NATURAL CAPITAL INITIATIVE AT MANOMET REPORT

Biomass Sustainability and Carbon Policy Study

Chapter 3

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CHAPTER 3
FOREST BIOMASS SUPPLY

3.1 INTRODUCTION AND MAJOR FINDINGS

Massachusetts has attracted the attention of bioenergy proponents and investors, in part due to a substantial rise in timber inventories over the last several decades. Recent studies on the availability of biomass to support new bioenergy plants have focused on incremental forest growth—implicitly treating inventory accumulation as potential supply—and confirmed expectations that inventories will continue to rise significantly. These studies thus concluded that available biomass is more than adequate to furnish several large-scale electric power plants without reducing timber inventories below current levels.

At this juncture, state policymakers require a better understanding of biomass supply, looking at factors beyond forest growth. Policymakers need to know whether the objectives of different energy policies are consistent with available wood supply, and how forest biomass harvests might respond to different economic realities that may be driven policy choices. With this perspective, we have crafted this analysis of forest biomass supplies in 2010–2025 around two central questions:

- How much forest biomass would be supplied at current biomass stumpage prices if there is an increase in demand from bioenergy plants?
- How much would forest biomass supplies increase if bioenergy plants pay higher prices for wood?

Another goal of this supply analysis is to better understand the implications of potential biomass harvest levels for forest health and forest harvesting guidelines.

3.1.1 CONCEPTUAL FRAMEWORK FOR FOREST BIOMASS SUPPLY ANALYSIS

Key Study Features

Our approach focuses on economic issues and landowner behavior and has been developed with an eye toward the availability and quality of relevant data. Unlike previous forest-growth-based studies 4, this study of forest biomass supply in Massachusetts has several features that are different: 1) it is explicitly linked to energy prices; 2) it incorporates data on biomass harvesting and production costs; 3) it provides a detailed analysis of historical harvesting patterns on private lands, thus recognizing landowner willingness to harvest along with harvest intensity; 4) it considers the effect of stumpage prices and per-acre income on landowner behavior; 5) it is closely linked to available timber inventory in terms of accessible areas, mature volumes on private lands, and stocks of low-value trees; 6) it treats public lands separately and utilizes information on historical harvest levels, new Forest Resource Management Plans, and the Forest Futures Visioning Process; and 7) it incorporates sustainability criteria that have been developed and presented in Chapter 4.

We define forest biomass as wood supplied from forest management activities on private lands and public lands. These two ownership categories are considered separately in our analysis because they differ in several important ways: 1) the factors that determine the decision to harvest; 2) forest management objectives on private and public lands, and thus silvicultural prescriptions and harvesting techniques; and 3) harvest intensity and timber yields. In terms of area harvested in Massachusetts each year, private lands dominate with an average of about 22,000 acres harvested annually in 2000–2009[5]. In contrast, only about 4,000 acres of public land were harvested annually in the same time period. Note that we do not include land clearing as a source of forest biomass, because it is not a forest management activity and there are issues related to definitions of renewability. Nevertheless, it is the source of a substantial volume of wood (the average area of land cleared for development in 1999–2005 was estimated to be almost 5,000 acres per year) and so we have provided a separate section on potential biomass volumes from this source.

Incremental Biomass Production

The purpose of this supply study is to evaluate how much forest biomass would be available to furnish the potential expansion of bioenergy capacity and production in Massachusetts. For this reason, our analysis and projections are focused on incremental biomass production, not total production. The volume of biomass chips that has been produced from forest sources historically is considered to be 'utilized' and, since this wood is already accounted for, it is not available to meet the demand from new bioenergy plants. We sometimes refer to this incremental production as 'new' biomass.

Two Biomass Price Scenarios Linked to Energy Prices

We have developed two biomass price scenarios—linked to energy prices—that are intended to provide DOER with guidance as to how much wood may be available to furnish new bioenergy plants. These scenarios recognize the importance of stumpage prices and income in influencing landowner behavior, and the important relationship between delivered biomass prices and harvesting systems/logging costs. This section discusses these scenarios with respect to electricity prices; thermal and CHP

[4] Recent studies using the forest-growth approach to assess biomass availability in Massachusetts are reviewed in Appendix 3-A. While these studies provide useful information on how much wood could be harvested on an ongoing basis without reducing inventories below current levels, they do not address the complex economic and social factors that will determine how much of this biomass would actually be available to furnish new biomass facilities. We have developed estimates of biomass availability using a forest-growth approach in Section 3.2.5 so that they may be compared with the results of the approach that we have developed.

[5] The data and information provided in this section are summarized from the main body of this chapter. Sources and references are contained in the relevant sections.

are addressed in the following section. Note that this assessment is intended to provide estimates of forest biomass potential over the medium term; in the near term, logging and infrastructure constraints (not addressed in this study) could be significant obstacles to harvest increases.

Our starting point is to estimate the potential of forest biomass to supply electric power plants in Massachusetts. This is an area of immediate concern for DOER given that they are now considering proposals for several facilities and the adequacy of wood supplies to furnish these plants is a central issue. In this scenario, our assumptions have been developed to reflect the current pricing environment for electricity and biomass: real electricity prices are assumed to remain near recent levels as are the price of renewable energy credits.[6, 7] Consistent with this assumption, real biomass prices are also assumed to remain near recent levels: delivered wood prices at power plants would be about $30 per green ton, and biomass stumpage prices would average $1–$2 per green ton. We refer to this scenario as the "Low-Price Biomass" scenario.

Our second scenario is intended to provide perspective on the upper bound for forest biomass production if bioenergy demand and prices increase beyond the level established in the Low-Price Biomass scenario. It is not reasonable to specify an absolute maximum for biomass supply since supply is an economic concept which depends on timber prices (and a host of other factors). Thus, we need to specify a "high" biomass stumpage price, and then consider how private landowner harvests might respond to this price level. Forest biomass volumes could still increase beyond this level, but it would be increasingly difficult to due to biophysical, economic, and social constraints and increasingly unlikely due to macroeconomic and energy constraints. We refer to this future outlook as the "High-Price Biomass" scenario.

How high should the biomass stumpage price be in this 'limiting' case? For increased demand from new wood-fired electric power capacity, we have developed an upper-range electric price scenario that leads to real biomass stumpage prices of about $20 per green ton.[8] The significant increase in real electricity prices needed for power plants to purchase wood in this scenario could be triggered by either macroeconomic or policy shifts.[9] Also, policy initiatives (such as REC's) that provide higher income for utilities could be compatible with this level of biomass stumpage prices.[10] We should note that we think that the high level of electricity prices that would drive this scenario is unlikely on the basis of macroeconomic trends and projections of future escalation in coal and natural gas prices. Significant changes in government policies would probably be necessary for this scenario to unfold and could take the form of greater incentives for electric power, or policies that spur substantial investment in thermal, CHP plants, and pellet plants.

How much forest biomass would landowners be willing to supply in response to higher prices? As demand and prices increase, more wood can be supplied from private lands by increasing removals of low-value wood from sites that are already under harvest, diverting wood from other end-use markets (such as pulpwood) to biomass, and increasing the number of acres being harvested. The standard and most direct approach to answering this question would be to estimate the effect of price changes on harvest volumes directly (that is, the timber supply elasticity). We have presented some results from our analysis of this relationship in Massachusetts, but they are merely suggestive due to the poor quality of the data on both harvest volumes and prices.

A second approach would be to rely on the literature for estimates of timber supply elasticities that have been developed in other regions. Available studies generally show that timber supply is very inelastic (that is, price changes have little or no influence harvest volumes).[11] However, these results are not necessarily relevant in evaluating the biomass supply situation in Massachusetts because the characteristics of the landowners, timber inventory, and forest products industry are very different. Importantly, there are two issues not addressed in previous research that are likely to have a significant effect on forest biomass supply behavior in Massachusetts and call for an alternative approach.

The first issue relates to biomass prices and per-acre incomes. Studies which examine the relationship between harvests and prices generally focus on sawtimber prices (and sometimes pulpwood) because these dominate the value of a harvest in most regions.

6 Reference case (or base case) forecasts of electricity prices suggest that real prices will remain relatively flat over the next 15 years, as they play off a projected declining trend in real natural gas prices and a slightly increasing trend in real coal prices (see for example, Annual Energy Outlook 2010: U.S. Energy Information Administration, 2009).

7 The assumption about REC's is important since they provide a significant share of revenue for wood-fired power plants and they can be modified by state policy.

8 The delivered wood and electricity prices consistent with this scenario are discussed later in this report.

9 There are numerous policies under consideration that could lead to such changes (see U.S. Environmental Protection Agency, 2009: EPA Analysis of the American Clean Energy and Security Act of 2009).

10 If electric power plant demand for wood increases but there are no increases in electricity prices that would allow power producers to pay the higher prices needed to generate more wood supply, then direct payments to landowners would be another policy that could lead to more biomass production.

11 There are many issues with these studies that raise concerns, perhaps the most serious being data limitations and errors in measuring price and harvest variables. In addition, many studies estimate binary choice models and only address the question of whether or not price has an effect, not the magnitude of that effect.

However, if biomass prices rise significantly, they can make an important contribution to income and influence landowner decisions.[12] The second issue is the age structure of the inventory in Massachusetts. Many empirical studies consider inventory levels in a broad sense, but none directly consider the age structure of the inventory. A large percentage of the private forests in Massachusetts are now over 60 years old and are ready—if not overdue—to be thinned for landowners interested in commercial timber production[13]; financial incentives could have an important effect on the decisions of these landowners.

These concerns have led us to an approach for the High-Price Biomass scenario that recognizes landowner characteristics, the age structure of the inventory, and the importance of per-acre income levels. While we believe this method provides a better estimate of forest biomass supply than traditional economic approaches, a good deal of uncertainty concerning landowner responses cannot be eliminated since we are considering behavior that is well beyond our historical experience. As demand and prices increase, the confidence intervals grow wider and it is important to recognize and acknowledge this uncertainty.

