 ^{3/}	215.7
Ash, White	.4828 ^{4/}	8,583 ^{3/}	206.3
Birch, White	.4627 ^{4/}	8,335 ^{3/}	203.6
Cedar, Western Red	.5172 ^{4/}	9,400 ^{5/}	201.8
Cedar, White	.5154 ^{4/}	8,090 ^{3/}	233.6
Douglas-fir	.5050 ^{4/}	8,500 ^{5/}	217.9
Elm	.4632 ^{4/}	8,490 ^{3/}	200.1
Fir, White	.4855 ^{4/}	8,000 ^{5/}	222.5
Hemlock, Eastern	.5033 ^{4/}	8,885 ^{3/}	207.7
Hemlock, Western	.5060 ^{4/}	7,700 ^{5/}	241.0
Hickory	.4853 ^{4/}	8,354 ^{3/}	213.0
Larch, Western	.4760 ^{4/}	8,500 ^{5/}	205.4
Maple	.4932 ^{4/}	8,288 ^{3/}	218.2
Oak, Red	.4963 ^{4/}	8,363 ^{3/}	217.6
Oak, White	.4957 ^{4/}	8,490 ^{3/}	214.1
Pine, Eastern White	.4974 ^{4/}	8,603 ^{3/}	212.0
Pine, Lodgepole	.5032 ^{4/}	8,300 ^{5/}	222.3
Pine, Ponderosa	.5247 ^{4/}	8,800 ^{5/}	218.6
Poplar	.4800 ^{4/}	8,616 ^{3/}	204.3
Spruce	.4995 ^{4/}	7,800 ^{5/}	234.8

^{1/} Hong and Slatick (1994) calculation using formula [1], see text p. 7.^{2/} USGS (2010), average value of samples.^{3/} Marker (2004), average of published high and low heat value.^{4/} Lamblom and Savidge (2003).^{5/} Ince (1979), published high heat value minus 300.

5.4. Electricity generation technology characteristics. As noted in the previous section, the Manomet Center study report states that “Energy generation, whether from fossil fuel or biomass feedstocks, releases GHGs to the atmosphere. The GHG efficiency – i.e., the amount of lifecycle GHG emissions per unit of energy produced – varies based on both the characteristics of the fuel and the *energy generation technology*” (MCCS 2010a, p. 96, italics added). The characteristics of electricity generation technology vary in how efficiently the energy or heat value of the fuel is captured, and coal-fired electricity has approximately a 10% advantage. According to the Manomet Center study report, wood-fired electricity technology converts 25% of the heat produced from combustion into electricity and coal-fired electricity converts 32% of it (MCCS 2010a, Appendix 2-B, p. 129). The energy wasted in conversion processes should be factored in, so an equivalent statement is that 75% of the heat from biomass combustion is dissipated or wasted in producing electricity and 68% of the heat from coal combustion is wasted. This means the wood-fired electricity production process is 10% more inefficient relative to GHG emissions converting energy to electricity than coal-fired facilities ($((75-68)/68 \times 100 = 10.3)$) or coal-fired electricity is 9% less inefficient than wood-fired electricity ($((75-68)/75 \times 100 = 9.3)$). In short, coal has about a 10% conversion efficiency advantage.

5.5. Conclusions. The difference in CO₂ emissions from burning wood or coal to make electricity is not large. “Wood burned in a boiler instead of coal does not significantly alter combustion emissions” (Searchinger et al. 2009, on-line supporting material). Coal-fired electricity has about 15 percent less emissions, but is dependent on the types of wood and coal and the technology for conversion of heat from combustion into electricity. The quantity of CO₂ emissions is sensitive to the carbon and heat content of various types of wood and coal. Using an average value for the carbon and heat content of wood, on a per Btu basis 5 percent more CO₂ is produced from direct combustion of wood than from West Virginia coal burned in Massachusetts. In Montana, using the same value for wood, burning Powder River coal produces more CO₂ than wood and there is no “biomass carbon debt” (Table 1).



