Review of the Manomet Biomass Sustainability and Carbon Policy Study

Prepared by Mary S. Booth, PhD

For the Clean Air Task Force

July, 2010

Table of Contents

EXECUTIVE SUMMARY

The purpose of this document is to evaluate the science behind the Manomet biomass report and the validity of the report's main conclusions concerning net carbon emissions from biomass energy, relative to fossil fuels. The report comes to two main conclusions:

1. **For utility-scale generation, net emissions are higher from biomass than fossil fuels.** When biomass is used to generate electricity in utility-scale plants, the net emissions after 40 years, even taking forest regrowth into consideration, are still higher than if the power had been generated with coal. When biomass is used instead of natural gas, net emissions are still higher even after ninety years (exhibit 6-14, p. 112).

2. **Net emissions profiles from biomass thermal and CHP plants may be better.** The Manomet study concludes that when biomass replaces fossil fuels for small-scale thermal applications and in combined heat and power plants, net emissions by 2050 can be lower than would occur if oil had been burned, but are still significantly higher than if natural gas were used as fuel.

The study relies on a number of assumptions to achieve these conclusions that minimize the calculation of net carbon emissions from biomass power, meaning that actual emissions are likely greater than the study concludes. Thus, the first conclusion of the report – that net emissions from biomass are greater than from coal and especially natural gas even after decades of regrowth by forests – is qualitatively correct, but it likely underestimates the magnitude of biomass emissions. The second conclusion, that small-scale thermal and CHP biomass facilities may yield a carbon "dividend" relative to fossil fuels after forty years is likely not correct, since actual biomass emissions likely exceed fossil fuel emissions even under the thermal and CHP scenarios.

The study's major conclusion, that net biomass emissions are significantly higher than if natural gas were used as fuel even after ninety years of forest regrowth, is especially notable for the New England area where the majority of electricity generated comes from natural gas. Using biomass to "reduce" emissions from the power generation sector will have the opposite effect, particularly where biomass displaces power generation from natural gas.

The Manomet model estimates net carbon emissions for both biomass and fossil fuels as fuel lifecycle emissions minus forest carbon sequestration on a hypothetical acre which is cut for timber but not biomass (the fossil fuel/business-as-usual scenario), and one which is cut for both timber and biomass (the biomass scenario). As the forest regrows on the plot cut for biomass, the net carbon balance transitions from representing a "carbon debt" to providing a "carbon dividend", as carbon moves from the atmosphere into new forest growth. This "single plot" analysis of forest recovery after cutting serves as the building block for an integrated analysis, which assesses the cumulative impact of a biomass industry that cuts new forest for fuel each year and thus increases the relative amount of land that still has a "carbon debt". The study unfortunately downplays the cumulative effects analysis, instead focusing on the "single plot" analysis, which would only be relevant to the calculation of carbon impacts from a facility that operated for a single year.

Some of the many assumptions upon which the Manomet study's conclusions rely are listed here; all minimize the calculation of carbon emissions from biomass. The model is sensitive to these assumptions, therefore if any one of them is violated in reality, actual emissions will be greater than reported in the study's conclusions.

1. **Large trees are used for biomass fuel**. Because forest regrowth rates in the model are to a large extent a function of the intensity of harvest (with heavier harvests of larger, older trees opening up more space for regrowth to occur), the model achieves maximal regrowth and resequestration of carbon released by biomass burning by assuming that relatively large, old trees are logged for biomass. However, this is not representative of actual biomass harvesting, which is more likely to remove low-diameter, low-value material. Actual regrowth rates of forests where low-diameter material is removed will be much slower than modeled.

2. **Harvested forest stands must not be recut pending carbon sequestration.** The model additionally requires that once a stand has been cut, it must not be re-cut until it has achieved a large proportion of the amount of standing carbon in an unmanaged stand. The Manomet report itself acknowledges this is unlikely.

3. **A high percentage of tops and limbs are used as fuel**. Because the tops and limbs of trees harvested for timber under the BAU scenario are assumed to stay in the forest and rot, producing carbon, the model assumes almost no carbon penalty for collecting this material and burning it. The model assumes that 65% of all tops and limbs generated on acres harvested for biomass can be removed from the forest for use as fuel, supplying a relatively large "low carbon" source of fuel in the model. Removal of this amount of tops and limbs appears to be necessary to achieving the transition from biomass carbon debt to carbon dividend in the model, but is not compatible with maintaining soil fertility and other forest ecological functions.

4. **Biomass harvesting only occurs on land that is already being harvested for timber**. The study takes as its BAU assumption that when land is harvested for timber, all residues are left in the forest, whereas a portion is collected for fuel in the biomass scenario. The study draws no conclusions concerning carbon dynamics and regrowth in forests cut solely for biomass. This assumption is necessary for generating the "low carbon" fuel source of tops and limbs from commercial timber harvesting that is integral to calculating carbon dividends from biomass in a timely way. Land cut solely for biomass would take a much longer time to achieve a carbon dividend.

5. **Soil carbon emissions are negligible**. The soil carbon pool is extremely large, and a significant fraction of it is easily decomposed and evolved as CO2 when soils are disturbed by logging. However, the Manomet model completely disregards this source of emissions that are associated with biomass harvesting. This assumption is challenged by the author of a major review on soil carbon emissions cited, and dismissed, by the Manomet study.

6. **Firewood harvesting is not impacted**. Although indirect land use effects can be major sources of greenhouse gas emissions from biomass harvest, and although the RFP for the Manomet study requested that the study evaluate indirect land use effects, the study does not acknowledge that displacement of firewood harvest by biomass harvest could result in "leakage" of firewood harvesting and more forestland being cut for firewood.

7. **Wood pellet manufacture incurs no more carbon debt than green chips**. Although it is well-established that manufacture of wood pellets requires significant inputs of green wood in excess of the heating value actually embodied in the pellets produced, as well as significant fossil fuel expenditures, the study treats wood pellets as embodying the same amount of carbon and energy as green wood chips.

8. **Wood from land-clearing incurs little carbon debt.** The study concludes that woody biomass from non-forestry sources, such as from land-clearing, will not entail any greater greenhouse gas emissions than forestry wood. However, no modeling is conducted to substantiate this conclusion. The study also does not discuss how wood from land-clearing can be considered eligible under requirements that biomass fuels be available on a renewable and recurring basis, as required under the Regional Greenhouse Gas Initiative.

To the extent that these assumptions are not warranted, the Manomet study has underestimated the net carbon emissions of biomass power, and policy-makers should be extremely cautious about accepting the study's optimistic conclusions concerning the point in time when biomass can start providing a carbon dividend.

INTRODUCTION

The purpose of this document is to evaluate the science behind the Manomet biomass report and the validity of the report's main conclusions. The Manomet study is large, and covers much background material on biomass policies in the United States and internationally. This evaluation will focus only on the core conclusions of the study that deal with carbon accounting. Overall, the conclusion of this evaluation is that the Manomet study's basic approach to calculating net carbon emissions from biomass is valid, but it relies on a number of overly optimistic assumptions and omits categories of greenhouse gas emissions from the study's lifecycle analysis. It is highly likely that net carbon emissions from biomass are actually higher than concluded by the Manomet study.

Organization of this paper

This summary reviews the carbon modeling aspects of the Manomet report. It begins by setting out the two main conclusions of the study. This is followed by an explanation of how the Manomet carbon model was constructed.

Next is a short list of the main assumptions of the model, upon which the conclusions depend. This is followed by a critique of each assumption.

Once the assumptions behind the modeling are aired, this allows the conclusions of the Manomet study to be assessed more thoroughly.

Throughout, this summary paper relies extensively on text copied from the Manomet report itself, with page numbers included to guide the reader to relevant sections. Points of particular importance are highlighted.