Biomass Supplies for Thermal and CHP Plants

It is relatively straightforward to extend the above scenarios to evaluate the availability of forest biomass supplies for wood-fired thermal and CHP plants. The cost structure of thermal and CHP plants and their competition with facilities that use oil and natural gas allow them to pay much higher prices for wood than electric power plants. For example, in current markets (assuming oil prices of $3 per gallon), thermal and CHP plants could pay up to $85–$95 per green ton of wood (45% moisture content) and still cover their full cost of capital (based on the analysis in Chapter 2).

In terms of wood supply, one important difference between electric power and thermal/CHP plants is that the latter prefer higher-quality chips that are uniform in size and shape and have low ash content (Maker, 2004; P Squared Group and Biomass Energy Resource Center, 2008). Clean chips and chip specifications in general may add about $10–$15 per green ton to the cost of chip production. Thus, thermal and CHP plants would need to pay $40–$45 per delivered green ton compared to $30 for an electric power plants.[14] Importantly, in the same woodshed, thermal and CHP plants can pay this difference—and much more if necessary—and remain profitable.

At the high end of the supply curve, if the market price of delivered wood for electric power plants is $50–$60 per green ton, thermal and CHP plants would face wood prices in the range of $65–$75 per green ton. This price level is still below the range that these plants could afford to pay today and cover their full costs. Of course, if electric power prices increase due to macroeconomic factors and fuel costs, it is a safe bet that oil prices would be much higher as well; in fact, most forecasts indicate that oil prices will increase faster than electricity prices (which are tied more closely to the cost of coal and natural gas).

In sum, higher-quality chip specifications for thermal and CHP plants shift the supply curve for delivered wood chips upward relative to that of electric power plants. Under reasonable energy price scenarios, when these plants compete for the same wood supply, thermal and CHP plants will be able to outbid electric power plants due to their production economics and the competitive environment of the energy markets in which they operate.

Harvesting Systems and Logging Costs

We have conducted our assessment of wood biomass supply in Massachusetts with and without the harvesting restrictions—particularly with respect to the removal of tops and limbs—that are provided by the guidelines in Chapter 4 of this report.

Our assessment of biomass supply in Massachusetts suggests that if demand increases due to the expansion of electric power plants, it will almost certainly be accompanied by increases in whole-tree harvesting due to the limited supply of other forest biomass and the cost advantages of whole-tree methods. Generally, we assume that whole-tree harvesting can be used on private lands as long as it meets the forest practices standards required by the state. Given the uncertainty regarding the acceptance of whole-tree harvesting (particularly mechanical systems) in Massachusetts, our supply projections allow for the fact that many landowners, foresters, and loggers will still favor alternative harvesting methods.

Thermal and CHP plants are not constrained to use whole-tree harvesting methods because of their ability to pay higher prices for delivered wood chips. These facilities could buy wood procured with log-length methods, in which trees are delimbed and bucked at the stump and the logs are forwarded or skidded to the landing. Log-length methods may be selected over whole-tree methods if management plans call for leaving tops and limbs scattered on the site and/or there is concern about damage to soils or to the

[12] Landowners may also respond differently to an equivalent amount of income from harvesting biomass and sawtimber because the removal of low-value biomass may have a different impact on the value of non-timber amenities than the removal of large trees.

[13] Kelty et al. (2008) reference silvicultural research that indicates that 50 years is the recommended age for first thinning (cited from Hibbs and Bentley, 1983), but indicate that first thinnings in Massachusetts are commonly delayed until stands reach 70 years of age.

[14] While thermal and CHP plants will compete for bole chips, electric power plants can use whole-tree chips from tops and limbs. However, given the wood supply situation in Massachusetts, it appears that electric power plants would need to obtain most of their wood from whole trees and thus could face the prospect of competing directly with thermal and CHP plants for bolewood when operating in the same woodshed.

residual stand (Fight et al., 2006). As noted earlier, our estimates indicate that log-length harvesting methods would add about $10–$15 to the cost of a green ton of chips.

3.1.2 MAJOR FINDINGS AND CONCLUSIONS

Here we summarize the major findings of our wood supply assessment:

Forest Biomass Supply Available in Massachusetts with Low-Price Stumpage

- At current prices for biomass stumpage, we estimate that about 150,000–250,000 green tons of "new" biomass could be harvested annually from forest lands in Massachusetts.[15] Most of this material would be sourced from standing trees due to the small size of the forest industry in Massachusetts, and hence the limited supply of logging residues and limited opportunities for log merchandizing. This wood would be available to electric power, thermal, CHP or other bioenergy plants; however, if the wood is harvested as feedstock for electric power plants, whole-tree harvesting would be necessary to produce chips at $30 per delivered green ton.

- We estimate that virtually all of the "new" forest biomass supply would be harvested from private lands. Given the low price of stumpage in this scenario, biomass producers would have economic access only to low-value wood and it would be harvested almost exclusively on sites that are already being harvested for sawtimber. If whole-tree harvesting operations are established for biomass production, it would also become economical to remove sawtimber logging residues from those same sites. Applying the ecological guidelines provided in Chapter 4 of this report, our projection shows that tops and limbs from industrial roundwood would account for about 15%–20% of the "new" biomass harvest from private lands.

- We find that there would likely be little or no increase in biomass production from public lands. Our review of Forest Resource Management Plans and anticipated forest policies leads us to conclude that the total volume of wood harvested on public lands in 2010–2025 will be about the same level that we have observed during the past decade. We have assumed that biomass fuel will not be diverted from other end uses (such as pulpwood) in this scenario. Logging residues are not projected to contribute to supply because of ecological restrictions and poor economics.

Forest Biomass Supply Available in Massachusetts with High-Price Stumpage

- Higher biomass stumpage prices could dramatically affect the supply of biomass by providing economic incentives that bring more private land into timber production, increase the harvest intensity on all lands that are harvested, and divert wood from pulpwood and other end-use markets to biomass. With our scenario of biomass stumpage prices at $20 per green ton, per-acre income from wood sales could double and we estimate that about 685,000–885,000 green tons of "new" forest biomass could be produced annually in Massachusetts.

- Increased prices would not be expected to lead to higher harvest levels on public lands. However, at these higher stumpage prices, biomass supplies would increase as wood from public lands would likely be diverted from pulpwood to bioenergy plants. The volumes would be small, however, and would account for only about 5% of "new" statewide forest biomass production.

- We have estimated a "sustainable" level of biomass supply using the criteria that harvests do not exceed net growth and that biomass harvests can be maintained at the same level for the foreseeable future. Based on our estimates of operable private land area and our growth estimates in Chapter 5, we have calculated that average annual biomass supply could be 900,000 green tons per year. Thus, the high end of the range that we derived using our approach (885,000 green tons) would be considered "sustainable" by this definition. In addition, our analysis suggests that the "supply" estimates developed using forest-growth approaches would only be consistent with very high biomass stumpage prices.

Forest Biomass Supply Available from the Border Counties

- We evaluated supplies in the border counties (NH, VT, NY, CT, and RI) by considering timberland area, timber inventory, growth rates, ownership characteristics, and forest products production. There is no simple scheme to weight these factors, but our best estimate is that incremental forest biomass production in the border counties would be about 50% greater than that of Massachusetts. The logic of our two scenarios still applies: at low biomass stumpage prices, "new" volumes would be limited because they come primarily from the additional harvest of low-value wood on sites already being logged for other commercial timber; at high biomass stumpage prices, the harvested land base would increase considerably, as would the harvest intensity on these sites.

- Biomass produced in the border region could be consumed in the 'local' market, shipped to Massachusetts, or shipped to the next ring of bordering counties and beyond. The eventual destination for this wood will depend on the location and timing of new capacity investment throughout the region and a variety of other factors such as transportation costs, infrastructure, and supply logistics. While this is a complex problem with a high degree of uncertainty, we think that as a general planning guide it would be prudent to assume that Massachusetts could successfully purchase only half of the available wood. Thus, in the Low-Price Biomass scenario, "new" forest biomass available from the border counties to

[15] The major uncertainty that accounts for this range is the average volume of biomass material removed from an acre. It is also possible that some pulpwood could be diverted to biomass fuel at relatively low biomass stumpage prices, but we have not introduced this potential shift in the Low-Price Biomass scenario.

furnish bioenergy plants in Massachusetts would be about 110,000–190,000 green tons per year. With the assumption of high biomass stumpage prices, forest biomass supplies from adjacent counties would increase to about 515,000–665,000 green tons annually.

Our projections for incremental forest biomass production in Massachusetts and the border counties are summarized in Exhibit 3-1. Although we have provided a range of estimates in this table, there are, of course, a wider set of possible outcomes for these scenarios. This uncertainty is largely due to our limited historical experience with biomass harvesting in Massachusetts, and this becomes a greater concern when we analyze the impact of much higher biomass prices. We have conducted sensitivity analysis of some of our key assumptions within this chapter. Perhaps the most significant source of uncertainty is how private landowners will respond to the prospect of earning higher income from biomass harvests. Another general issue is the acceptance and adoption of whole-tree harvesting by landowners, foresters, and loggers in Massachusetts—this is particularly important in scenarios involving electric power expansion since whole-tree harvesting would likely be necessary due to cost considerations. For the border counties, it is more difficult to address the issue of confidence intervals because our estimates were established relative to Massachusetts, and then scaled down to recognize that facilities outside of Massachusetts would compete in this same woodshed.

Exhibit 3-1: Summary of Forest Biomass Fuel Supplies for 2010–2025

Low- and High-Price Biomass Scenarios 000 Green Tons per Year		
	Low-Price	**High-Price**
Massachusetts		
Private Lands	150–250	650–850
Public Lands	0	35
Total	150–250	685–885
Border Counties	110–190	515–665
Combined Total	260–440	1,200–1,550

Note: Estimates have been rounded for this table.