6. Comparison Among Bioenergy Sources

EPA is also interested in comments on accounting methods that might be appropriate for different types of biological feedstocks and bioenergy sources. What bases or metrics are appropriate for such a comparison among sources? In other words, are all biological feedstocks (e.g. corn stover, logging residues, whole trees) the same, and how do we know? (EPA 2010a)

The analysis and formula [1] in Section **5.3** are based on the carbon content and heat value of various fuels. This is an accepted method for calculating emissions.



7. Renewable or Sustainable Feedstocks

Specifically with respect to bioenergy sources (especially forest feedstocks), if it is appropriate to make a distinction between biomass feedstocks that are and are not classified as “renewable” or “sustainable,” what specific indicators would be useful in making such a determination?

Biomass resources used for electricity production in the U.S. today are primarily waste and residue materials (Morris 2008). Buried deep within the Manomet Center study report is a statement reflective of the actual situation throughout the U.S. in which wood residues are used as bioenergy feedstocks: “all bioenergy technologies – even biomass electric power compared to natural gas electric – look favorable when biomass ‘wastewood’ is compared to fossil fuel alternatives” (MCCS 2010a, p. 110). The study report defines “wastewood” as logging residues (tops, limbs, etc.) or non-forest biomass such as tree trimming/landscaping or land-clearing debris; mill residues are also recognized as an important source of non-forest biomass, but one that already is fully utilized.

Wood bioenergy provides roughly 2 percent of the energy consumed in the U.S. (EIA 2009), mostly from the combustion of sawmill and pulpmill residues to produce heat and power. A substantial resource in the form of logging residues exists, but its use is inhibited by the high costs of collecting and transporting logging slash to a processing facility. The Manomet Center study report states that unutilized mill residues and logging slash in Massachusetts are insufficient to supply the feedstock needs of announced biopower facilities, thus whole-tree harvests expressly for bioenergy would be necessary (MCCS 2010a). Some amount of such whole-tree harvests could be considered as timber stand improvements rather than biomass harvests, and perhaps many forest areas would benefit from such thinnings. The study report however, states that such thinnings might remove future timber crop trees and thereby diminish rather than enhance forest values (MCCS 2010a, p. 73)

A forestry company in northern California now uses whole-tree harvesting for biomass after harvesting saw logs. It is generally done 2-3 years after a single-tree selection (uneven-aged) harvest. The maximum diameter of harvested trees is 12” unless dead, dying or deformed. Most of the sites are mechanically harvested and skidded using rubber tired or track-laying skidders. This material is chipped and purchased by a local wood biopower plant. The harvesting operations are typically for fuel reduction/stand improvement objectives. Although the firm does not make much money on the operations there are other benefits. Marking trees during the next harvest (every 10-12 years) is easier, thus quicker and cheaper. Future logging operations are also easier, and wildfire risk is reduced, so there is less chance of burning up forest capital. Other operators in the area do similar stand improvement or fuel reduction operations focusing on non-merchantable material. These trees are cut, skidded and chipped as whole trees. Firms also harvest a considerable amount of biomass during normal logging operations and chip this material, mostly tops, for biopower feedstocks (B. Morris, review comments).

The approach described above is supported in the literature, except for the Manomet Center study report. With respect to bioenergy feedstocks, Kharecha et al. (2010) stated that “. . . a sound approach uses biomass waste products or low-input/high-diversity perennial plants grown on degraded or marginal lands.” This is consistent with strongly expressed support for using waste materials as bioenergy feedstocks in several *Science* articles (e.g., Fargione et al.

2008, Searchinger et al. 2008, Tilman et al. 2009). Combustion of “waste wood” does not deplete the forest carbon stock, but agreement on what might be considered waste wood is lacking (Johnson 2009). According to Zanchi et al. (2010), forest residues used for bioenergy produce a GHG benefit in the atmosphere from the beginning of its use; a similar result is produced from burning wood from new plantations on lands with low carbon stocks prior to conversion.