MAIN CONCLUSIONS OF THE MANOMET STUDY

Regarding net carbon emissions from biomass relative to fossil fuels, the study had two main conclusions:

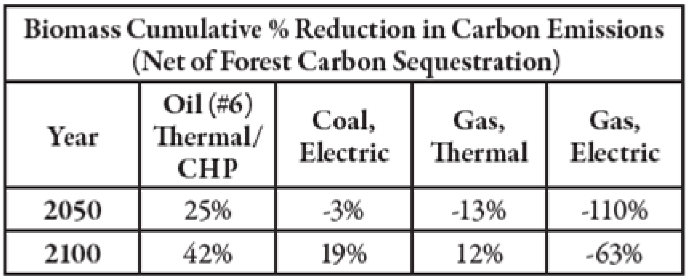
1. **For utility-scale generation, net emissions are higher from biomass than fossil fuels.** When biomass is used to generate electricity in utility-scale plants, the net emissions after 40 years, even taking forest regrowth into consideration, are still higher than if the power had been generated with coal. When biomass is used instead of natural gas, net emissions are still found to be higher after ninety years (exhibit 6-14, p. 112).

2. **Net emissions profiles from biomass thermal and CHP plants may be better.** The Manomet study concludes that when biomass replaces fossil fuels for small-scale thermal applications and in combined heat and power plants, net emissions by 2050 can be lower than would occur if oil had been burned, but are still significantly higher than if natural gas were used as fuel.

Prior to further discussion, it is important to note that the results presented in the executive summary of the Manomet report do not represent the full results presented in the body of the report. Most importantly, the study concluded that the net carbon balance of biomass energy depended on the intensity of harvesting both for commercial timber and biomass removal itself, and thus examined six different harvesting scenarios, reporting the carbon balance results under each. Unfortunately, the results of only one of the scenarios is presented in the executive summary.

These are the results for cumulative carbon impacts presented in the executive summary. Negative numbers indicate that in the year specified, net emissions from biomass still exceed those from fossil fuels:

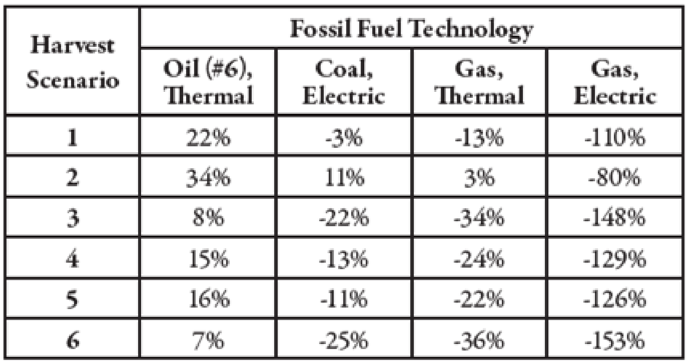
Figure 4: Cumulative Carbon Dividends from Biomass Replacement of Fossil Fuel



Biomass Cumulative % Reduction in Carbon Emissions (Net of Forest Carbon Sequestration)				
Year	Oil (#6) Thermal/ CHP	Coal, Electric	Gas, Thermal	Gas, Electric
2050	25%	-3%	-13%	-110%
2100	42%	19%	12%	-63%

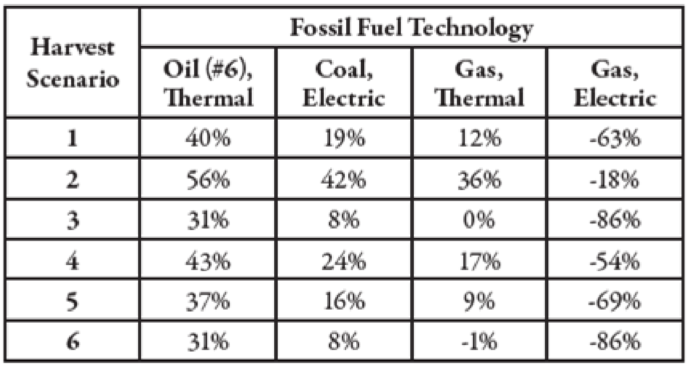
Below is the full table from Chapter 6, from which the results presented in the executive summary are drawn. The table presented in the executive summary repeats the results from Harvest Scenario 1. The assumptions behind these results are discussed in more detail below, but critical to placing these results in context is understanding that all harvest scenarios assume that biomass harvesting occurs only on land already harvested for timber at varying intensities, and that a large proportion of tops and limbs from commercial timber harvesting are available as "low-carbon" biomass fuel.

Exhibit 6-14: Cumulative Carbon Dividends: 2010 to 2050



Harvest Scenario	Fossil Fuel Technology			
	Oil (#6), Thermal	Coal, Electric	Gas, Thermal	Gas, Electric
1	22%	-3%	-13%	-110%
2	34%	11%	3%	-80%
3	8%	-22%	-34%	-148%
4	15%	-13%	-24%	-129%
5	16%	-11%	-22%	-126%
6	7%	-25%	-36%	-153%

Exhibit 6-15: Cumulative Carbon Dividends: 2010 to 2100



Harvest Scenario	Fossil Fuel Technology			
	Oil (#6), Thermal	Coal, Electric	Gas, Thermal	Gas, Electric
1	40%	19%	12%	-63%
2	56%	42%	36%	-18%
3	31%	8%	0%	-86%
4	43%	24%	17%	-54%
5	37%	16%	9%	-69%
6	31%	8%	-1%	-86%

HOW THE MANOMET MODEL WAS CONSTRUCTED

The Manomet model compares the emissions from biomass power for electricity only, thermal only, and combined heat and power plants against emissions from gas and coal in the case of electricity only plants, and gas and oil in the case of thermal and CHP plants. Lifecycle emissions consist of emissions at the stack from fuel combustion, as well as emissions associated with collection and transportation of the fuel.

Net carbon emissions are estimated as fuel lifecycle emissions minus forest carbon sequestration on a hypothetical acre which is cut for timber but not biomass (the fossil fuel/business-as-usual scenario), and one which is cut for both timber and biomass (the biomass scenario). Net carbon emissions from fossil fuels and biomass burning are compared by calculating the amount of lifecycle carbon emissions which are sequestered into new forest growth under the two scenarios. The model employs the Forest Vegetation Simulator, a model that uses Forest Service data on tree growth and forest composition, to estimate the recovery and regrowth of the forest following harvesting.

The report describes the approach:

> 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. **(p. 99).**
>
> At the most general level, the carbon accounting framework we employ is constructed around **comparisons of fossil fuel scenarios with biomass scenarios producing equivalent amounts of energy**. The fossil fuel scenarios are based on lifecycle emissions of GHGs, using "CO2 equivalents" as the metric (CO2e). Total GHG emissions for the fossil scenarios include releases occurring in the production and transport of natural gas, coal or oil to the combustion facility as well as the direct stack emissions from burning these fuels for energy. Similarly, GHG emissions from biomass combustion include the stack emissions from the combustion facility and emissions from harvesting, processing and transporting the woody material to the facility. Most importantly, both the fossil fuel and biomass scenarios **also include analyses of changes in carbon storage in forests through a comparison of net carbon accumulation over time** on the harvested acres with the carbon storage results for an equivalent stand that has not been cut for biomass but that has been harvested for timber under a business-as-usual (BAU) scenario. Our approach includes the above- and below-ground live and dead carbon pools that researchers have identified as important contributors to forest stand carbon dynamics.
>
> The conceptual modeling framework for this study is intended to address the question of how atmospheric GHG levels will change if biomass **displaces an equivalent amount of fossil fuel generation** in our energy portfolio. With this objective, the modeling quantifies and compares the **cumulative net annual change in atmospheric CO2e for the fossil and biomass scenarios**, considering both energy generation emissions and forest carbon sequestration. In the fossil fuel scenarios, there is an initial CO2e emissions spike associated with energy generation—assumed here to be equivalent to the

> energy that would be produced by the combustion of biomass harvested from one acre—**which is then followed by a drawing down over time (resequestration) of atmospheric CO2e by an acre of forest from which no biomass is removed for energy generation**. For the biomass scenario, there is a similar initial release of the carbon from burning wood **harvested from an identical acre of natural forest**, followed by continued future growth and sequestration of carbon in the harvested stand. **(p. 96)**

In the modeled acre cut for biomass, the forest is cut for timber at the same intensity as in the BAU scenario, but then more trees are removed to provide biomass fuel. Additionally, a portion (65%) of the branches and treetops from the trees cut for timber are removed as fuel, and the same amount of tops and branches from trees cut for biomass are removed as fuel, along with all trunk wood. The model thus assumes that 35% of all tops and branches are left onsite, and that this material rots and emits CO2 over time. The Manomet study examines six alternative harvesting scenarios at various intensities of removal.