We have focused on two price scenarios for forest biomass supply, with the high-price scenario intending to provide an approximate upper bound for incremental biomass harvests. Clearly, these two price levels represent only two points on a supply curve that embodies many price-harvest combinations. A few comments on the shape of this curve are appropriate. At current/low price levels, the supply curve for private owners is presumed to be flat suggesting that any volume of forest biomass up to the range of 150,000–250,000 green tons per year could be procured at these prices. At high-end prices, we would expect that the slope of the curve would be relatively steep reflecting landowner resistance to harvesting additional acres due to the greater value that owners at the margin may place on non-timber amenities. This nonlinearity suggests that if bioenergy capacity increases in Massachusetts, it may not be difficult to procure wood at affordable prices in the early stages of expansion, but it could become more problematic as prices rise nearer to the levels assumed in the High-Price Biomass scenario.

3.1.3 POTENTIAL WOOD BIOMASS SUPPLIES FROM OTHER SOURCES

This assessment has focused on the core issue of biomass production from forest sources. It is important to recognize that there are other biomass sources that could potentially make a substantial contribution to the supply of wood available for new bioenergy facilities in Massachusetts. These can be classified into three major categories: 1) wood from land clearing; 2) wood from mill residues and tree care/landscaping sources; and, 3) wood grown in short-rotation plantations.

Wood From Land Clearing

There is a high degree of uncertainty in estimating the area of land that is cleared each year in Massachusetts, the amount of wood removed from that land, and the current disposition of that wood. As a result, it is difficult to estimate the volume of incremental biomass supplies that could be generated from land clearing over the next 15 years. Holding the area of land cleared annually constant, we have calculated that a 10% increase in the recovery rate[16] would yield an additional 30,000 green tons per year of biomass that could furnish an expansion in bioenergy plants. Given current disposal costs for cleared wood and current potential uses for that wood, it would seem that an increase in recovery rates from 30% to 70% (at high biomass stumpage prices) would provide reasonable bounds for the potential supply from this source. This translates to a maximum volume of 120,000 green tons of 'new' biomass given our assumptions on the area of land cleared and the expected diversion of high-quality wood to other end-use markets.

Wood Biomass From Mill Residues and Tree Care/ Landscaping Sources

Among these other sources, the most significant is wood from tree care/landscaping sources. This wood is often referred to as "urban wood" which is somewhat of a misnomer because it includes wood not only from tree care in urban areas, but also wood from tree care from sources such as county parks and recreation areas and maintenance of electric power lines. The term can also be confusing because it is not always clear whether it includes 'urban waste' such as construction debris.

A literature review conducted in 2002 indicated that tree care/ landscaping sources accounted for 1.0 million tons (42%) out the total available supply of 2.5 million tons of non-forest wood biomass in Massachusetts (Fallon and Breger, 2002). However, given the difficulties in estimating this volume (noted in the report), this estimate is perhaps best used to suggest that the potential from

16 We define the recovery rate as the percentage of wood cleared that is used for industrial roundwood products or industrial and residential fuelwood.

these sources may be substantial and worthy of further investigation (importantly, the carbon profile of this material is generally similar to logging residues and thus very favorable compared to that of harvesting standing trees).

Two other important sources of wood biomass that should be noted are mill residues and urban waste (municipal solid waste, and construction and demolition debris). Although mill residues can be a valuable source because they are clean, dry and easily accessed, they are generally fully utilized. Moreover, mill residue supplies in Massachusetts have been declining in parallel with the contraction in lumber production. On the other hand, solid waste and C&D debris may be considered under-utilized, but are expensive to sort and can be difficult to recover due to contamination issues.

Short-Rotation Wood Plantations

DOER and DCR commissioned a study that included an evaluation of the potential of growing short-rotation willow crops in Massachusetts for bioenergy use (Timmons et al., 2008). In light of our forest biomass supply assessment, there are three reasons that the potential of this supply source on marginal agricultural lands may deserve more attention if DOER wishes to promote bioenergy development. First, our economic analysis has shown that the potential to produce forest biomass chips in the current pricing environment and with current policy incentives is significantly less than suggested by previous studies that were focused on forest growth. Second, although BCAP policies are now undergoing revision, the proposed rules offer significant subsidies for the establishment and development of wood energy crops (see policy review in Chapter 1). Third, if carbon emissions are an important consideration in state energy policies, closed-loop short-rotation crops have some obvious advantages when compared to natural forest biomass sources.

3.1.4 REPORT ORGANIZATION

This report is organized as follows. Section 3.2 provides an in-depth analysis of biomass supplies from private lands in Massachusetts. We begin with a review of historical levels of timber harvesting since we believe this is fundamental to understanding future biomass supplies—biomass production often makes economic sense only when integrated with sawtimber harvests. The forecast for low-price biomass supply requires the review of three important topics: 1) costs of whole-tree harvesting; 2) low-value wood supply in sawtimber stands; 3) landowner willingness to increase harvest intensity. In order to generate a forecast of high-price biomass supplies, the discussion is extended to include: 1) the size of the operable land base after adjusting for biophysical factors and landowner characteristics; 2) landowner response to higher wood prices and higher per-acre income levels.

Section 3.3 discusses the potential for harvesting "new" biomass supply from public lands, and covers both historical harvest levels and projections of wood harvests. Our forecasts for forest biomass supplies in Massachusetts are summarized by source for our two biomass stumpage price scenarios in Section 3.4. Section 3.5 reviews potential biomass production from other sources, including land clearing and conversion.

In Section 3.6, we present our assessment of biomass supply from nearby states by evaluating their potential relative to Massachusetts. Key topics covered include timberland area, timber inventory, timber growth, forest products industry status and associated harvesting levels, and landowner characteristics. After developing estimates of potential additional biomass production in the border region, we conclude by discussing some of the factors that determine where this wood might eventually be consumed.

Some of our work and analysis has been presented in several Appendices, which include the following topics: 1) a review of results of previous studies on forest biomass availability in Massachusetts (Appendix 3-A); 2) logging residue data and methods for estimation (Appendix 3-B); 3) firewood production and consumption in Massachusetts (Appendix 3-C); 4) an analysis of biomass potential in southern New Hampshire (Appendix 3-D).

3.2 BIOMASS SUPPLY FROM PRIVATE LANDS IN MASSACHUSETTS

Private timberlands in Massachusetts are by far the most important source of "new" or incremental forest biomass production because of their size and the ability of landowners to adjust their harvest decisions in response to changes in market conditions. The analysis in this section is organized as follows: 1) historical estimates of timber harvests; 2) review of potential supplies from logging residues; 3) projection of biomass supplies in the Low-Price Biomass scenario; and 4) projection of biomass supplies in the High-Price Biomass scenario. Our projections include a review of harvesting costs, and examine the important role of stumpage prices in influencing production volumes.

3.2.1 HISTORICAL ESTIMATES OF TIMBER HARVESTS ON PRIVATE TIMBERLAND

The economics of forest biomass production are generally most favorable when biomass harvests are integrated with sawtimber harvests. In this section, we provide a detailed analysis of historical patterns of timber harvests in Massachusetts to lay the groundwork for our projections of sawtimber and other industrial roundwood harvests. Unless income incentives increase substantially under some scenarios that are described under our High-Price Biomass scenario, the harvesting footprint with biomass is likely to be very similar to that for industrial roundwood alone. Biomass production will then come from increasing the harvest intensity on these lands, by taking tops, limbs, and low-value standing trees.

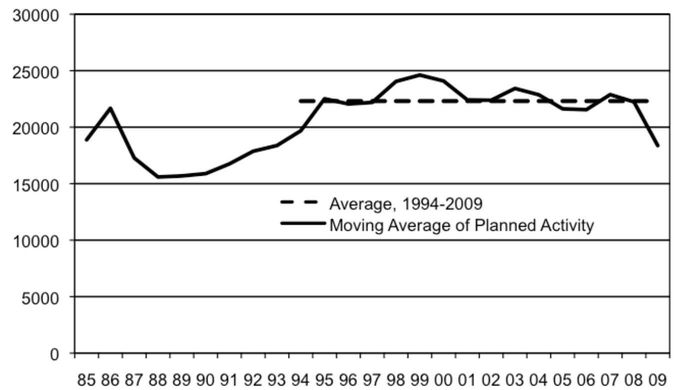
Unlike several states in the Northeast region, Massachusetts does not track and collect data on annual harvest levels. Thus, this analysis relies on forest cutting plans (FCPs) that are required by the state under the Forest Practices Act. Although FCPs have several important limitations with regard to coverage and timing[17], they are the best data source available to identify important long-term trends in harvesting activity in Massachusetts. We have obtained these data for 2001–2009 from the Massachusetts Department of Conservation and Recreation, and for 1984–2000 from research at the Harvard Forest (Kittredge et al., 2009).

The FCP data indicate that the average annual volume of wood "harvested" from private lands in 2001–2009 was 323,000 green tons.[18] Average volumes by end-use market according to these plans were 224,000 green tons of sawtimber, 84,000 green tons of 'pulpwood,' and 16,000 green tons of fuelwood. However, one must be cautious in interpreting these data because wood that is classified as pulpwood may actually be consumed for fuel, either in residential or industrial uses—wood classifications and conversions to green tons are discussed in more detail later in this section.

In order to analyze these data, we first consider acres harvested on all private lands, which are shown in Exhibit 3-2. Harvested acres dropped sharply in the late 1980s, but rebounded by the mid-1990s and have been relatively flat since that time. In fact, the stability of the private land area harvested over the past 15 years is remarkable given the number of factors that influence this trend, including overall demand levels for wood products, and harvest volumes supplied from public lands and land clearing activity. We should note that forest industry lands are only a small portion of the private land base in Massachusetts (harvests on industrial lands account for only about 5% of acreage as well as 5% of volume removed); thus, we have not disaggregated private lands into industrial and non-industrial components as is commonly done in timber supply analysis.

