NATURAL CAPITAL INITIATIVE AT MANOMET REPORT

Biomass Sustainability and Carbon Policy Study

Executive Summary

Prepared for:

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EXECUTIVE SUMMARY

BIOMASS SUSTAINABILITY AND CARBON POLICY

INTRODUCTION

This study addresses a wide array of scientific, economic and technological issues related to the use of forest biomass for generating energy in Massachusetts. The study team, assembled and directed by the Manomet Center for Conservation Sciences, was composed of experts in forest ecosystems management and policy; natural resource economics; and energy technology and policy. The Commonwealth of Massachusetts Department of Energy Resources (DOER) commissioned and funded the study.

The study provides analysis of three key energy and environmental policy questions that are being asked as the state develops its policies on the use of forest biomass.

1. What are the atmospheric greenhouse gas implications of shifting energy production from fossil fuel sources to forest biomass?
2. How much wood is available from forests to support biomass energy development in Massachusetts?
3. What are the potential ecological impacts of increased biomass harvests on forests in the Commonwealth, and what if any policies are needed to ensure these harvests are sustainable?

The goal of the report is to inform the development of DOER's biomass policies by providing up-to-date information and analysis on the scientific and economic issues raised by these questions. We have not been asked to propose specific policies except in the case where new approaches may be needed to protect the ecological functioning of forests. We do not consider non-forest sources of wood biomass (e.g., tree care and landscaping, mill residues, construction debris), which are potentially available in significant quantities but which have very different greenhouse gas (GHG) implications.

This Executive Summary highlights key results from our research and the implications for the development of biomass energy policies in Massachusetts. While certain of the study's insights are broadly applicable across the region (e.g., estimates of excess lifecycle emissions from combustion of biomass compared to fossil fuels), it is also important to recognize that many other conclusions are specific to the situation in Massachusetts—particularly greenhouse gas accounting outcomes that depend on the forest management practices of the state's landowners, which likely differ considerably from those in neighboring states. Nonetheless, the framework and approach that we have developed for assessing the impacts of wood biomass energy have wide applicability for other regions and countries.

SUMMARY OF KEY FINDINGS

Greenhouse Gases and Forest Biomass: 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.

The atmospheric greenhouse gas implications of burning forest biomass for energy vary depending on the characteristics of the bioenergy combustion technology, the fossil fuel technology it replaces, and the biophysical and forest management characteristics of the forests from which the biomass is harvested. 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 1). 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.

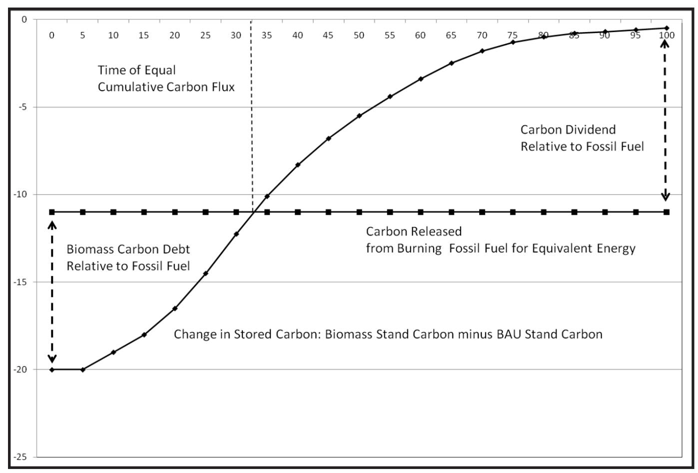

Figure 1 (tonnes of carbon). The schematic above represents the incremental carbon storage over time of a stand harvested for biomass energy wood relative to a typically harvested stand (BAU). The initial *carbon debt* (9 tonnes) is shown as the difference between the total carbon harvested for biomass (20 tonnes) and the carbon released by fossil fuel burning (11 tonnes) that produces an equivalent amount of energy. The *carbon dividend* is defined in the graph as the portion of the fossil fuel emissions (11 tonnes) that are offset by forest growth at a particular point in time. In the example, after the 9 tonnes biomass carbon debt is recovered by forest growth (year 32), atmospheric GHG levels fall below what they would have been had an equivalent amount of energy been generated from fossil fuels. This is the point at which the benefits of burning biomass begin to accrue, rising over time as the forest sequesters greater amounts of carbon relative to the typical harvest.