The analysis that compares the carbon sequestered over time on a single forest acre under the BAU scenario, versus that on an acre cut for biomass, serves as the basic "building block" of an integrated analysis that considers the summed emissions over time, and the summed regrowth over time. This can best be explained by inserting the figures 6-2a and 6-2b from the Manomet study. The first graph shows the regrowth on an acre of forest harvested only for timber (BAU) and one harvested for timber, with additional trees cut to provide biomass fuel. Because the heavier removal on the acre cut for biomass actually increases the growth rate in the recovering forest, the two curves eventually converge:

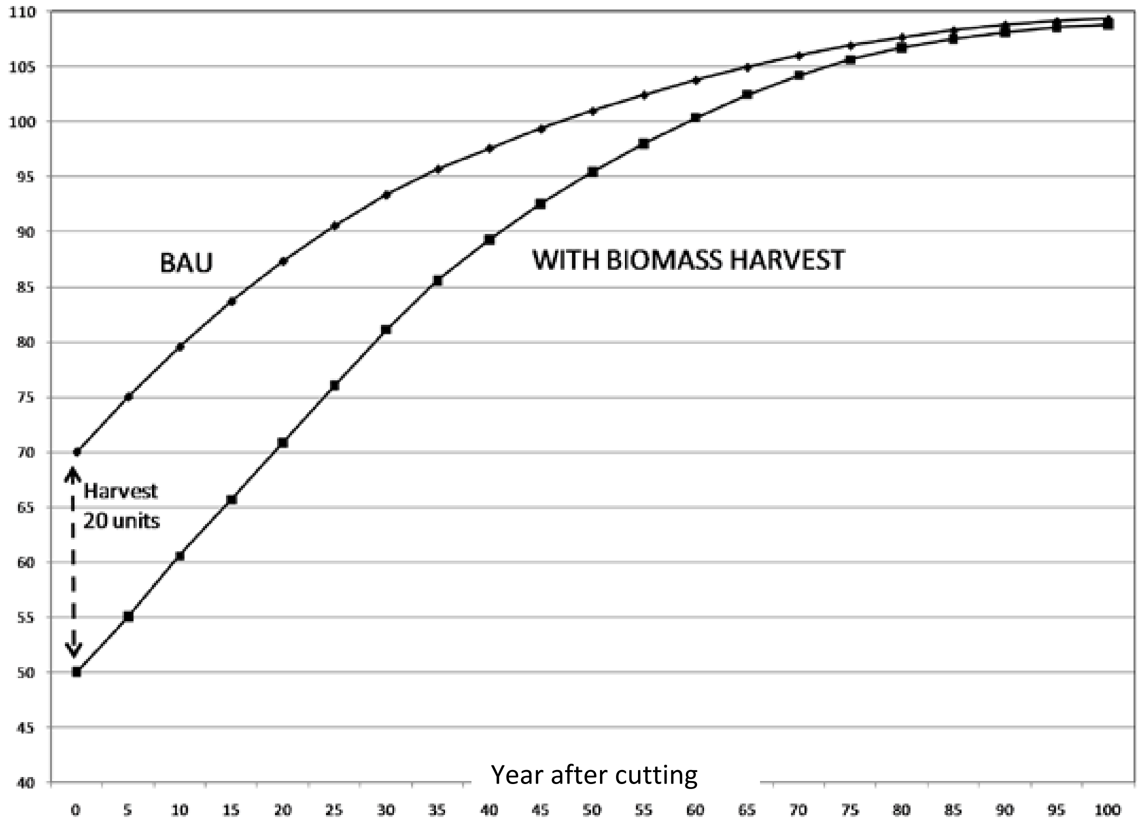


Figure 1. Forest growth following harvest in the "business-as-usual"timber harvesting scenario, and the scenario which harvests for both timber and biomass. This graph is labeled 6-2a in the Manomet report.

The next graph shows the cumulative net emissions from biomass and fossil fuel combustion, tracking the reduction in net emissions through time as the forest grows back. The single regrowth curve represents the subtraction of the BAU curve from the biomass curve in the graph above, essentially treating the carbon that would have been sequestered under the BAU scenario, which is now lost, as an "emission" that is associated with biomass harvesting. Immediately following harvest, the biomass scenario thus starts out with a "carbon debt" of an additional 9 tons of carbon that are harvested for biomass fuel after the initial 11 tons of carbon are removed for commercial timber. The point where the curve (which describes the net emissions from biomass burning) intersects the flat line (which describes the cumulative emissions from fossil fuel burning) is the point in time when the net emissions of the two scenarios are equivalent. This occurs at approximately Year 32 in this scenario.

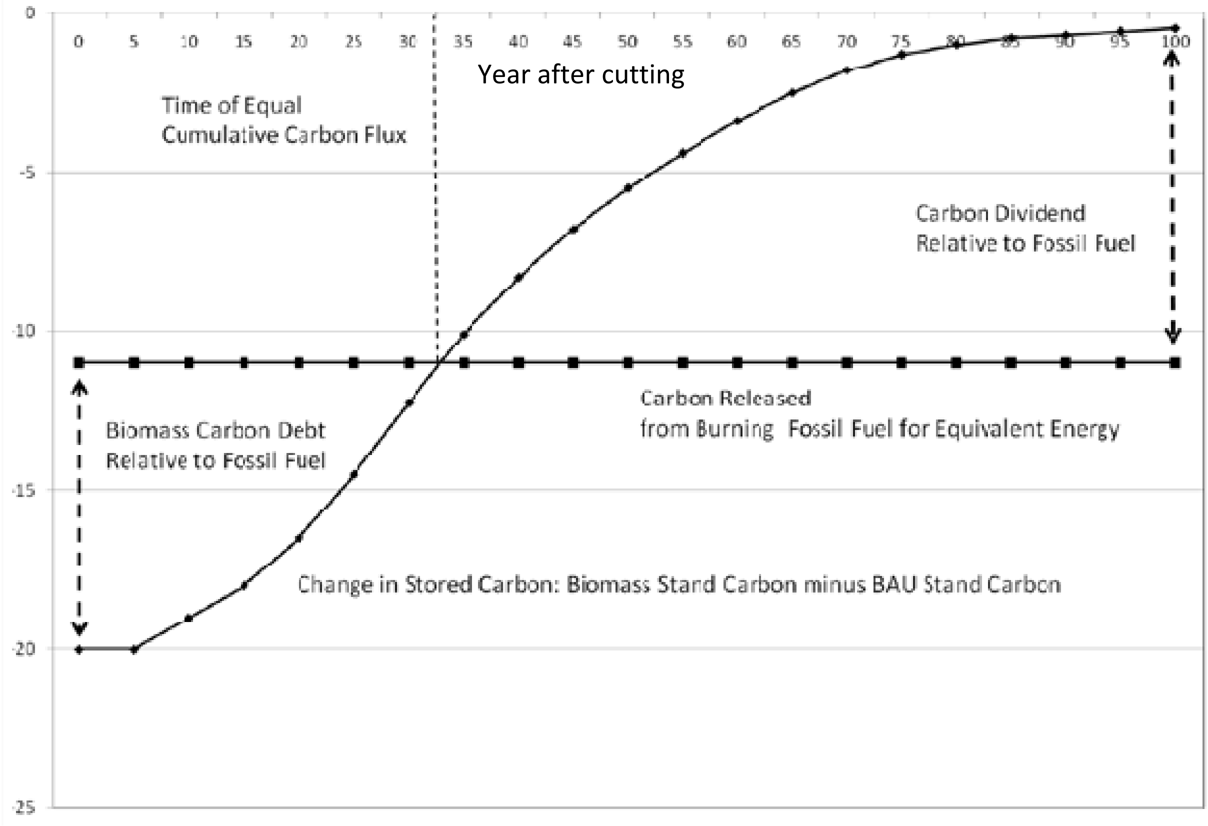


Figure 2. Biomass carbon debt under the biomass scenario, relative to carbon emissions from fossil fuel use, for forest cutting from a single year. The two lines cross at Year 32, a point where net emissions from biomass have achieved parity with net emissions from fossil fuels. Prior to this point, biomass power represents a carbon debt; after this point, it provides a carbon dividend , but only for a single year's worth of cutting on a particular harvested area. This graph is labeled 6-2b in the Manomet report.