This "stable" trend is more interesting in light of the fact that the area of private timberland in Massachusetts has declined by 20% during this period, from 2.5 million acres in 1985 to 2.0 million acres in 2008 according to FIA data[19] (these data suggest that this shift was primarily due to a transfer of timberlands from private to public ownerships, with land conversion playing a much less important role[20]). While the stability in area harvested is open to various interpretations, the most probable explanation would relate to the small share of land that is harvested. Thus, in spite of the increasing fragmentation of the land base and the small average parcel size of ownership, the data suggest that much of the harvesting in Massachusetts may take place on an operable land base that may not have changed much over this period of time.

Exhibit 3-2: Acres Harvested on All Private Lands, 1985–2009



Note: Derived from Forest Cutting Plans assuming 95% of plans are completed.

As noted above, sawtimber demand is the key driver of harvesting activity on Massachusetts timberland and thus critical to the analysis of potential biomass supply. Over the historical time period, the sawtimber harvest on a per-acre basis has ranged from a low of about 1,600 board feet (International ¼" log rule) in 1991 to a high of 2,200 board feet in 2006 (Exhibit 3-3). The average in 1994–2009 was 2,000 board feet per acre.[21]

The stability in the volume of sawtimber harvested on private lands in 1994–2009 contrasts markedly with the large decline in lumber production during this period. Lumber production in Massachusetts was just over 100 million board feet in 1993 and edged higher to 104 million board feet in 1996; however, production was estimated to have been only 69 million board feet in 2001 and 49 million board feet 2005 (Damery et al., 2006). On public lands, sawtimber harvests were also flat over the past 15 years according to FCP data. One interpretation of these trends

17 Important limitations include: 1) they are pre-harvest plans and thus the volume to be harvested is only an estimate of what was actually cut; 2) once filed, the plans can be implemented over the following two years and there may be extensions (for two additional years); in addition, those who file may choose not to harvest at all; 3) they are only required for wood harvests greater than 50 cords or 25,000 board feet; 4) they are only required if the land remains in forest use and thus do not include land clearing. These issues are discussed in Ch. 132 of the Massachusetts Forest Cutting Practices Act and by Kittredge et al., 2009.

18 Although these data are pre-harvest levels as stated in the Forest Cutting Plans, we refer to them as though they are "actuals," partly for convenience, but also because we have adjusted them, reducing the levels by 5% (based on information reported by Kittredge et al., 2009) and using a distributed lag function to allocate harvests over multiple years to account for the fact that those who file plans have up to two years to harvest with the possibility of extensions.

19 Reference to FIA data is made frequently throughout this report. FIA refers to the Forest Inventory and Analysis National Program which provides detailed data on forests and forestland based on surveys by the U.S. Forest Service.

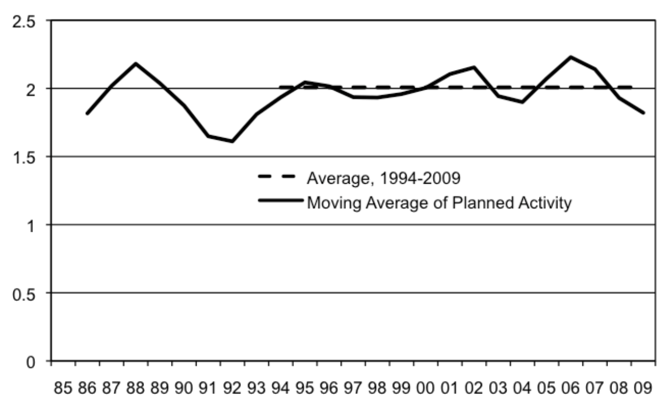
20 It should be noted that it is difficult to quantify accurately the magnitude of these land shifts and different data sources can lead to different conclusions. For example, using the same FIA database and considering forestland in Massachusetts (forestland area is about 5% greater than timberland area) suggests larger losses in the private land base, smaller gains in the public land base, and a much higher share of land lost to conversion. Data that provide direct measurements of land conversion in Massachusetts are discussed later, but these data also have numerous problems and are not consistent with the FIA trends.

21 It is interesting to note that Kelty et al., 2008 report that a 50% overstory thinning on average private lands in Massachusetts would yield 2 MBF (International ¼" log rule) per acre.

would be that the contraction in lumber production was less a function of final demand than of the competitive position of sawmills in Massachusetts, and high-quality sawlogs continued to be cut and shipped out of state to be processed elsewhere. Another factor that needs to be considered is that it appears that land clearing dropped sharply over this time frame; thus, a potentially important source of sawlogs declined substantially and may have increased the demand for sawlogs from private lands.

Most importantly for this study, in spite of major changes in local processing capacity and demand and some significant price swings, acres harvested and sawtimber harvests have remained relatively stable. These trends provide the basis for our projections of future harvest levels in Massachusetts.

Exhibit 3-3: Average Sawtimber Harvest Intensity on All Private Lands, 1985–2009 (000 board feet, International ¼" log rule per acre)



Note: Derived from Forest Cutting Plans assuming 95% of plans are completed.

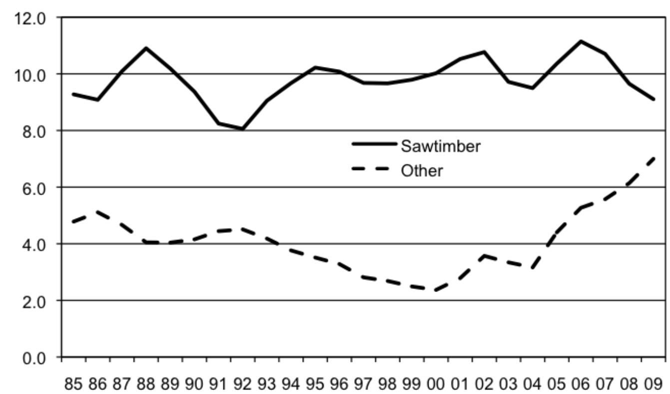
In order to project forest biomass supply, it is also important to consider the volume of timber that is being harvested for other end uses. These calculations provide insight into other demands on the resource base, harvest intensities on timberland, and the potential for additional harvests of biomass. In order to compare the harvest volumes reported on the FCPs, we converted sawtimber (MBF, International ¼" log rule), pulpwood (reported as 128 cubic-foot cords), and fuelwood (reported as green tons) to common units (green tons in this case). Harvest intensity for sawtimber in green tons per acre is contrasted with the other industrial roundwood uses in Exhibit 3-4.[22] Other industrial roundwood fell from about 4 green tons per acre in the early 1990s to only about 2 green tons per acre in 2000. Since that time, other industrial roundwood harvests have climbed sharply, reaching 7 green tons per acre in 2009 (according to plan data, this consists of 5 green tons of pulpwood and 2 green tons of fuelwood).

22 We have combined pulpwood and fuelwood into "other industrial roundwood" because the two classifications are not reliable indicators of their end-use markets. Some pulpwood—perhaps more appropriately referred to as cordwood—can be cut and split for firewood, and may be chipped for biomass. Fuelwood is comprised of roundwood that is processed for residential firewood, and also wood that is chipped for industrial biomass use.

We should also note that our analysis of historical timber harvests includes only a small percentage of the total volume of firewood that is cut and consumed in Massachusetts. FCPs are required only for harvests that exceed 50 cords and it appears that most firewood is produced in much smaller operations. This is consistent with Massachusetts landowner surveys that suggest that many owners of small parcels are interested in firewood harvests, but not harvests of industrial roundwood.

Exhibit 3-4: Average Harvest Intensity on All Private Lands, 1985–2009

Sawtimber compared with Other Industrial Roundwood (green tons per acre)



Note: Derived from Forest Cutting Plans assuming 95% of plans are completed.

For this study, we have assumed that residential fuelwood harvests do not have a significant impact on the potential for forest biomass supply since most of the biomass for industrial use is likely to come from larger harvesting operations. However, there is an interface between the two sectors as some residential fuelwood does get cut during industrial roundwood harvests, and sometimes in follow-up harvests if crews move in to remove smaller wood or standing dead wood. This area may deserve additional study because of the large volume of firewood production in Massachusetts, which we estimate may be two-to-three times the volume of industrial roundwood harvested (see Appendix 3-C).

3.2.2 LOGGING RESIDUES

Most studies of potential forest biomass availability start with logging residues because: 1) they represent a substantial volume of wood (4.5 billion cubic feet in the U.S. in 2006, which compares with 15.0 billion cubic feet of roundwood harvested for all products (Smith et al., 2009); 2) their removal has been considered integral to forest and ecological health in many situations due to potential fire hazard and insect damage; 3) they are perceived to be underutilized and have additional value as product output; 4) they are assumed to be the most easily procured—and thus the least costly—source of biomass supply from forests. Logging residues have been a central focus of many studies (for example, the "Billion-Ton-Study," Perlak et al., 2005) and are considered a key source of forest biomass fuel.

3.2.2.1 Logging Residue Generation

Here we consider the potential volume of forest biomass supplies from logging residues in Massachusetts. The primary source of logging residue data in most studies is the Timber Products Output (TPO) reports from the U.S. Forest Service. These data could not be used directly for Massachusetts due to problems in the underlying database (see Appendix 3-B for a full discussion of the logging residue data). In addition, the TPO methodology tends to overstate the volume of logging residues available for biomass fuel because the data include a significant volume attributable to breakage and residual stand damage.

For these reasons, we have devised an alternative approach in which we estimate the volume of tops and limbs associated with harvesting trees of varying diameter classes (the derivation of these estimates is provided in 3-B). When these percentages of top and limb material are applied to recent industrial roundwood harvest levels, they suggest that the total volume of "logging residues" generated on private lands in Massachusetts is on the order of 100,000 green tons per year.[23]

3.2.2.2 Logging Residue Recovery

Most studies that evaluate the availability of logging residues make the assumption (sometimes implicitly) that the bulk of logging residues are delivered to a landing as part of normal harvesting operations. In these logging operations, a tree is assumed to be delivered to the landing for the value of the sawlog and pulpwood, while the "wastewood" is assumed to be a by-product of the operation with zero costs for "delivery" to a landing. With these assumptions, the portion of the tree that could be considered biomass fuel is inexpensive and available for the cost of chipping and transport to a bioenergy facility. While this may be true in many regions, it is generally not the case in Massachusetts where logging operations commonly consist of manual felling, bucking into logs in the field at the stump, and cable skidding or forwarding; thus, most tops and limbs remain on the ground where the trees are felled.