8. Other Biogenic Sources of CO₂

Other biogenic sources of CO₂ (i.e., sources not related to energy production and consumption) such as landfills, manure management, wastewater treatment, livestock respiration, fermentation processes in ethanol production, and combustion of biogas not resulting in energy production (e.g., flaring of collected landfill gas) may be covered under certain provisions of the CAA, and guidance will be needed about exactly how to estimate them. How should these “other” biogenic CO₂ emission sources be considered and quantified? In what ways are these sources similar to and different from bioenergy sources? (EPA 2010a)

Data or analysis related to this topic are not provided herein.



9. Additional Technical Information

EPA is also interested in receiving quantitative data and qualitative information relevant to biogenic greenhouse gas emissions, including but not limited to the following topics:

- Current and projected utilization of biomass feedstocks for energy.
- Economic, technological, and land management drivers for projected changes in biomass utilization rates.
- Current and projected levels of GHG emissions from bioenergy and other biogenic sources.
- Economic, technological and land management drivers for projected changes in emissions.
- Current and projected C sequestration rates in lands used to produce bioenergy feedstocks.
- Economic, technological and land management drivers for projected changes in sequestration rates.
- The types of processes that generate or are expected to generate emissions from bioenergy and other biogenic sources.
- The number of facilities that generate or are expected to generate such emissions.
- Emission factor information, particularly for the biogenic CO₂ source categories of wastewater treatment, livestock management, and ethanol fermentation processes.
- Potential impacts on specific industries and particular facilities of various methods of accounting for biogenic GHG emissions.
- Potential impacts of GHG emissions from bioenergy and other biogenic sources on other resources such as water availability and site nutrient quality.
- Potential impacts of GHG emissions from bioenergy and other biogenic sources on other air pollutants such as VOCs, other criteria pollutants, and particulate matter. (EPA 2010a)

Each of the above topics is given a number from 1 to 12 below. Some of these topics are discussed, but most of them are not.

9.1. Current and projected utilization of biomass feedstocks for energy.

Woody biomass provides almost 2 percent of the energy consumed in the United States, and by 2030, biomass feedstocks are expected to provide almost 8 percent of the nation's energy consumption (EIA 2009). Wood bioenergy production uses proven, cost-effective technology to provide homegrown, reliable baseload energy by converting mill residues from wood products and pulp/paper manufacturing into steam heat and electrical power. Around the nation most of these mill residues are already fully utilized (O'Laughlin 2009).

Co-firing biomass with coal is projected to increase substantially. Combustion of woody biomass for heat and power currently provides almost two percent of the energy consumed in the U.S. (EIA 2009). The U.S. Department of Energy (USDOE) projects that woody biomass will be used increasingly to produce additional electricity ("biopower"). Stand-alone wood biopower generation is projected to increase at an annual average of 5.9% per year until 2030. Co-firing biomass with coal is expected to increase 12.9% per year. Wind power, by comparison, is projected to increase 6.3% per year through 2030, at which time wind is projected to provide

1.29 quadrillion Btus, which is 45 percent less than the 1.87 quadrillion Btus provided today by wood-fired heat and power (EIA 2009).

9.2. Economic, technological, and land management drivers for projected changes in biomass utilization rates.

Wood bioenergy growth is limited by the many factors that affect forest products businesses, including transportation costs, economic feasibility, and lack of a reliable long-term supply of timber in many western states (O’Laughlin 2009). Additional wood bioenergy production can help revitalize rural communities as well as restore forest health, fire resiliency and wildlife habitat. An added bonus is that the carbon sequestration capability of forests can be enhanced by active management to accomplish the above objectives and thereby mitigate climate change potential. The benefits from wood bioenergy substantially exceed the value of energy alone because of uncompensated benefits and avoided costs. These benefits include reduced air pollution and landfill disposal burdens. In addition pre-wildfire forest management activities designed to modify fire behavior provide quantifiable benefits from avoided costs of wildfire suppression and post-wildfire fire site rehabilitation, as well as providing renewable energy feedstocks (O’Laughlin 2009).