It is important to understand that this curve only describes the recovery of carbon and the net carbon balance on a single acre of land harvested for biomass. The objective of the approach is to track regrowth following harvest through time, to determine the year in which the net carbon release from biomass is equivalent to the net release by an equivalent amount of energy produced by fossil fuels – the "time of equal cumulative carbon flux", which for this plot is approximately at Year 32. However, this does not describe the integrated picture of carbon emissions from a biomass facility, which operates continuously over many years and requires new forest to be cut every year. The integrated picture is more complex and consists of a series of curves, one for each year of cutting. Taking Manomet's graph of recovery on a single acre, above, and changing it to represent several years of cutting produces the following graph, which for the sake of clarity and spacing treats the forest cutting episodes as if they happen every five years, instead of every year as they would in reality:

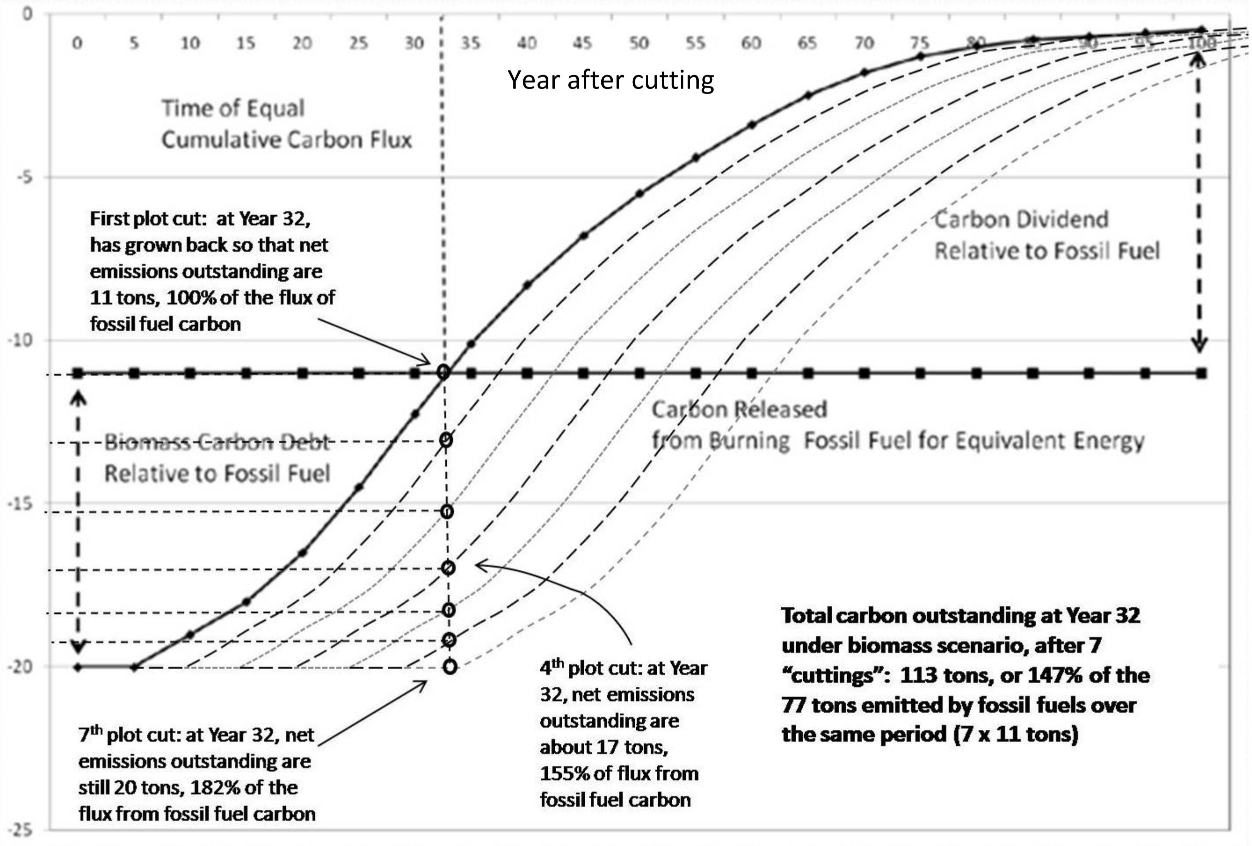


Figure 3. Integrated carbon emissions for a hypothetical biomass facility, assessed over a number of years. Whereas the first plot cut has regrown and achieved parity with fossil fuel emissions by Year 32, this is not the case for all subsequent plots cut, which still have carbon debts outstanding. Emissions from an actual facility, as assessed in this integrated picture, are considerably higher than for the single plot analysis presented above. At Year 32, net emissions from biomass in this hypothetical example are still 147% of those from fossil fuels.

A central problem with the Manomet study is the amount of space the report devotes to discussing the recovery of a single plot after cutting, and the relatively minimal of space used to discuss the integrated picture of total facility carbon emissions. This may be confusing to the typical reader of the report who is unlikely to have time to review it in detail. As can be seen from the analysis associated with the last graph, it takes much longer to achieve parity between biomass and fossil fuel carbon emissions when more than one year of cutting is considered. Whereas the single year analysis finds parity for biomass and fossil fuel emissions at Year 32, cumulative analysis of several years finds that biomass emissions are still 147% of fossil fuel emissions at Year 32.

The Manomet report does make this point. However, the analysis of cumulative effects, which is central to understanding the impact of biomass power, is only found at the very end of the report, where it is described as simply "another way" of looking at the data (this description also occurs in the executive summary, after the explanation of single-year results).

> Another way of comparing the relative contributions of carbon debts and carbon dividends is to **estimate the difference in cumulative net atmospheric carbon emissions between using biomass and fossil fuel for energy at some future point in time**. Due to the importance of demonstrating progress in reducing greenhouse gas emissions by 2050 as part of the Massachusetts Global Warming Solutions Act, we have provided such a comparison for our six harvest scenarios in Exhibit 6-14. **(p. 111)**

Chapter 6, where the modeling results are described, devotes 15 pages to developing the results for the single-year analysis, even presenting charts such as exhibit 6-13 that create the impression that the time to parity under different forms of energy generation (thermal, CHP, and electric-only) is as low as 7 years when oil thermal heat is replaced, *a conclusion that would only be true if a biomass facility operated for a single year, then shut down*. A single page is devoted to discussion of the integrated multi-year analysis.

In the executive summary, these same time-to-parity results for the single-year analysis are presented *before* the discussion of cumulative effects, giving the impression that these are the more significant results. This is a major deficit in the report, particularly since the actual time-to-parity results for the cumulative effects analysis are never calculated.

Assumptions upon which the study conclusions depend

All of the assumptions listed below minimize the calculation of net carbon emissions from biomass. To the extent that these assumptions are not warranted, the Manomet study has underestimated the actual carbon emission impacts of biomass power, calling into question its conclusion that biomass will emit less net carbon over time than other forms of generation.

1. **Large trees are used for biomass fuel**. Because forest regrowth rates in the model are to a large extent a function of the intensity of harvest (with heavier harvests of larger, older trees opening up more space for regrowth to occur), the model achieves maximal regrowth and resequestration of carbon released by biomass burning by assuming that relatively large, old trees are logged for biomass.

2. **Harvested forest stands must not be recut pending carbon sequestration.** The model additionally requires that once a stand has been cut, it must not be re-cut until it has achieved a large proportion of the amount of standing carbon in an unmanaged stand.

3. **A high percentage of tops and limbs are used as fuel**. Because the tops and limbs of trees harvested for timber under the BAU scenario are assumed to stay in the forest and rot, producing carbon, the model assumes almost no carbon penalty for collecting this material and burning it. The model assumes that 65% of all tops and limbs generated on acres harvested for biomass can be removed from the forest for use as fuel, supplying a relatively large "low carbon" source of fuel in the model.