While it may be feasible to recover scattered logging residues in some circumstances, it seems fair to conclude that biomass supply from logging residues in Massachusetts would be minimal without some modifications to existing harvesting operations. Although these logging residues do have the advantage of having been felled at no cost to the biomass producer, the high cost of collection and delivery to a central location would generally be prohibitively expensive.

In order to produce biomass competitively from tops and limbs, whole-tree harvesting operations would likely be necessary to reduce the costs of landed residue material. Rather than topping and limbing felled trees at the stump, trees could be skidded to a landing with some portion of the top and limbs remaining intact. Tops and limbs could then be removed at the landing and chipped there. If biomass is produced in this manner, the primary costs would be chipping (about \$6–\$7 per green ton for slash) and transport from the landing to a bioenergy plant (directly dependent on distance, but averaging about \$8–\$12 per green ton).[24] Thus, total delivered costs would be \$14–\$19 per green ton.[25]

3.2.2.3 Forecast of Forest Biomass Supply from Logging Residues on Private Lands

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. Some issues, such as difficulties in handling large hardwood crowns, encompass both ecological and economic concerns.

Harvests of logging residues have been considered in conjunction with harvests of standing forest biomass in the following sections. We did not consider it useful to develop a separate biomass supply scenario for only logging residues. Biomass production from logging residues would be widely dispersed and given historical harvest levels, it would amount to only about 2–3 green tons on an average acre. It may be feasible to economically recover this material in some locations with small chippers and chip vans. However, in the broader context of biomass markets, the economic case for producing forest biomass makes more sense when more volume is produced on a per-acre basis. Thus, our projections of biomass supplies from logging residues are combined with harvests of other low-value standing trees and these projections are discussed below.

3.2.3 LOW-PRICE BIOMASS FROM PRIVATE TIMBERLANDS

At this stage of the analysis, we remain focused on biomass supplies from acres that are already under harvest for sawtimber and other industrial roundwood products. We restrict the potential for forest biomass to this footprint because of our assumption that biomass stumpage prices remain near recent levels. As shown in Exhibit 3-5, stumpage prices for forest biomass chips averaged

23 One shortcoming of this approach is that it is not possible to estimate how much of this topwood and limbwood may already be utilized for products (due to differing utilization standards), or harvested for firewood.

24 These data are based on the combination of a literature review and informal survey of industry professionals.

25 Although we have assumed that tops and limbs are free at the landing in this case, increased competition for this material in response to higher biomass demand would likely cause the value of the wood to be bid higher, thus raising the cost of delivered wood. There are also some additional logging costs associated with piling or 'putting up' the material at the landing.

only $1–$2 per green ton in southern New Hampshire in 2008 and 2009. Prices were lower than this in western Massachusetts, but higher in Maine. At these price levels, there will be little incentive for landowners to bring additional acres into production. Historically (at least for the past several decades), timber harvests in Massachusetts have been driven by the demand for sawtimber[26] and in this scenario, this continues to be the case.

Exhibit 3-5: Average Cost of Fuel Grade Chips in Southern New Hampshire

Dollars per Green Ton			
	Delivered	**Stumpage**	**Difference**
2005	$18	$0.8	$17
2006	$23	$0.8	$22
2007	$22	$0.9	$21
2008	$32	$1.2	$31
2009	$30	$1.6	$28

Source: Compiled from average quarterly prices as reported by the New Hampshire Timberland Owners Association's Market Pulse and reported in the Timber Crier magazine.

If the demand for biomass fuel increases in response to an expansion in bioenergy plants, how much "new" biomass could be harvested economically from areas already under harvest for sawtimber in Massachusetts? There are three analytical tasks involved in this projection. First, we address the issue of harvesting costs in Massachusetts: if new biomass demand originates from electric power plants, it would almost certainly be accompanied by an increase in whole-tree harvesting; thus, we start with an analysis of these costs. As shown in Exhibit 3-5, delivered prices for fuel grade chips were about $30 per green ton in 2008–2009 and we are assuming that biomass producers must be close to that target for electric power plants. If new biomass demand originates from thermal and CHP plants, they can pay higher prices for wood chips and thus have the option of using alternative logging methods; in addition, they will be competing for bolewood because of their need for higher-quality chips. Second, we consider the issue of how much low-value timber (that is, timber with low stumpage prices) is available on typical stands that are being harvested for sawtimber? Once we have established how much low-value wood is available and the cost of harvesting it, we then consider whether landowners would be amenable to these higher harvest levels. Using this information, we conclude this section with a projection of how much forest biomass supply would be available at current energy prices.

3.2.3.1 Costs of Whole-Tree Harvesting

In whole-tree harvesting systems, trees are felled by either mechanical or manual means and moved to a landing with most or all of their tops and branches. For our analysis, the costs of whole-tree harvesting in Massachusetts are important because low-value trees that are cut only for biomass chips have to bear the full variable costs of the harvest. If a logging operation is arranged to include biomass chip production, some portion of the cost of getting equipment to the site and setting up operations should also be covered by biomass. These fixed costs are one reason that production volume is an important economic variable in determining the profitability of biomass harvests.

In order to estimate the costs of whole-tree harvesting in Massachusetts, we have conducted a large number of simulations with the Fuel Reduction Cost Simulator.[27] Our main interest in this analysis is to understand the relationship between tree size and the chip production costs because it commonly stated that pre-commercial thinnings and small trees can make a significant contribution to forest biomass supply. This model can also be used to analyze the relationship between chip production costs and a host of other factors such as block size and skidding distance.[28]

We designed this analysis to determine the cost of producing 25 green tons of wood chips on one acre (this volume is based on our analysis of availability in the next section) using different combinations of the size and number of trees.[29, 30] The results are presented in Exhibit 3-6. Although these parameters will differ by individual site, logging equipment, harvest layout and many other factors, we believe our general conclusions are robust.

26 According to Forest Cutting Plan reports for 1984–2003, 95% of harvests included sawtimber.

27 The Fuel Reduction Cost Simulator (FRCS) was developed by the U.S. Forest Service (Fight et al., 2006) to estimate the costs associated with fuel reduction treatments in harvests of whole trees, logs, and chips with a variety of harvesting systems. Although originally developed for forests in the Northwest, the model has been subsequently expanded to other regions (including the Northeast) by Dennis Dykstra and is available on the U.S. Forest Service website at: www.fs.fed.us/pnw/data/frcs/frcs.shtml

28 Our analysis in Task 5 has also utilized this model as a key source in developing estimates of diesel consumption as a component of the life-cycle analysis.

29 Assumptions made so that conditions would be representative of average conditions of Massachusetts include: a) harvest block size of 50 acres, and thus an average skidding distance of 600 feet; b) terrain sloped 5%; c) species mix evenly distributed between softwood and hardwood.

30 We also assumed no move-in costs simply to avoid the issue of how these costs should be shared with sawtimber operations. Move-in costs depend directly on the total tons produced from a given logging operation. In our simulations, producing 25 green tons on 50 acres (1250 tons total) results in move-in costs of $1-$2 per green ton (assuming a 15-mile move) if there is no complementary sawtimber/pulpwood harvest to share the expense. If 25 green tons are produced on 25 acres, then move-in costs per green ton remain about the same because the doubling in fixed costs is approximately offset by the reduction in skidding costs due to shorter hauls.

Exhibit 3-6: The Influence of Tree Size on the Cost of Chips ($/GT, FOB Truck, at Landing) Using Mechanical and Manual Whole-Tree Harvesting

DBH, in	Height, ft	# Trees*	GT/Tree	Mech WT	Man WT
3.0	25	980	0.03	$92	$160
5.0	35	287	0.09	$51	$63
7.0	45	92	0.27	$26	$28
9.0	55	46	0.54	$19	$21
11.0	60	30	0.85	$16	$17
13.0	65	21	1.22	$14	$13
15.0	70	15	1.63	$13	$11

*Notes: * "# Trees" denotes the number of trees at each diameter and height that are required to yield 25 green tons of chips.*

In these calculations, mechanical harvesting uses a drive-to-tree feller-buncher and grapple skidder. Manual harvesting uses chainsaw felling in combination with chokers and cables to skid unbunched trees.

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. In addition to harvesting costs, this estimate allows for: 1) $1–$2 per green ton for biomass stumpage; 2) $8–$12 per green ton for truck transport to the bioenergy plant; 3) recognition of the potential range in model estimates due to site-specific factors and modeling errors.[31] It is important to note that these estimates include machinery and equipment costs. While lower delivered prices may not attract new investment in machinery and equipment, those who already have equipment may choose to operate if they are able to cover only their variable costs of production.

Costs rise exponentially when tree sizes decrease below this level because of the exponential relationship between tree diameter and weight. For example, it would take about 40 trees that are 3-inches DBH to produce one ton of green chips, and thus it would take almost 1000 trees to generate 25 tons of green chips. The number of trees required for 25 green tons could be reduced to about 100 at 7-inches DBH and to only 10 trees if tree DBH was 18 inches.

We also tried to estimate the costs of such logging operations on the basis of a literature review. Available studies show wide variation in costs due to factors such as species, size, quality, terrain, and harvesting equipment: the range extends from about $20-to-$50 per green ton. However, without information that links harvesting costs to timber size, it is not possible to put these estimates in our context. 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. In addition, manual harvesting is much more expensive than mechanical in the small-diameter classes primarily due to the high costs of gathering and skidding unbunched trees. However, the cost curves for these two whole-tree systems converge (and eventually cross) as tree diameter increases. This may be important for management plans on some forests because the two systems will have different impacts on soils and harvest sites.