Which is more environmentally friendly, biomass or coal? According to the U.S. Environmental Protection Agency, “Biomass contains much less sulfur and nitrogen than coal; therefore, when biomass is co-fired with coal, sulfur dioxide and nitrogen oxides emissions are lower than when coal is burned alone. When the role of renewable biomass in the carbon cycle is considered, the carbon dioxide emissions that result from co-firing biomass with coal are lower than those from burning coal alone” (EPA 2010d). Although the latter part of this EPA quotation regarding CO₂ emissions is currently being reevaluated under the “tailoring rule” for commencing with regulation of GHG emissions sources (EPA 2010c), whatever the agency decides about that is not likely to affect its stance on emissions from sulfur dioxide and nitrous oxides.

If the EPA decides that biomass is worse than coal from a carbon standpoint, then co-firing suddenly becomes undesirable.

9.3. Current and projected levels of GHG emissions from bioenergy and other biogenic sources.

Data or analysis related to this topic are not provided herein.

9.4. Economic, technological and land management drivers for projected changes in emissions.

Data or analysis related to this topic are not provided herein.

9.5. Current and projected C sequestration rates in lands used to produce bioenergy feedstocks.

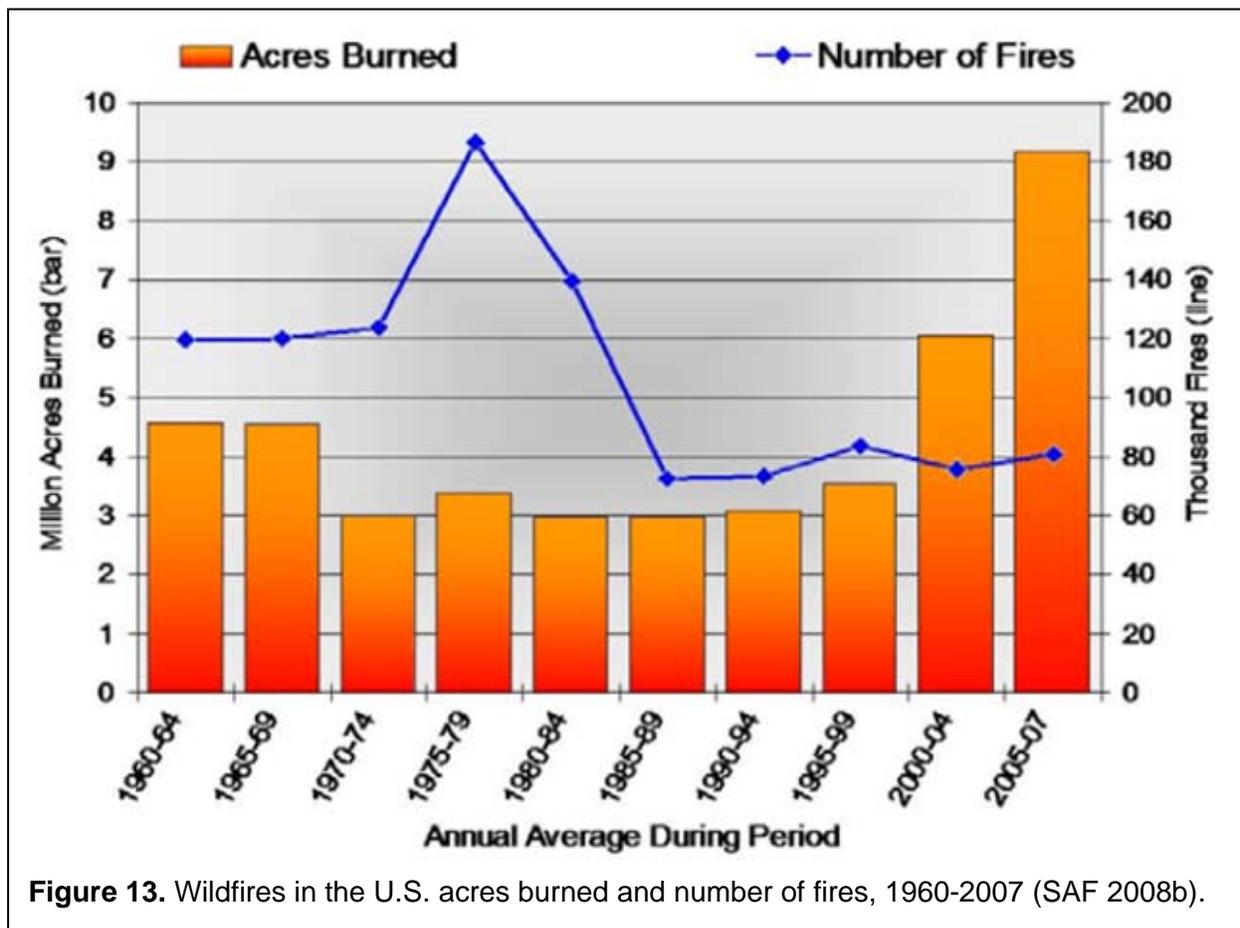
Data or analysis related to this topic are not provided herein.