4. **Biomass harvesting only occurs on land that is already being harvested for timber**. The study takes as its BAU assumption that land is harvested for timber, and that all residues are left in the forest in this case, whereas a portion is collected for fuel in the

biomass scenario. The study draws no conclusions concerning carbon dynamics and regrowth in forests cut solely for biomass.

5. **Soil carbon emissions are negligible**. The soil carbon pool is extremely large, and a significant fraction of it is easily decomposed and evolved as CO2 when soils are disturbed by logging. However, the Manomet model completely disregards this source of emissions that are associated with biomass harvesting.

6. **Firewood harvesting is not impacted**. Although indirect land use effects can be major sources of greenhouse gas emissions from biomass harvest, and although the RFP for the Manomet study requested that the study evaluate indirect land use effects, the study does not acknowledge that displacement of firewood harvest by biomass harvest could result in "leakage" of firewood harvesting and more forestland being cut for firewood.

7. **Wood pellet manufacture incurs no more carbon debt than green chips**. Although it is well-established that manufacture of wood pellets requires significant inputs of green wood in excess of the heating value actually embodied in the pellets produced, as well as significant fossil fuel expenditures, the study treats wood pellets as embodying the same amount of carbon and energy as green wood chips.

8. **Wood from land-clearing incurs little carbon debt.** The study concludes that woody biomass from non-forestry sources, such as from land-clearing, will not entail any greater greenhouse gas emissions than forestry wood. However, no modeling is conducted to substantiate this conclusion.

REVIEW OF ASSUMPTIONS

Large trees are used for biomass fuel

Because forest regrowth rates in the model are to a large extent a function of the intensity of harvest (with heavier harvests of larger, older trees opening up more space for regrowth to occur), the model achieves maximal regrowth and resequestration of carbon released by biomass burning by assuming that relatively large, old trees are logged for biomass.

> Alternatively, for some stands, and **especially for slow-growing older stands**, harvesting would be expected to **increase the carbon accumulation rate** (at least after the site recovers from the initial effects of the harvest) and lead to relatively more rapid increases in carbon dividends. Determining the time path for paying off the carbon debts and accumulating carbon dividends is a principle focus of our modeling approach. (**p. 99**)

Although biomass harvesting is often presented as a way of clearing out small trees in overgrown forests, the model does not treat the smallest trees as an available source of biomass fuel, instead setting a minimum diameter of 7 inches for trees to be cut:

> Approximately 65% of the standing trees on Massachusetts timberland are 1"–5" DBH; however, in spite of their large numbers, these sapling-size trees represent only 5% of the timber volume on a tonnage basis (FIA Statistics for 2008). **It would**

> **be cost prohibitive to harvest trees in this size class based on our analysis**. In order to be competitive in current markets, biomass producers would need to harvest trees with low stumpage value that are greater than 5" DBH. (**p. 42**)

> The model suggests that the **minimum size threshold for whole-tree harvesting in Massachusetts is in the range of 7.0–9.0 inches DBH** if the economic objective is to deliver chips to a bioenergy plant at a cost of about $30 (or less) per green ton.(**p. 41**)

> It seems that **pre-commercial thinnings and small trees should be excluded as part of the biomass resource in Massachusetts**—as one logger in Maine told us anecdotally, "the fastest way to go broke in the biomass business is to harvest 2-to-6 inch trees... These model results clearly demonstrate the critical importance of tree size and handling costs in the economics of whole-tree harvesting: **whole-tree harvesting appears to be cost prohibitive for sapling-size trees**. (**p. 41**)

The study concedes that some of the harvesting assumptions in the model could decrease the future economic value of the forest:

> However, new biomass markets may cause the harvest of trees that would **eventually develop into valuable crop trees if left to grow**. A straight, healthy 10" oak tree that would someday grow to be an 18" high-value veneer log might be removed too early in order to capture its much lower biomass value today. The misuse of low thinnings to remove biomass **could also remove the future sawtimber crop** as well as the forest structure referred to earlier.(**p. 73**)

Biomass harvesting is often portrayed as a way to create a market for small, low-value understory trees that are removed in thinning operations on commercial timber stands. However, removal of such trees does not cause the same growth and recovery in forest carbon as removing large trees does. Therefore, actual carbon recovery times are likely longer than represented by the harvesting scenarios that Manomet modeled, meaning that carbon debts persist longer.

Harvested forest stands must not be recut pending carbon sequestration.

The model additionally requires that once a stand has been cut, *it must not be re-cut* until it has achieved a large proportion of the amount of standing carbon in an unmanaged stand. However, the study itself acknowledges this assumption is likely unwarranted:

> The scenarios we defined as "biomass" harvests (Biomass 40%, Biomass BA40, Biomass BA60) maintain high growth rates for several decades. Because of this increased growth rate, even the heavier harvested stands can reach almost 90% of the volume that could have been achieved in an unmanaged scenario. So, over a long period of time, biomass harvests have an opportunity to recover a large portion of the carbon volume removed during the harvest. However, this **assumes no future harvests in the stand as well as an absence of any significant disturbance event. Both are unlikely**. (**p. 86**)

Despite acknowledging that it is unlikely that having been cut for biomass, forests would be left uncut until a required level of carbon sequestration had been achieved, some of the central findings of the model depend on this assumption. For instance, the table of cumulative carbon dividends presented in exhibit 6-15, which describes the amount by which carbon sequestration under the biomass scenario would exceed that under the fossil fuel scenario for the 2010 to 2100 period, is based on the assumption that these acres would not be re-cut over this period. Even assuming that every one of the approximately 22,000 acres of private land cut for timber each year[1] were also available to provide biomass, the assumption that no acre could be recut over the 2010 to 2100 period would take a cumulative 1.98 million acres of forest out of production pending carbon resequestration. On a practical level, it seems unrealistic to assume that forests would be left uncut for even much shorter periods, if only because of the difficulties of enforcement. Presuming that biomass fuel would be licensed in some way by the state, the permissibility of any source would depend on future actions – i.e., the ongoing management of land into the future to ensure carbon sequestration – which seems much to ask for an already overburdened state government.

The study does attempt to grapple with the kinds of protections and enforcement that would be necessary to put in place at the state level, noting that many existing protections in forestry are voluntary and are probably not sufficient:

> Although in many cases BMPs are voluntary, water pollution control requirements are not, and therefore landowners are compelled by law to adopt water quality BMPs to avoid legal penalties. This may explain the relatively high rates reported for national compliance (86%) and in the Northeast (82%) (Edwards 2002). Biomass harvesting standards must address several management criteria such as protection and maintenance of forest structure for wildlife habitat, soil nutrient protection, and forest-stand productivity. **These criteria, unlike those for water quality, typically have no legal foundation to compel compliance**. (**p. 69**)

The study concedes that the harvest scenarios upon which their results depend are probably not realistic for other reasons, as well. For instance, the Forest Vegetation Simulator does not have the flexibility to simulate the kinds of harvests that are actually conducted by landowners:

> The impact of different silvicultural prescriptions has been more difficult to evaluate using the FVS model. The present set of scenarios uses a thin-from-above strategy linked to residual stand carbon targets for all harvests. **These types of harvests tend to open the canopy and promote more rapid regeneration and growth of residual trees**. While this silvicultural approach may provide a reasonable representation of how a landowner who harvests stands heavily in a BAU is likely to conduct a biomass harvest, **it is less likely that someone who cuts their land less heavily would continue to remove canopy trees for biomass** (unless they had an unusual number of canopy cull trees remaining after the timber quality trees are removed). More likely in this case is that the landowners would harvest the BAU timber trees and then selectively remove poor quality and suppressed trees across all diameter classes down to about 8 inches. We hypothesized that **this type of harvest would result in a slower recovery** compared to thinning from above. Unfortunately, the complexity of this type of harvest was difficult to mimic with FVS.

---

[1] The study states on p. 31 that an average of 22,000 acres of private land are harvested each year.