There are a variety of other harvesting systems that could be employed in removing forest biomass. Thermal and CHP plants often demand higher-quality chips than electric power plants and can pay more for delivered wood; thus, more harvesting options are available for procuring their wood supply. Log-length methods may be selected instead of whole-tree methods if the manager or operator wishes to leave tops and limbs scattered on the site and/or is concerned about residual stand damage (to both soils and standing trees). Two common log-length methods that could be used are cut-to-length (in which mechanized harvesters are used to fell, delimb, and buck trees at the stump) and manual systems (in which chainsaws are used to fell, delimb, and buck trees at the stump) (Fight et al., 2006). Logs can then be debarked and chipped at the landing, or transported to a plant and processed there. Using the FRCS model, we have estimated that these harvesting systems will add about $10–$15 per green ton to the cost of delivered chips.

In future decisions regarding the choice between mechanical and manual harvesting systems, labor issues also are an important consideration. As labor costs rise and the labor force ages, there will be a preference for mechanized harvesting to reduce overall labor costs (including improving safety and reducing insurance premiums for health, liability, and worker's compensation). Labor costs have been identified as having an important role in increasing mechanized harvesting—both whole-tree and cut-to-length—in some regions.

3.2.3.2 The Availability of Low-Value Wood in Massachusetts Forests

The Low-Price Biomass scenario assumes that biomass stumpage will be available for $1–$2 per green ton, which is generally the price we see throughout markets in New England. Here we provide a broad overview of the volume of wood in Massachusetts forests that might be available at such low prices.

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.

31 Modeling errors can arise from many sources. For example, on the fixed cost side, key areas of concern would be the choice of equipment and the calculation of ownership costs for situations in Massachusetts. On the variable cost side, wage costs and diesel costs are important parameters that may vary significantly over time and for different operations.

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.

As discussed earlier, sawtimber harvests are crucial in opening timber stands to biomass production. In Massachusetts, sawtimber harvests will typically take place in stands that are 60-to-100 years old, and FIA data for 2008 indicate that these stands account for 80% of total growing stock volume. Thus, these age classes are by far the most important in identifying the availability of low-cost wood.

Exhibit 3-7 presents the total volume and volume per acre for timber stands classified in the 61–100 year age class in Massachusetts.[32] The key groups that are potential sources of biomass potential are: 1) rough cull trees, with 8% of the average stand volume; 2) grade 4 & 5 trees, with 16% of the volume; and 3) pulpwood trees,33 with 21% of the volume. As reported in this table, the combination of these three groups totals 59 green tons per acre.

Exhibit 3-7: Timber Volume by Tree Grade, Age Classes 61–100 Years in Massachusetts (All Timberland) 000 Acres and Million Green Tons, 2008

	Quantities	Share	GT / Acre
Acres (000's)	2,120		
Total Volume (millions)	273.2	100%	129
Grades 1 & 2	76.4	28%	36
Grade 3	67.9	25%	32
Grades 4 & 5	44.7	16%	21
Pulpwood	57.8	21%	27
Rough Cull	23.0	8%	11
Rotten Cull	3.5	1%	2

Note: FIA data; include all live volume (merchantable volume, tops, limbs, and stumps) in trees ≥ 5 inches DBH.

These data provide only a starting point and need several adjustments before they can serve as a useful upper bound for potential biomass supply. About 30% of grade 4 & 5 trees are greater than 25" DBH; it is not practical to harvest these trees with standard equipment. On the opposite end of the spectrum, about 20% of the pulpwood trees are less than 7" DBH and we exclude half of these (those that may be in the 5"–6" range) because of their higher harvesting costs. Finally, as discussed earlier, some poletimber-size trees are already being harvested for pulpwood/fuelwood end uses; these total about 10 green tons per acre (when adjusted to a comparable basis with the inclusion of tops and limbs).

With these adjustments, the availability of grade 4 & 5 trees is reduced from 21 to 15 green tons per acre; pulpwood is reduced from 27 to 12 tons per acre; and rough cull remains at 11 tons per acre; hence, the revised total of available biomass is 37 green tons per acre. At the risk of appearing overly precise, we should recognize that this timber will continue to grow: if we assume the volume increases by an average net annual growth rate of 2% per year for 7½ years to reflect the average availability in 2010–2025, timber availability rises to 43 green tons per acre.[34]

This review characterizes the potential availability of biomass in broad terms of value and economic accessibility, but there is still a good deal of uncertainty in defining what share of this volume would be available at very low stumpage prices. At this level of aggregation, there is no straightforward way to address this, but it would be reasonable to assume that not more than half of low-grade sawtimber and poletimber could be purchased and harvested at low stumpage prices. This would reduce available supply to the range of 20–25 green tons per acre. On the basis of the information and assumptions presented above, we think that 15 green tons per acre is a good "ballpark" estimate of incremental whole-tree biomass potential—we also consider 20 green tons per acre as a potential upper bound.

3.2.3.3 Landowner Willingness to Harvest

We have identified a significant volume of low-value wood in Massachusetts that could be harvested at low cost, at least with whole-tree harvesting systems. The question that remains is: if the demand for forest biomass from private timberlands in Massachusetts increases (from bioenergy plants established in Massachusetts, nearby states, or overseas), what is the likelihood that we would see increased biomass harvests in conjunction with sawtimber operations? Would landowners be receptive to these changes? In many cases, there could be strong economic incentives, even though they would not be the result of direct, immediate income in the Low-Price Biomass scenario.

While there is a tendency to use landowner surveys to highlight the lack of interest in timber production in Massachusetts, there is a flip side to this viewpoint. Every year, an average of 22,300 acres of private timberland in Massachusetts is harvested, primarily for sawtimber. More than half of the private acreage in Massachusetts (1.2 million acres) is held in parcels that are 50 acres or

32 These volumes represent total tree biomass, not just bole volumes. Since we are not interested in total volumes for individual ownerships, we have combined the data for private and public lands to obtain more accurate estimates of grade shares and per-acre volumes.

33 Pulpwood is defined as 5"–9" DBH for softwood trees, and 5"–11" DBH for hardwoods.

34 Increasing the available volume for growth has the same effect as the inventory variable in standard economic models of timber supply.

larger (Butler, 2008).[35, 36] Owners of 40% of the family forest land (about 650,000 acres) reported that a commercial harvest—sawlogs, veneer logs, or pulpwood—occurred since they acquired the land.[37] The large majority of these owners stated that they harvested trees because the trees were mature and/or they wished to improve the quality of the remaining trees. Suffice to say, while timber production is certainly not the number one priority on most private forest land in Massachusetts, there is a significant component of the forest land base in Massachusetts that is used to generate timber income and would likely be available for more aggressive forest management under the right circumstances.

There are landowners who would like to pursue forest management practices that will enhance the growth of their forest for future commercial timber production. With no market for biomass, these owners need to pay loggers for the cost of harvesting and collecting low-value wood and then may have an additional cash outlay for slash disposal. This could be a substantial investment with a return not seen for many years. However, with a "new" market for biomass fuel, the prices for delivered biomass may be sufficient to cover logging costs and may go beyond break-even to generate positive stumpage values for this material. Thus, harvesting of forest biomass could open the door for alternative forest management practices that are focused on improving sawtimber growth and value.

3.2.3.4 A Forecast of Forest Biomass Supply in Massachusetts with Low-Price Biomass Stumpage

Here we combine the information above to forecast how much "new" forest biomass could be supplied if demand from bioenergy facilities increases while real biomass stumpage prices remain at recent levels. The forecast is intended as an upper limit in the sense that any volume less than this could be produced to meet the demand from bioenergy plants at similar prices.

This projection is predicated on several key assumptions:

- The total land area harvested remains at the historical average.
- One half of this area is managed as it has been in recent years. The same volume of sawtimber and other industrial roundwood will be harvested and no logging residues are harvested for biomass because such operations are not justified by the economics (due to scattered material which is costly to harvest and low volumes per acre). Due to the low level of pulpwood stumpage prices, it is possible that some of this material could be diverted to biomass fuel, but we have not included this potential shift as part of the Low-Price Biomass scenario.
- The other half of the land area harvested receives silvicultural treatments that include whole-tree biomass harvesting.[38] While many landowners will find this management option suitable for their objectives, many others will not look favorably upon heavier logging of their woodlots.
- On the acres that are harvested more intensively with whole-tree methods, 65% of tops and limbs removed for industrial roundwood production are harvested for biomass. (As noted above, pulpwood is assumed not to be diverted to biomass in this scenario.)
- For whole-tree biomass harvests, 15 green tons are cut per acre. Of this volume, 10% is left on the harvest site for ecological reasons (this is equivalent to 1/3 of tops and limbs).

Projections for this biomass harvest scenario are shown in Exhibit 3-8. Land is classified as "½ Current" (land harvested as in recent years) and "½ WT" (land harvested with whole-tree harvesting). Removals per acre average 21.8 green tons in "½ Current," compared to 36.8 green tons in "½ WT," so the removals per acre average 29.3 green tons statewide (compared to 21.8 tons with no additional biomass harvesting). Total forest biomass fuel harvested averages 16.5 green tons per acre in "½ WT," and 8.3 green tons per acre for all private lands in Massachusetts. On the acres where biomass is harvested, 13.5 green tons come from whole trees, while 3.0 green tons consist of residues from sawtimber/pulpwood harvests.

As shown in Exhibit 3-8, this scenario results in 184,000 green tons of additional biomass produced for bioenergy on private lands in Massachusetts. If we increase the biomass removal rate to 20 green tons per acre, the biomass harvest increases to 235,000 green tons. The availability of low-value stumpage (timber that will be sold for only $1–$2 per green ton) and the implications for removal rates is one of the key assumptions in this scenario. Further analysis of these removal rates is provided below.