9.6. Economic, technological and land management drivers for projected changes in sequestration rates.

Data or analysis related to this topic are not provided herein.

9.7. The types of processes that generate or are expected to generate emissions from bioenergy and other biogenic sources.

According to the EPA (2010e, p. A-308) “The United States does not consider forest fires within its national boundaries to be a net source of greenhouse emissions.” Although the average annual number of wildfires has not increased since 1985, the acreage burned has tripled (**Figure 13**). The EPA’s GHG emissions inventory shows that during 2005-2008, U.S. forests sequestered on average 804 million tonnes of CO₂ per year. This is equivalent to 13% of all U.S. CO₂ emissions. Each year during that same period, U.S. forest fires emitted on average 250 million tonnes of CO₂ per year (EPA 2010e), thus diminishing the value of the forest carbon sink by returning 31% of the CO₂ sequestered in an average year back into the atmosphere.



Emissions from fires need to be included in a GHG accounting system. In the current system they are identified (EPA 2010e, Table 7-9) but not included in the emissions total because forest inventory methods account for changes in carbon stocks in the forests. If this “stock change” approach is appropriate for effects of wildfires and prescribed fires on terrestrial ecosystems, it should also be appropriate for burning biomass to produce energy, as Johnson (2009) suggests.

As an article in *Science* pointed out, “The overall importance of climate in wildfire activity underscores the urgency of ecological restoration and fuels management to reduce wildfire hazards to human communities and to mitigate ecological impacts of climate change” (Westerling et al. 2006). In the 15 western states there are at least 28 million acres of forest that could benefit from some type of mechanical treatment to reduce hazardous fuel loading. About

60 percent of this area could be operationally accessible for treatment. Two-thirds of this forest area is on public lands, and most of the volume is in trees 6 inches diameter and greater that have conventional utilization opportunities. Any serious effort to reduce hazardous fuels will create large volumes of biomass and require additions to the workforce (USFS 2005). The low-value thinnings and residual “waste wood” logging slash from timber harvests could provide a substantial renewable energy resource.

9.8. The number of facilities that generate or are expected to generate such emissions.

Data or analysis related to this topic are not provided herein.

9.9. Emission factor information, particularly for the biogenic CO₂ source categories of wastewater treatment, livestock management, and ethanol fermentation processes.

Data or analysis related to this topic are not provided herein.

9.10. Potential impacts on specific industries and particular facilities of various methods of accounting for biogenic GHG emissions.

Data or analysis related to this topic are not provided herein.

9.11. Potential impacts of GHG emissions from bioenergy and other biogenic sources on other resources such as water availability and site nutrient quality.