The initial level of the carbon debt is an important determinant of the desirability of producing energy from forest biomass. Figure 2 provides a summary of carbon debts, expressed as the percentage

of total biomass emissions that are in excess of what would have been emitted from fossil fuel energy generation. Replacement of fossil fuels in thermal or combined heat and power (CHP) applications typically has lower initial carbon debts than is the case for utility-scale biomass electric plants because the thermal and CHP technologies achieve greater relative efficiency in converting biomass to useable energy. As a result, the time needed to pay off the carbon debt and begin accruing the benefits of biomass energy will be shorter for thermal and CHP technologies when the same forest management approaches are used in harvesting wood.

Figure 2: Carbon Debt Summary Table

Excess Biomass Emissions as % of Total Biomass Emissions				
Scenarios	**Coal**	**Oil (#6)**	**Oil (#2)**	**Natural Gas**
Electric	31%			66%
Thermal/ CHP		2%-8%	9%-15%	33%-37%

The absolute magnitude and timing of the carbon debts and dividends, however, is sensitive to how landowners decide to manage their forests. Since future landowner responses to increased demand for forest biomass are highly uncertain, we modeled the recovery of carbon in growing forests under a number of alternative management scenarios.

For a scenario that results in relatively rapid realization of greenhouse gas benefits, the switch to biomass yields benefits within the first decade when oil-fired thermal and CHP capacity is replaced, and between 20 and 30 years when natural gas thermal is replaced (Figure 3). Under comparable forest management assumptions, dividends from biomass replacement of coal-fired electric capacity begin at approximately 20 years. When biomass is assumed to replace natural gas electric capacity, carbon debts are still not paid off after 90 years.

Figure 3: Carbon Debt Payoff

Fossil Fuel Technology	Carbon Debt Payoff (yr)
Oil (#6), Thermal/CHP	5
Coal, Electric	21
Gas, Thermal	24
Gas, Electric	>90

Another way to consider greenhouse gas impacts of biomass energy is to evaluate at some future point in time the cumulative carbon emissions of biomass (net of forest recapture of carbon) relative to continued burning of fossil fuels. The Massachusetts Global Warming Solutions Act establishes 2050 as an important reference year for demonstrating progress in reducing greenhouse gas emissions. Figure 4, comparing 40 years of biomass emissions with 40 years of continued fossil fuel burning, shows that replacement of oil-fired thermal/CHP capacity with biomass thermal/CHP fully offsets the carbon debt and lowers greenhouse gas levels compared to what would have been the case if fossil fuels had been used over the same period—approximately 25% lower over the period under a rapid recovery scenario. For biomass replacement of coal-fired power plants, the net cumulative emissions in 2050 are approximately equal to what they would have been burning coal; and for replacement of natural gas cumulative total emissions are substantially higher with biomass electricity generation.

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%

Forest Biomass Supply: Future new supplies of forest biomass available for energy generation in Massachusetts depend heavily on the prices that bioenergy facilities are able to pay for wood. At present, landowners in the region typically receive between $1 and $2 per green ton of biomass, resulting in delivered prices at large-scale electricity facilities of around $30 per green ton. Under current policies that are influenced by the competitive dynamics of the electricity sector, we do not expect that utility-scale purchasers of biomass will be able to significantly increase the prices paid to landowners for biomass. Consequently, if future forest biomass demand comes primarily from large-scale electric facilities, we estimate the total "new" biomass that could be harvested annually from forest lands in Massachusetts would be between 150,000 and 250,000 green tons—an amount sufficient to support 20 MW of electric power capacity—with these estimates potentially increasing by 50%–100% when out-of-state forest biomass sources are taken into account (these estimates do not include biomass from land clearing or other non-forest sources such as tree work and landscaping). This is the amount of incremental biomass that would be economically available and reflects the costs of harvesting, processing and transporting this material as well as our expectations about the area of land where harvest intensity is likely to increase. Thermal, CHP, and other bioenergy plants can also compete for this same wood—which could support 16 typically sized thermal facilities or 4 typical CHP plants—and have the ability to pay much higher prices on a delivered basis; thus, they have more options for harvesting and processing forest biomass and can outbid electric power if necessary.