35 Landowner survey results show that only 43% of the 1.7 million acres that are family owned are 50 acres or larger; however, 88% of the remaining 0.4 million acres held by private owners belong to this size class.

36 The National Woodland Owner Survey provides a substantial of information intended to characterize the behavior of private forest owners in the United States. The main report summarizing these data is Family Forest Owners of the United States, 2006 (Butler, 2008). An on-line version—NWOS Table Maker Ver 1.01—provides users with the ability to create their own customized tables for individual states.

37 Among survey respondents, 25–30 years seems like a reasonable approximation of the average ownership tenure for family-owned land (measured by area, not number of owners): the ownership tenure was 25–49 years for about 40% of the family-owned acreage and 10–24 years for about 30% of the acreage.

38 This assumption is consistent with an electric power demand scenario. It can be easily modified for thermal or CHP demand. We would assume that stumpage prices remain at the same level—thermal and CHP could pay more for stumpage but there is no reason to do so unless competing for higher-value timber. The main difference would be that if loggers do not use whole-tree methods, then tops and limbs would be excluded from the harvest volumes.

The share of land assumed to be harvested using whole-tree methods is also a critical assumption in this scenario. The relationship between biomass production and this share is linear in our formulation since we are working with "average" acres. Thus, if whole-tree harvesting and increased harvesting intensity were used on only one-quarter of all private lands being harvested commercially, production of biomass for bioenergy would be reduced to 92,000 green tons; similarly, if these practices were extended to all commercial harvests on private lands, biomass production would increase to 368,000 green tons.

In the next section, we review related data from nearby states to provide some perspective on these estimates of forest biomass production for Massachusetts. The data from nearby states give us some confidence that our forecasts are in the appropriate range; however, it is difficult to say for sure without more detailed analysis of timber sales and more experience with biomass harvesting in Massachusetts.

Exhibit 3-8: Biomass Supplies Available from Massachusetts Private Lands under the Low-Price Biomass Scenario

Annual Rates, 2010–2025 (Green Tons and Acres)				
	Current	**Low Biomass Price**		
	Harvest	**½ Current**	**½ WT**	**Total**
Area Harvested (acres)	22,300	11,150	11,150	22,300
Wood Removals	**Green Tons per Acre**			
Industrial Removals	21.8	21.8	21.8	21.8
Roundwood Harvest	17.1	17.1	17.1	17.1
Logging Residues Generated	4.7	4.7	4.7	4.7
Left on Site	4.7	4.7	1.6	3.2
Harvested for Biomass Fuel	0.0	0.0	3.0	1.5
Whole-Tree Biomass Removals	0.0	0.0	15.0	7.5
Whole-Tree Harvest	0.0	0.0	13.5	6.8
Logging Residues Left on Site	0.0	0.0	1.5	0.7
Total Removals	21.8	21.8	36.8	29.3
Total Biomass Harvest	0.0	0.0	16.5	
Wood Removals	**000's of Green Tons**			
Industrial Removals	485	243	243	485
Roundwood Harvest	381	191	191	381
Logging Residues Generated	104	52	52	104
Left on Site	104	52	18	70
Harvested for Biomass Fuel	0	0	34	34
Whole-Tree Biomass Removals	0	0	167	167
Whole-Tree Harvest	0	0	151	151
Logging Residues Left on Site	0	0	17	17
Total Removals	485	243	410	652

Notes: "Current Harvest"" is a projection assuming that commercial harvests continue at average levels of the past several years and there is no additional harvesting for biomass. With the increased harvest in the Low-Price Biomass scenario, one half of acres are assumed to be managed in the same way as in the Current Harvest Projection ("½ Current"), and one half of acres are assumed to be managed more intensively using whole-tree harvesting techniques ("½ WT").

3.2.3.5 The Experience in Nearby States

It is useful to consider this outlook for whole-tree harvesting with respect to other states in New England where whole-tree harvesting is now more extensive than in Massachusetts and has a much longer history, and thus might be considered to be in a mature phase. Maine and New Hampshire, with relatively large forest products industries and well-developed wood-fired power plant sectors, may represent the potential for whole-tree harvesting when the industry pursues more aggressive harvest yields with mechanization. State harvest reports indicate the following: in Maine (Maine Forest Service, 2009), forest biomass chips comprised 23% of the total harvest of roundwood products in 2008 (3 million green tons out of a total harvest of 13 million green tons); in New Hampshire (New Hampshire Report of Cut, 2008), the comparable share was 24% in 2000–2006 (790,000 green tons out of a total harvest of 3.2 million green tons, on average). Whole-tree harvesting is not practiced to the same extent in Vermont (Vermont Forest Resource Harvest Summary, various years), where forest biomass chips represented an average of 13% in 2000–2006 (200,000 green tons out of a total harvest of 1.5 million green tons, on average).

For Massachusetts, our Low-Price Biomass scenario (assuming removal of 15 green tons in silvicultural treatments with biomass) yields a harvest share for forest biomass chips of about 33% (this figure includes whole-tree chips from tops and limbs produced in harvesting industrial roundwood). Thus, relative to the northern New England experience, it appears that our scenario would represent a reasonable upper bound for expected outcomes. With assumed biomass removal rates of 20 green tons per acre, the forest biomass harvest share in Massachusetts would increase to 38%, which would seem high, particularly when considered in the context of differences in parcel size, attitudes, and social factors among the states. However, this share will depend on other factors that could favor a higher share in Massachusetts including: the availability of low-value timber on forest stands that are being harvested; and, the extent of alternative outlets for pulpwood along with the relative strength of demand and prices for pulpwood and biomass fuel. Given these uncertainties, we have reported the likely biomass harvest as a range from 150,000 to 250,000 green tons per year, thus spanning the estimates (184,000 and 235,000 tons) provided above.

3.2.4 HIGH-PRICE BIOMASS FROM PRIVATE TIMBERLANDS

How much would forest biomass supplies increase if bioenergy plants could pay higher prices for stumpage? As demand and prices increase, more wood can be supplied from private lands by increasing the volume of wood removed from sites that are already under harvest for industrial roundwood, diverting wood from other end-use markets (such as pulpwood) to biomass, and increasing the number of acres being harvested. This scenario is intended to provide perspective on the upper bound for forest biomass production if bioenergy demand and prices increase beyond the level established in the Low-Price Biomass scenario. It is not reasonable to specify an absolute maximum for biomass supply since supply is an economic concept that depends on timber prices (and a host of other factors). Thus, we need to specify a "high" biomass stumpage price, and then consider how private landowner harvests might respond to this price level. Forest biomass volumes could still increase beyond this level, but it would be increasingly difficult to due to biophysical, economic, and social constraints and increasingly unlikely due to macroeconomic and energy constraints.

The amount that bioenergy plants can afford to pay for wood is a function of the prices they receive for their output. In order to determine a biomass stumpage price in this limiting case, we have assumed that the increase in demand for biomass comes from an expansion in electric power capacity (this assumption does not, however, restrict the usefulness of these results for other types of bioenergy). We have considered several electric price scenarios and selected $20 per green ton as the real biomass stumpage price that would reflect the high end of projections for electricity prices.

A biomass stumpage price of $20 per green ton would be consistent with a significant increase in the price of electricity. Although we have not modeled the dynamics of the harvesting and transport sector, it would be reasonable to assume that these costs would also increase in the near term due to the limited supply of loggers, foresters, machinery, and equipment; thus, delivered wood prices would likely rise well above $50 per green ton. However, we would anticipate that harvesting and transport costs would subsequently retreat with increasing competition and new investment in harvesting machinery and equipment. If these increases in wood costs were fully incorporated into the price of electricity, the impact would be as follows: a $20 per green ton increase in delivered wood prices (from $30 currently to $50) would equate to an increase of 3.2 cents per Kwh; delivered wood prices of $60 per green ton would translate to an increase of 4.8 cents per Kwh; and $70 per green ton would equate to an extra 6.4 cents per Kwh.

There are a variety of other scenarios that could lead to the production of much higher volumes of forest biomass fuel supplies. A key factor distinguishing these scenarios are those in which exogenous factors affect biomass demand directly (examples would be increasing energy production or high export demand for biomass fuel) and those that stimulate other commercial timber production (examples would be housing policy or local product promotion) and increase biomass production as by-product. Generally, biomass prices will rise in cases where there is direct demand stimulus; however, if biomass production rises as a by-product of expanded sawtimber production, biomass prices will remain low. We have assumed that higher biomass demand drives this scenario for two reasons: 1) we are primarily interested in energy policy, and whether forest biomass supplies would be adequate to support an expansion of bioenergy capacity; and 2) the probability of a substantial increase in sawtimber production seems fairly remote.[39]

39 Although lumber production is likely to recover from the recent downturn, we are aware of no studies that project the lumber industry in this region (or in the U.S. North in general) to move above the trend levels of the past decade. Although the sawtimber inventory is rising in Massachusetts, there appear to be few other competitive advantages that would promote an expansion of the sawmilling industry: 1) maturing timber has not resulted in increasing sawtimber harvests in the past two decades; 2) sawmills are closing in Massachusetts, not expanding, and lumber capacity has contracted sharply over the past decade; 3) there are questions about sawtimber quality due to age and years of partial cutting for sawtimber production; 4) there is plenty of 'cheap' timber in competing areas of North America and the world and this is especially true over the coming decade due to delays in timber harvesting that have occurred as the result of the housing debacle of 2007–2010.

There are several issues that need to be considered in gaining an appreciation for how much biomass could be harvested from private lands in Massachusetts if biomass stumpage prices were to rise substantially. These include:

- How large is the operable land base, or in other words, how much land should be excluded from potential harvesting due to biophysical constraints or lack of landowner interest in timber production?
- What is an appropriate harvest schedule for these lands, or over what period might we expect initial harvests to begin and for these lands to be brought under management?
- What share of this land is likely to be drawn into production at different price levels? Harvesting these lands is not an all or nothing proposition, so here we consider how landowners may respond to higher biomass prices and the higher income they may receive from such harvests.