Data or analysis related to this topic are not provided herein.

9.12. Potential impacts of GHG emissions from bioenergy and other biogenic sources on other air pollutants such as VOCs, other criteria pollutants, and particulate matter.

It should be noted that management of GHG emissions may be an important societal objective, but other environmental objectives also matter. Hazardous pollutants are near the top of the list, and wood-burning using modern technology trumps coal in most such categories.



Conclusions

Policy for biomass carbon is unsettled. The forest carbon science synthesis published by the Ecological Society of America concluded with this statement: “Elevating carbon storage to the primary focus of management could potentially impede the other co-benefits of forests. A focus on carbon storage to the detriment of other ecosystem services would be short-sighted” (Ryan et al. 2010, p. 15). In a written response to questions posed by *New York Times* journalist Tom Zeller Jr., Manomet Center President John M. Hagan and Thomas Walker, Manomet Center study team leader, stated a weakness of the Manomet Center study report:

Finally, we’d emphasize that there are many other considerations besides greenhouse gas emissions when making energy policy—these include energy security, air quality, forest recreation values, local economics, other environmental impacts of extracting fossil fuels (and not just greenhouse gas emissions of burning fossil fuels), and quality of place, among others. Policymakers need to weigh all these factors in making energy policy (Zeller 2010b).

The Manomet Center study report short changes policymakers by focusing primarily on analysis of GHG emissions, using a novel model designed to replace the long-established principle that biomass combustion results in a zero net emissions increase because it is part of the continuously ongoing carbon cycle. In so doing the Manomet Center study report treats biomass as if it were mined like fossil fuels, until sometime in the future when the biomass has regrown and repaid its “carbon debt.” In reality, that “debt” is imaginary because biomass was produced by the carbon cycle and will be replaced by it unless deforestation occurs. Furthermore, the use of wood products that replace concrete and steel immediately produces the benefit of a permanent reduction in GHG emissions much greater than the “biomass carbon debt.” In addition, by selecting a small area to analyze, the model ignores the fact that adjacent vegetation will immediately reabsorb the carbon emitted to the atmosphere from dead vegetation, whether death is the result of harvesting biomass to make wood products or energy, or from fire, insects and disease.

Forest carbon accounting makes sense if a) it spans the life cycle of trees and explicitly recognizes that trees die and return their stored carbon to the atmosphere whether they are grown on a tree farm in western Massachusetts or in the Frank Church River of No Return Wilderness in central Idaho; b) the boundary around the area for accounting analysis is sufficiently large—a state might be considered sufficiently large, a county likely would not; and c) all carbon pools are included in the accounting framework.

In 2008, the Commonwealth of Massachusetts stated in a report on *Woody Biomass Energy* that bioenergy is part of its renewable energy strategy (Urquart and Boyce 2008). Now, two years later, the Manomet Center study report has at least one official reconsidering the role of wood bioenergy in Massachusetts’ renewable energy portfolio. According to Ian Bowles, Administrator of the Executive Office of Energy and Environmental Affairs:

Biomass energy can be renewable over the long term; it has benefits independent from imported fossil fuels. But now we know that electricity from biomass harvested from New England forests is not “carbon neutral” in a timeframe that makes sense given our legal mandate to cut GHG emissions, we need to re-evaluate our incentives for biomass. . . . These findings have broad implications

for clean energy and the environment in Massachusetts and beyond (MEOEEA 2010).

It should be noted that the social context for wood bioenergy policy is unsettled in Massachusetts and elsewhere, including Florida and the State of Washington (see, e.g., Zeller 2010a). The Manomet Center study report stated that “the framework and approach we have developed for assessing the impacts of wood biomass energy have wide applicability for other regions and countries” (MCCS 2010a, p. 6). Manomet Center President John M. Hagan said that although the study was conducted for Massachusetts, the team’s carbon accounting approach has worldwide relevance for informing biomass energy policies (MCCS 2010b). It is uncertain whether the Manomet Center study report will influence carbon accounting or bioenergy policy beyond the Commonwealth border, as the study team, Dr. Hagan and Mr. Bowles believe it might, but one would certainly hope that policymakers will not base bioenergy policy decisions solely upon GHG emissions.