> Although project resources were not adequate to manually simulate this type of harvest for all FIA stands, we did conduct a sensitivity analysis for two stands with average volumes. For each of these stands we simulated a BAU harvest removing 20% of the stand carbon, followed by removal of residual trees across all diameter classes above 8 inches down to basal areas similar to the target in Scenario 4. For these two stands, the results, shown in Exhibit 6-11, **do indicate a slowing of carbon recovery profiles** relative to Scenario 4, although two stands are not enough to draw any conclusions about average impacts of this silvicultural prescription. **What can be said is that stands harvested in this manner will probably recover carbon more slowly** than would be suggested by Scenario 4; how much more slowly on average we did not determine; it is clear however that on a stand-by-stand basis the **magnitude of the slowdown can vary considerably**. (**p. 109**)

It is unfortunate that despite acknowledging a number of uncertainties in the text, the Manomet study still presents results for the time required for biomass scenarios to switch from incurring carbon debts to providing carbon dividends as if there is a high degree of confidence in the modeling.

A high percentage of tops and limbs are used as fuel

Because the tops and limbs of trees harvested for timber under the BAU scenario are assumed to stay in the forest and rot, producing carbon, the model assumes almost no carbon penalty for collecting this material and burning it. The model assumes that 65% of all tops and limbs generated from timber harvesting can be used for fuel, supplying a relatively large "low carbon" source of biomass in the model. The study states the rationale as follows:

> In order to project biomass supplies that can be used to meet potential demand from new bioenergy plants, we have assumed that 65% of the tops and limbs from harvested trees can be recovered on acres where silvicultural prescriptions include whole-tree biomass harvests. This percentage was selected for two reasons: 1) **it leaves behind more than enough material to conform to the ecological guidelines** that have been spelled out in Chapter 4; 2) it recognizes that a significant share of tops and limbs remain uneconomic due to timber breakage, small pieces, and small branches. (**p. 39**)

However, the ecological guidelines set out in Chapter 4 are quite general, an issue treated in more detail below, and the reader is left with little confidence that firm ecological guidelines have been set, much less conformed to. It seems likely that selection of 65% as an allowable level of harvest for tops and limbs, which are essentially treated as a low-carbon source of fuel by the model, is actually necessary to achieve the switch from biomass carbon debt to carbon dividend in a timely manner:

> The harvest and use of tops and limbs for biomass can have an **important influence on carbon recovery times and profiles**: tops and limbs decay quickly if left in the forest and so their use comes with little carbon "cost" which tends to shorten carbon recovery times. **Conversely, if tops and limbs from a biomass harvest of cull**

> **trees were left in the woods to decay, this "unharvested" carbon would delay recovery times, effectively penalizing wood biomass relative to fossil fuels**.(**p. 109**)
>
> **When tops and limbs are left on-site, all three scenarios show net carbon losses between the initial period and the 10-year mark**; in addition, **carbon losses in year 10 are substantial** relative to the recovery levels in the scenarios in which tops and limbs are taken and used for bioenergy. (**p. 110**)

In other words, it seems likely that the Manomet study would not have been able to portray biomass with even as favorable a carbon profile as it did, had a smaller percentage of tops and limbs been considered available as fuel. Given the several permutations on modeling described in the study, it is regrettable the study did not provide more detail about how leaving more tops and limbs in the forest would affect net carbon emissions.

Is it feasible to collect tops and limbs? The study in fact concludes that the practice is economical only in conjunction with whole-tree harvesting:

> As discussed in the wood supply analysis in Chapter 3, the **harvest of tops and limbs would likely be economical only when harvested with whole-tree systems**. Biomass harvested in this manner can be used for any type of bioenergy technology. However, biomass can also be harvested with traditional methods or cut-to-length methods when these systems are preferred due to operating restrictions and/ or landowner preferences. These roundwood operations tend to be more costly, **but yield higher-quality bole chips that are preferred by thermal, CHP and pellet facilities**. Importantly, leaving tops and limbs behind as forest residues would **increase carbon recovery times** for bioenergy technologies that utilize the bole chips that are produced. (**p. 109**)

The distinction between facilities that use just chips from boles/ trunks and those that use whole-tree chips is an important one. Many small thermal biomass facilities depend on "higher quality" wood produced from boles, wood that is cleaner-burning and more consistent in quality. Pellet manufacture also preferentially uses bole wood. Questions of how preferentially harvesting for bole wood will affect the total amount of trees cut for clean chips and pellet feedstock are just starting to be explored, but given the Manomet study's endorsement of the thermal and CHP facilities that prefer these higher quality wood sources, it is unfortunate that the study does not explore these questions in more detail.

Soil nutrient implications of taking tops and limbs for fuel

The tops and limbs of a tree are the repository of a large share of its total nutrients, and this low-diameter material may actually represent a significant proportion of the biologically available pool of soil nutrients. How much such material should be left after logging not only to maintain these nutrient stocks, but also to protect soils against erosion and provide wildlife habitat, is the focus of many questions concerning the responsible use of woody biomass. Regarding the importance of leaving tops and limbs for forest ecological function, the Manomet study relies heavily on studies from the Forest Guild, specifically the Evans and Kelty "Ecology of Deadwood" report, which is included in an appendix to the study. The Manomet study repeats the conclusions of Forest Guild studies that there is little consensus regarding how much material should be left:

> A review of scientific data suggests that when both sensitive sites (including low-nutrient) and clearcutting with whole-tree removal are avoided, then nutrient capital can be protected (see also Hacker 2005). **However, there is no scientific consensus on this point because of the range of treatments and experimental sites** (Grigal 2000). It is important to emphasize that the **impact on soil nutrients is site dependent**. Low-nutrient sites are **much more likely to be damaged** by intensive biomass removal than sites with great nutrient capital or more rapid nutrient inputs. A report on impacts of biomass harvesting from Massachusetts suggested that with partial removals (i.e., a combination of crown thinning and low thinning that removes all small trees for biomass and generates from **9 – 25 dry t/ac** or 20 – 56 Mg/ha) **stocks of Ca, the nutrient of greatest concern, could be replenished in 71 years** (Kelty et al. 2008). The Massachusetts study was based on previous research with similar results from Connecticut (Tritton et al. 1987, Hornbeck et al. 1990). Leaching, particularly of Ca due to acidic precipitation, can reduce the nutrients available to forests even without harvests (Pierce et al. 1993). However, the Ca-P mineral apatite may provide more sustainable supplies of Ca to forests growing in young soils formed in granitoid parent materials (Yanai et al. 2005). (**p. 141** of Manomet report).

The Kelty study cited in the report concluded that removal of just 9 – 25 dry tons of biomass per acre, an amount similar to that contemplated in the Manomet harvesting scenarios, could lead to soil nutrient depletion that lasted seven decades. The Manomet study downplays this finding, instead calling for more study of the issue and formulation of site-specific guidance for how much top and limb material can be removed:

> In Massachusetts it will be **important to identify the soils where there are concerns regarding current nutrient status** as well as those soils that could be degraded with repeated biomass harvests. (**p. 75**)

Despite acknowledging considerable uncertainty regarding the ecological sustainability of removing a large proportion of tops and limbs, the Manomet study does not present any substantive data or nutrient budgets to support the conclusion that 65% of tops and limbs can be removed at all sites. However, the carbon accounting component of the study relies on at least this much material being available, implicitly assuming that the maximum amount of tops and limbs can be removed in every case.

Although the study does call for the creation of guidelines on how much material should be retained in the forest, there is little discussion of how such guidelines could be practically implemented or the unusual amount of knowledge about a site's nutrient status and both <u>past and future</u> harvest plans that would be required of foresters when deciding how much material to leave:

> In areas that do not qualify as low-nutrient sites, where 1/3 of the basal area is being removed on a 15- to 20-year cutting cycle, it is our professional judgment that **retaining 1/4 to 1/3 of tops and limbs will limit the risk of nutrient depletion** and other negative impacts in most forest and soil types. Additional retention of tops and limbs may be necessary **when harvests remove more trees or harvests are more frequent**. Similarly where the **nutrient capital is deficient** or the **nutrient status is unknown**, increased retention of tops, branches, needles, and leaves is recommended. **Conversely, if harvests remove a lower percentage of**

> **basal area**, **entries are less frequent**, **or the site is nutrient-rich**, then fewer tops and limbs need to be retained on-site. (**p. 48**)

Implementing such protections and ensuring sufficient material is left onsite to maintain soil productivity would also involve foresters willingly forgoing a revenue stream from which they would otherwise profit.