Paying higher prices to landowners for forest biomass could potentially increase forest biomass supplies significantly. For this to occur, electricity prices would need to rise, due to substantially higher fossil fuel prices or significant policy shifts. Thermal, CHP, and pellet facilities can already pay much higher prices for biomass at current energy prices, and would remain competitive if prices paid to landowners were to rise significantly. If these prices were

to increase to $20 per green ton, we estimate that supplies of forest biomass from combined in-state and out-of-state sources could be as high as 1.2 to 1.5 million green tons per year. However, this high-price scenario is unlikely given current expectations of fossil fuel prices and existing renewable energy incentives.

Figure 5 shows the potential bioenergy capacity that could be supported from these estimated volumes of "new" forest biomass in Massachusetts. The upper end of the range for Massachusetts forest biomass supplies under our high-price scenario is approximately 885,000 green tons per year—this is close to the annual quantity of biomass that can be harvested without exceeding the annual net growth of the forest on the operable private land base. If additional forest biomass supplies that would be potentially available from out-of-state sources are taken into account, the biomass quantity and number of bioenergy facilities that could be furnished would be 50%–100% higher than shown in this table.

Figure 5: Potential Bioenergy Capacity from "New" Forest Biomass Sources in Massachusetts

	Green Tons per Year
Current Massachusetts Harvest *	325,000
Potential Forest Biomass Supply (Massachusetts only) **	
Current Biomass Prices	200,000
High-Price Scenario	800,000
	Number of Facilities
Electric Power Capacity: Number of 50 MW Plants	
Current Biomass Prices	0.4
High-Price Scenario	1.6
Thermal Capacity: Number of 50 MMBtu/hr Plants ***	
Current Biomass Prices	16
High-Price Scenario	62
CHP Capacity: Number of 5 MW/34 MMBtu/hr Plants ***	
Current Biomass Prices	4
High-Price Scenario	15

Notes: * *Average of industrial roundwood for 2001–2009.*
** *Based on mid-point of the range of volumes estimated for new biomass in Massachusetts.*
*** *Thermal plants are assumed to operate 1800 hours per year, while CHP plants operate 7200 hours per year.*

Forest Sustainability and Biomass Harvests: In Massachusetts, the possibility of increased harvesting of biomass for energy has raised a number of sustainability issues at both the landscape and stand levels. At the landscape scale, potential impacts to a broad range of societal values arise with increases in biomass harvesting. However, in our low-price scenario for biomass, we anticipate that harvested acreage will not increase from current levels—biomass will come from removal of logging residues and poor quality trees at sites that would be harvested for timber under a business-as-usual scenario. Furthermore, in this scenario the combined volume of timber and biomass harvests represents less than half of the annual net forest growth across the state's operable private forest land base. Under our high-price biomass supply scenario, although harvests still represent annual cutting on only about 1% of the forested lands in the state, the total harvest levels approach the total amount of wood grown each year on the operable private forest land base.

Under either price scenario, however, harvests for bioenergy facilities could have more significant local or regional impacts on the landscape. These might include aesthetic impacts of locally heavy harvesting as well as potential impacts on recreation and tourism and the longer-term health of the wood products sector of the economy. We have outlined four general options encompassing a wide range of non-regulatory and regulatory approaches that the state may wish to consider if it determines that further actions are needed to protect public values at the landscape scale.

- Option 1: Establish a transparent self-monitoring, self-reporting process for bioenergy facilities designed to foster sustainable wood procurement practices.
- Option 2: Require bioenergy facilities to purchase wood from forests with approved forest management plans.
- Option 3: Require bioenergy facilities to submit wood supply impact assessments.
- Option 4: Establish formal criteria for approval of wood supply impact assessments—possible criteria might include limits on the amount of harvests relative to anticipated forest growth in the wood basket zone.

At the stand level, the most significant sustainability concerns associated with increased biomass harvests are maintenance of soil productivity and biodiversity. Current Chapter 132 Massachusetts forest cutting practices regulations provide generally strong protection for Massachusetts forests, especially water quality; however, they are not currently adequate to ensure that biomass harvesting is protective of ecological values across the full range of site conditions in Massachusetts. Other states and countries have recently adopted biomass harvesting guidelines to address these types of concerns, typically through new standards that ensure (1) enough coarse woody debris is left on the ground, particularly at nutrient poor sites, to ensure continued soil productivity and (2) enough standing dead wildlife trees remain to promote biodiversity. While the scientific literature does not provide definitive advice on the appropriate practices for Massachusetts' forests, recent guidance from the Forest Guild and other states provides the State Forestry Committee with a useful starting point for developing additional stand level standards that ensure continued protection of ecological values in Massachusetts forests.