For example, Idaho Governor C.L. “Butch” Otter and Washington Governor Christine O. Gregoire wrote a letter to Carol Browner, Climate Change and Energy Advisor to President Obama, on August 10, 2010, and explained their call for a cohesive federal biomass policy based on forest health and related reasons:

. . . we are writing to express our concern about the absence of a clear and cohesive federal policy on the use of biomass for energy production. Biomass energy holds great potential for new markets in the forest products and energy sectors by creating demand and value for material derived from activities related to forest health and hazardous fuels reduction. Private investments associated with these new markets could help offset a clear and growing deficit of public financial resources needed to pursue urgently needed forest treatments. . . . we encourage all federal agencies to work with us to develop a clear and unambiguous federal biomass policy that reflects a fuller understanding of the benefits of utilizing forest residues for bioenergy at both the national and regional levels. We encourage the Administration to make the resolution of this issue a top priority so the nation does not lose a unique opportunity to achieve the equally important goals of healthy forests, clean air, productive economies and clean energy (Otter and Gregoire 2010).

A workable GHG emissions accounting framework for forest bioenergy would include all carbon pools, span centuries and, at minimum, several hundred thousand acres. Otherwise two realities of the carbon cycle are overlooked. *First*, trees do not live forever. They will die and return stored carbon to the atmosphere. Emissions of GHG related to processing biomass for energy production essentially replace what would normally occur if a forest were not managed. Because we know more about the past than the future, some of the centuries in the accounting framework should be in the past because that is where the biomass carbon pools in today’s forests came from. Analysts should not forget forest mortality in future scenarios as part of the full accounting picture for forest bioenergy.

Second, a large area of forest is needed to support a wood-based facility, whether it is making wood products or bioenergy. Sawmills that dry lumber onsite do both. For every acre harvested today, many other acres in the vicinity or “woodshed” of a sawmill or bioenergy plant will be growing and capturing released carbon (see **Figure 1**). This is why the USDOE, BEREC, and

other analysts cited herein consider bioenergy not only a source of renewable energy, but also one that features a zero net emissions increase by not adding new carbon to the atmosphere.

The novel carbon “debt-then-dividend” accounting framework developed by the Manomet Center study report may influence bioenergy policy in Massachusetts, and it may be that the principle of zero net emissions increase from biomass combustion will be cast in a new light by government agencies in the U.S. and perhaps elsewhere. However, the “debt-then-dividend” model based on stand-level analysis is not appropriate for sustainable forest management considerations over large areas and long time periods, thus is certainly inadequate for forest policy analysis.

The idea that the combustion of coal is somehow better for the atmosphere than the combustion of wood for bioenergy as currently practiced in the U.S. does not make sense. The current debate is likely to conclude that burning wood to produce electricity is an improvement over burning coal, now, but only if the feedstock comes from sustainably managed forests. The reason is not so much that biomass combustion result in a zero net emissions increase—although this is a valid argument because the carbon cycle is a continuous process—but rather because the bioenergy industry consumes “waste wood” residues that otherwise have no use and will be returned to the atmosphere in a short period of time anyway. This approach is strongly supported in the literature cited herein, including the Manomet Center study report. Logging residues are a substantial underutilized resource that enlightened forest and energy policy could convert from a liability to an asset. Improving the condition of forests in many areas of the nation would involve thinning overly dense forests and salvage of dead timber. These materials could be used as energy feedstocks. The policy question is not whether wood bioenergy emits more CO₂ than coal, but whether it makes sense to enable and facilitate use of biomass produced by the carbon cycle to substitute for fossil fuels, or encumber such use and continue to mine fossil fuels while allowing forests to decay and burn.



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