With regard to use of tops and limbs from timber harvests as a "low carbon" biomass fuel source, the picture that emerges is that removal of at least 65% of this material is necessary for the Manomet model to reduce the apparent carbon emissions from biomass, since this material is assumed to decompose anyway and thus to represent a negligible addition of carbon if it is combusted. However, the study is not able to say with confidence or produce a body of evidence to demonstrate that removal of this amount of tops and limbs will not deplete soils or damage other forest functions, instead stating that much more detailed study is needed. In sum, it appears that the goals of achieving low carbon dioxide emissions from biomass fuel and maintaining soil nutrient status may be incompatible in many cases.

Biomass harvesting only occurs on land already being harvested for timber

The study takes as its BAU assumption that land is harvested for timber, and that all residues are left in the forest in this case, whereas a portion is collected for fuel in the biomass scenario. The study does no modeling and draws no conclusions concerning carbon dynamics and regrowth in forests cut solely for biomass. Because the BAU scenario assumes that all sawlog residues are left in the forest, this generates a large amount of relatively "low carbon" material to be harvested as fuel under the biomass scenario, because the FVS model treats this material as if it decomposes relatively quickly. The fact that the study does not examine carbon dynamics in stands cut solely for biomass is a considerable omission from the model; in fact, under such scenarios, carbon debts would be considerably longer than the Manomet study concludes.

Soil carbon emissions are negligible

The soil carbon pool is extremely large, and a significant fraction of it is easily decomposed and evolved as CO2 when soils are disturbed by logging. However, the Manomet model completely disregards this source of emissions that are associated with biomass harvesting.

The study states

> Our FVS model simulations captured the carbon dynamics associated with the forest floor and belowground live and belowground dead root systems. **Mineral soils were not included in our analyses, but appear generally not to be a long-term issue**. A meta-analysis published in 2001 by Johnson and Curtis found that forest harvesting, on average, had little or no effect on soil carbon and nitrogen. However, a more recent review (**Nave et al., 2010**) found consistent losses of forest floor carbon in temperate forest, **but mineral soils showed no significant, overall change in carbon storage due to harvest, and variation among mineral soils was best explained by soil taxonomy**.(**p. 83**)

The preceding paragraph was sent to the lead author on the Nave study, to ask whether he agreed with this assessment of his paper's conclusions. From his answer, it seems that the significance of the Nave paper bypassed the Manomet team. Here is Lucas Nave's answer in its entirety, as he requested (emphases added):

> "Thanks for asking about the meta-analysis paper we had in Forest Ecology and Management. My coauthors and I went over every sentence of that manuscript to be sure that we had the whole thing right, and now you've provided a great example of what happens when one statement is considered without the context of the rest of the document.
>
> We did indeed use those exact words: 'variation among mineral soils was best explained by soil taxonomy.' However, we were not referring to the background level of variation in the amounts of carbon (C) stored in different forest soils, which is what is implied by the quote you sent (orig message below). **What we were referring to with that statement was that**, when you assess the degree to which forest mineral soils vary in their C storage responses to harvest, **meta-analysis of the entire database shows that the most important factor controlling that variation is soil type (or taxonomic order**). Hence, a more complete characterization of our study results would have included discussing the two soil taxonomic orders that consistently lost soil C after forest harvesting, and the fact that following certain post-harvest management prescriptions can be used to prevent those losses. In a biome-level sense (ours included all temperate forests), it is true to say that mineral soil C storage doesn't generally change following a forest harvest. But that ignores underlying complexity that matters when you're not just talking about general concepts, but rather a specific location with an actual biomass harvest/C accounting plan on the table. **If our study is used to suggest that it's not necessary to include the mineral soil (typically the largest temperate forest C pool) in a management plan that includes C accounting, then it is being misused**. **The authors of that section of the Manomet report would benefit from closely re-reading our entire paper, which has more detailed, relevant information concerning the effects of forest harvesting on mineral soil C storage.**"

It thus appears that omitting soil carbon losses from the Manomet model means that actual biomass carbon debts are probably larger than the Manomet model concludes, and that time to parity with fossil fuel emissions is longer.

Firewood harvesting is not impacted

Although indirect land use effects can be major sources of greenhouse gas emissions from biomass harvest, and although the RFP for the Manomet study requested that the study evaluate indirect land use effects,[2] the study does not acknowledge that displacement of firewood harvest by biomass harvest could result in "leakage" of firewood harvesting and more forestland being cut for firewood.

---

[2] The RFP for the sustainability study published by the Department of Energy Resources states: "The analysis will consider the carbon stack emissions of combusting biomass, the carbon absorbed by the forest growth, and emissions associated with biomass harvesting, processing, handling, transportation, and address whether there are any indirect land use impacts and the appropriate account for the displaced carbon emissions from fossil fuel otherwise used for energy."

To the extent that tops and branches and other low-value wood cut during timber harvesting are currently being removed as firewood, taking this material for biomass fuel could displace this firewood harvesting and lead to an overall increase in forest cutting. The study also does not consider the potential effects that use of low-value wood for biomass fuel could have on firewood costs.

The study states that firewood harvesting is a significant proportion of the wood removed from Massachusetts forests. The sources of this wood, which include cull trees, dead trees, tops and stumps of growing stock trees, overlap with the types of wood that are harvested for biomass fuel.

> The Timber Product Output reports provide one estimate of fuelwood production in Massachusetts; however, these data are derived from U.S. Census data rather than collected directly from U.S. Forest Service surveys (the source of other TPO data). TPO data indicate that **fuelwood production in Massachusetts in 2006 was 41.3 million cubic feet** (517,000 cords or 1.3 million green tons), **which would suggest that it would have accounted for about 83% of the timber harvest in Massachusetts** (see Exhibit 3C-1.) **According to this report, virtually all of the fuelwood comes from non-growing stock sources, which includes cull trees** (rough and rotten), dead trees, tops and stumps of growing stock trees, and non-forestland sources of trees such as yard trees. (**p. 136**)

However, the study is mixed in its acknowledgement that biomass harvesting could displace firewood harvesting, stating in some places that there are no leakage effects of increased biomass harvesting:

> More importantly for our analyses however, Chapter 6 assumes that the increase harvest intensity for biomass energy wood **doesn't change the disposition of materials that would be harvested absent biomass extraction**. (**p. 82**)

Elsewhere, the study does seem to acknowledge that biomass harvesting could displace other uses of wood, if not firewood specifically, at least under a scenario where biomass is worth more:

> This outlook assumes that biomass stumpage prices rise to $20 per green ton as a result of higher demand from bioenergy plants. A substantial increase in landowner income brings more land into production. Forest biomass fuel becomes a primary timber product, much as pulpwood is today, **and we assume that bioenergy plants can outbid their competitors for pulpwood and low-grade sawlogs and that this material is harvested more intensively as well**. (**p. 49**)

The study seems to acknowledge the impacts this could have on firewood harvesting on public lands, but does not discuss this issue for private lands:

> The main vehicle for achieving the increased biomass production on public lands will be the **diversion of wood from other end uses**: at the projected price levels for biomass stumpage, **bioenergy plants will be able to outbid their competitors for low-grade sawtimber, pulpwood, and residential fuelwood**. (**p. 53**)

However, public land is treated in the report as only a minimal potential source of biomass. Nowhere does the study examine the question of whether increased use of low-value wood as biomass fuel could increase firewood harvesting elsewhere, or whether there might be increases in price for the firewood resource upon which many households depend.

Wood pellet manufacture incurs no more carbon debt than green chips

Although it is well-established that manufacture of wood pellets requires significant inputs of green wood in excess of the heating value actually embodied in the pellets produced, as well as significant fossil fuel expenditures, the Manomet study treats wood pellets as embodying the same amount of carbon and energy as green wood chips.

> Our analyses also considered the carbon debt characteristics of wood pellet technology and CHP systems. **In general, we find that carbon debts associated with burning pellets in thermal applications do not differ significantly from debts resulting from use of green wood chips**. The differences relate primarily to location of GHG emissions associated with water evaporation from green wood rather than the overall magnitude of the lifecycle GHG emissions. (**p. 106**)

However, the conclusion that carbon debts will not differ between green chip- and pellet-fueled facilities will only be true if the two kinds of fuel require the same amount of tree harvesting, and the same amount of production inputs in terms of fossil fuel power, to produce the same amount of thermal energy. Without delving into the complexities of where the energy to drive off moisture is expended (at the pellet plant, where wood heat or fossil fuels are used to dry the pellet material; or in the case of green chips, in the actual combustion process), it is easy to see that this is not the case. The pellet industry prefers the use of bole or trunk wood for pellet production, and thus requires harvesting far more trees to acquire the same amount of wood than if whole tree chipping were used. Thus, even assuming that the only difference between green chips and pellets was the moisture difference in the product, the pellet industry would still require more trees to produce product.

The report cites a pellet industry-funded study[3] to support their conclusion that lifecycle emissions from pellets are approximately equivalent to those from green wood chips:

> Emissions for thermal pellet applications require the addition of emissions from plant operations and for transport and distribution of pellets from the plant to the final consumer. The limited analysis that we have seen for these operations (for example, Katers and Kaurich, 2006) suggest that the increased efficiencies in boiler combustion achieved with pellets approximately offsets most of the increased emissions from plant operations and additional transport of pellets from the plant to their final destination. (**p. 104**)

In fact, the energy and fossil fuels expended during pellet manufacture and drying do appear to be considerable; where fossil fuels are used for drying, the study cited by the Manomet report shows that drying and plant operation require about 13% of the energy inherent in the pellet product itself. To the extent that wood is used to provide process heat at pellet plants, this is an additional wood input in the pellet manufacturing process that has not been accounted for by the Manomet study.

---

[3] Katers, J. and Kaurich, J. 2007. Heating fuel life-cycle assessment. Study prepared for the Pellet Fuels Institute, February, 2007. University of Wisconsin, Green Bay. 54 pp.

The Manomet study also underestimates the amount of trees cut for pellet production because it underestimates typical wood moisture content. Their estimate that 1.575 tons of green wood is required to produce one ton of pellets at 6% moisture (p. 28), depends in part on the assumption that the green wood chips used to make pellet fuels have a moisture content of 40%, an assumption that does not match the standard industry estimate of 45% moisture content for green chips. Even the Katers and Kaurich study cited by the Manomet study itself assumes that green wood has a moisture content considerably higher than 40%:

> Dry wood feedstock can generally be obtained from saw mill waste or other similar industries that utilize kiln dried wood. This study assumed that a dry wood feedstock was available and drying the wood was not necessary, **which would not be the case for wood fuel pellets manufactured from green wood waste**. Green raw materials can often have **a moisture content in excess of 60%.** Moisture content will depend on time of harvest, relative humidity, as well as type of wood harvested. For this study it was assumed that the wood had a harvested moisture content of 55%. (**p. 8, Katers and Kaurich**).

The industry standard is that at least two tons of green wood are required to generate one ton of pellets, a calculation that is used in the commercially available wood products database from RISI, the global wood products information provider. The Manomet study appears to have significantly underestimated the actual amount of trees that would be required to provide pellet fuels.

Wood from land-clearing incurs little carbon debt

The Manomet study concludes that wood y biomass from non-forestry sources, such as from land-clearing, will not entail any greater greenhouse gas emissions than forestry wood. However, no modeling is conducted to substantiate this conclusion.

The report makes about 25 references to wood from land-clearing being a potential source of biomass fuel, but at no point are the carbon implications of this source of fuel critically examined. For instance, the study states

> Our carbon analysis considers only biomass from natural forests. Tree care and landscaping sources, biomass from land clearing, and C&D materials have very different GHG profiles. **Carbon from these sources may potentially enter the atmosphere more quickly and consequently carbon debts associated with burning these types of biomass could be paid off more rapidly, yielding more immediate dividends**. Our results for biomass from natural forests **likely understate the benefits of biomass energy development relative to facilities that would rely primarily on these other wood feedstocks.** (**p. 113**)

This conclusion, which is not substantiated with any analysis, appears to rest on the assumption that all wood from land-clearing must decompose very quickly, as is assumed for tops and limbs cut during BAU harvesting. This assumption is not warranted if the current fate of wood from land-clearing is not known; it is also not warranted if indirect land-use effects are not taken into account with regard to firewood harvesting. To the extent that wood from land-clearing is currently used for firewood, its use as biomass fuel could push timber harvest for firewood into new areas and result in an increase in forest cutting overall.

There is also no consideration of the impossibility for wood on permanently cleared land to regrow, which is the chief way that net emissions are considered to be reduced through time in the conventional biomass harvesting model. In Appendix 1-A, the study cites the Regional Greenhouse Gas Initiative (RGGI) Model Rule for the types of "eligible biomass", which, if used at a facility, generate emissions that can be deducted from the facility's total:

> *Eligible biomass includes sustainably harvested woody and herbaceous fuel sources that are available on a renewable or recurring basis (excluding old-growth timber), including dedicated energy crops and trees, agricultural food and feed crop residues, aquatic plants, unadulterated wood and wood residues, animal wastes, other clean organic wastes not mixed with other solid wastes, biogas, and other neat liquid biofuels derived from such fuel sources (quoted from the RGGI Model Rule,* ***p. 122*** *of Manomet report).*

There is no discussion within the Manomet report of how wood from permanent land-clearing can be considered "available on a renewable or recurring basis" as required under RGGI. Given that biomass facilities currently proposed in Massachusetts are claiming they will use wood from land-clearing as fuel, this is a serious omission in the report.

CONCLUSIONS

As disruptive as the results of the Manomet study could ultimately prove to the biomass industry, the study's conclusions actually likely significantly under-represent the actual carbon impacts of biomass energy. The conclusions that small-scale thermal and CHP biomass applications can repay carbon debts and yield carbon dividends relative to fossil fuels by 2050, and that net emissions from utility-scale biomass power exceed even those from coal after forty years of regrowth, rely on a number of assumptions that minimize the apparent emissions from biomass. These include assuming that large trees, rather than understory cull trees, are used as biomass fuel; that stands cut for biomass are not re-harvested until carbon resequestration has been achieved (a process that requires these stands be locked up from harvesting for decades); that only those lands already cut for timber are harvested for biomass; that a large proportion of "low-carbon" tops and limbs from timber harvesting are available for biomass fuel and that removal of this amount of material will not harm forest ecological function; that soil carbon emissions do not increase with harvesting; that indirect land use effects, particularly leakage of firewood harvesting, do not occur; and that pellet manufacturing does not incur a greater carbon debt than using green wood chips for fuel. In some cases, the report itself acknowledges that these assumptions are not likely justified; in other cases, the report is unfortunately silent on acknowledging the complexity of the carbon equation.

Even making these assumptions, the Manomet study concludes that net biomass emissions at utility-scale facilities still exceed those from coal after forty years, and are dramatically higher than emissions from natural gas. The lesson for New England, which generates much of its power from natural gas, is clear – relying on utility-scale biomass power to provide electricity to the grid causes a net increase in carbon emissions which undermines the emissions reductions goals of the Regional Greenhouse Gas Initiative. The best result that the Manomet model can produce for biomass performance relative to fossil fuels is that biomass carbon dividends in 2050 are on average 17% greater than from oil for small-scale thermal and CHP applications (averaging over the six modeled harvest scenarios) – a result that probably also underestimates actual greenhouse gas emissions from biomass power. In other words, this result depends on waiting 40 years to achieve a reduction in net greenhouse gas emissions that is at best is an extremely optimistic scenario, and likely within the range of model error, given the many assumptions upon which the modeling relies. Over this 40 year period, much may happen to forests. Permanent forest loss due to development is continuing apace at about 5,000 acres per year in Massachusetts, and climate change, including potential effects of warming stress and invasive insects, may increasingly threaten forest carbon sequestration. The results in the Manomet study should thus be viewed by policy-makers as an extreme best-case scenario unlikely to be achievable in reality, and any policy designed to promote small-scale thermal and CHP biomass should be further evaluated with modeling that makes more critical and realistic assumptions. Further promotion of utility-scale biomass should be discontinued immediately as a threat to climate, and forests.