After discussing each of these factors, we provide a forecast of biomass supplies at much higher demand and price levels. We then review some key areas of uncertainty and provide some sensitivity analysis for important assumptions.

3.2.4.1 Estimation of the Size of the Operable Private Forest Land Base in Massachusetts

As shown earlier, the area of private land harvested in Massachusetts has been very stable over the past 15 years, and has not exceeded 25,000 acres during the 25 years for which we have data. This sort of stability would be consistent with a regulated forest where each age class has the same number of acres. However, this is far from the case in Massachusetts, which would be better described as an even-aged forest due to the high concentration of timber in a few age classes: Exhibit 3-9 indicates that about 50% of the acreage on private lands in Massachusetts is in the 61–80 year stand-age grouping (according to Kelty et al., 2008, this is about the age that the first partial thinning is done by most owners interested in harvesting timber). Much of the standing timber inventory in Massachusetts can be considered already mature or approaching maturity; in fact, natural mortality exceeds removals according to the FIA data for 2008.[40] These age-class data suggest that with higher demand and higher prices, harvesting activity could increase and break out of the stable pattern seen historically.

[40] Although these differences are not statistically significant given the large sampling errors associated with both removals and mortality.

Exhibit 3-9: Number of Timberland Acres by Age Class, Private Land Owners, 000's (2004–2008)

Age Class	Acres	Percent
0–20	24	1%
21–40	69	3%
41–50	142	7%
51–60	202	10%
61–70	529	26%
71–80	507	25%
81–90	373	18%
91–100	101	5%
100–120	60	3%
120+	18	1%
TOTAL	2,026	100%

Source: FIA data.

In order to estimate the size of the operable land base on private lands, we rely on a variety of studies and a growing body of research on landowner behavior and factors that affect willingness to harvest. Our general approach, which has become fairly standard, is to reduce the total land area to account for: 1) physical land attributes that limit logging access; 2) small parcels that have a low probability of being harvested due to economic and social factors; and 3) lack of landowner interest in producing timber due to the higher value of nontimber benefits.[41]

Physical factors appear to be relatively unimportant in limiting harvesting activity in Massachusetts. A study by Butler et al. (2010) indicated that 6% of the land in family-forest ownership should be considered unavailable due to biophysical restrictions (primarily slope and hydric physiographic class). Kelty et al. (2008) assumed 7% of forest land was off limits to logging based on a review of forest plans for the Quabbin state forest. For our scenarios, we have reduced the private land area by 5% to account for these factors, and have done so assuming that the restrictions are distributed equally across all groups and size classes.

Our next step is to eliminate parcels of small size. The rationale for their removal is twofold: 1) the attitudes of owners holding small parcels, who tend to be focused on forest benefits other than

[41] We should note that we have not adjusted the total land area for land clearing and conversion. If forest land clearing continues at recent historical rates (which we discuss in more detail in Section 3.5.1), this would mean a reduction of about 70,000 acres of private forest land (only 3% of the total) over the next 15 years. However, as noted earlier, this number could be much larger historically (and going forward), but it is difficult to measure the magnitude of the shift accurately and to document the exact causes of land use changes. However, this shift clearly becomes of greater consequence over a longer time horizon. In addition, land clearing is linked to trends in land fragmentation which has important implications for wood supply.

timber income; and 2) the relatively high costs of wood production on small parcels, which becomes much more important when whole-tree harvesting of biomass fuel is considered. The distribution of acres across ownership size classes is presented in Exhibit 3-10.

Exhibit 3-10: Number of Acres Held by Size of Holdings, Private Land Owners, 000's (2002–2006)

Acre Class	Family	Other	Total	Percent	#Owners
1–9	562	0	562	26%	261
10–19	208	0	208	10%	17
20–49	187	61	248	11%	8
50–99	250	62	312	14%	4
100+	479	370	849	39%	3
TOTAL	1,686	493	2,179	100%	293

Notes: Data are from Family Forest Owners of the United States, 2006 (Butler, 2008). Family owners are defined as "families, individuals, trusts, estates, family partnerships, and other unincorporated groups of individuals that own forest land." Other private owners are industry, corporations, clubs, and associations.

Analysis of landowner attitudes leads to the conclusion that interest in timber production is highly correlated with size of forest holdings, and most owners of small parcels choose to own forest land for reasons other than wood harvesting (although they are often interested in obtaining fuelwood for their own use). For example, for the land held in parcels less than 10 acres, a large majority of the land would not be logged or there would be "minimal activity to maintain forest land" during the next five years, while all respondents said they would not harvest sawlogs or pulpwood.[42]

Butler et al. (2010) suggest that the minimum operable size for timber harvesting may now be about 15 acres, and might be increasing into the range of 30 acres, based on studies that have evaluated the economies of scale associated with modern harvesting equipment. Surveys of minimum economical scale for whole-tree harvesting in Vermont among different stakeholder groups provided responses that were concentrated around 800 green tons per logging operation (Sherman, 2007). Average responses by group were: foresters, 27 acres at 12 cords per acres (810 green tons); logging contractors, 23 acres at 14 cords per acre (805 green tons); chipping contractors, 15 acres at 21 cords per acre (788 green tons). These data suggest that removing an average of 25 green tons of the wood on an acre would require a logging site of at least 30 acres.

Using the information on both landowner attitudes and economies of scale, we have excluded parcels less than 20 acres from the operable land base. While there seems to be evidence that the harvest threshold may now be above this level, we have tried to be conservative in an effort to establish an upper bound to the operable harvest base. In addition, this lower level allows for the use of current equipment and harvesting methods that may be suitable for smaller-scale production for thermal and CHP plants.

Another reason that this threshold is likely to be "conservative" and tend to overstate the amount of land available for harvesting and biomass production is that we have not attempted to project changes in the distribution of land ownership by parcel size in the future. There have been significant reductions in average parcel size historically (Kittredge, 2009). Perhaps more importantly for our analysis, projections suggest that there are likely to be significant increases in private forest land development in central and southeastern Massachusetts from 2000 to 2030 (Harvard Forest, 2010). However, as noted with land clearing, it is difficult to quantify these developments and they are more critical for long-term projections than over the next 15 years.

The final adjustment to the land base relates to landowner attitudes of those who hold parcels that are greater than our threshold of 20 acres. Surveys of family forest owners indicate that those who hold parcels greater than 50 acres also place high value on benefits other than commercial timber production. For example, when asked about their management intentions for the next five years, owners of 56% of the land said they would do nothing or engage in minimal activity as compared to 43% who planned to harvest sawlogs. In response to their reason for owning their land, 71% (again, based on acreage) said for beauty and scenery, 51% said for privacy, and only 34% said to produce sawlogs or pulpwood. At the same time, although timber income is not a primary motivation for owning land, it is still important as owners of 66% of the land reported having a commercial harvest on some portion of their land during their tenure. (All data are from the National Woodland Ownership Survey, on-line data, Butler et al., 2008.)

Based on these survey data, we have reduced the available area of family-owned forest parcels that are greater (or equal to) 20 acres by 20%, which believe is conservative. We have assumed the same adjustment is appropriate for landowners in the "other private" category.

A summary of the results from our process of netting down the private land area to obtain the operable land base is shown in Exhibit 3-11. Our methodology and assumptions reduce the total private land base by 51%, thus leaving 1,071,000 acres of private land available for harvesting in Massachusetts. It is interesting to compare these results with two other studies for Massachusetts that use similar methods, but different assumptions. Kelty et al. (2008) provides two scenarios of private land availability: the higher has 1,072,000 operable acres when 10 acres is used as a parcel size threshold (and other constraints are introduced) [43]; a

[42] The rationale for eliminating these parcels from biomass harvesting becomes more obvious when one considers that the average parcel size in the 1–9 acre size class is only 2 acres.

[43] It is tempting to consider the nearly identical results as confirmation of the validity of one or both approaches. The two approaches are different, and the fact that the results are almost identical is coincidental.

second scenario with a 100-acre threshold shows only 379,000 acres available (which seems somewhat extreme compared to our calculations). Butler et al. (2010) estimate that biophysical and social constraints on private lands might reduce the wood available from family-owned forests by 68% (we show a 59% reduction for the family-forest category). That study also uses a 20-acre threshold, but assumes a much larger reduction due to social constraints.

Exhibit 3-11: Private Land Area Available for Timber Harvesting in Massachusetts

After Deductions for Biophysical and Social Constraints 000 Acres

	Family Owners	Other Private	Total
Total Timberland Area	1,686	493	2,179
Reduce for Physical Constraints (5%)	1,602	468	2,070
Reduce for Small Parcels (< 20 Acres)	870	468	1,339
Reduce for Other Social Factors (20%)	696	375	1,071
Percentage Available	41%	76%	49%

3.2.4.2 Harvest Schedule for the Operable Land Base

The above analysis provides an estimate the *total* size of the operable land base. The 22,300 acres that are already being harvested each year in Massachusetts (and in our Low-Price Biomass scenario) are assumed to be part of this land area. In this new scenario, higher biomass stumpage prices encourage more of the landowners in the operable land base to harvest timber in any given year. How many more acres would be harvested annually? Or, put another way, what would be a reasonable time frame over which to enter these stands and initiate forest management?

We have assumed that 25 years would be a reasonable period over which bring these stands into production. The most important factor is the age structure of these stands. As shown earlier (Exhibit 3-9), the majority of the timber on private lands in Massachusetts has reached the age where it is appropriate to begin thinning based on silvicultural and economic considerations. Another important factor is that the harvest is "scheduled" to accommodate the life expectancy of electric power and other bioenergy plants—the facilities will need some assurance that wood supplies will be adequate on an ongoing basis in order to attract capital for large-scale investments.

If we assume that 1,071,000 acres are available among the private land base in Massachusetts, and that partial harvests will occur on these lands over a 25-year period, then 42,800 acres would be potentially available for harvest each year.

3.2.4.3 The Supply Curve for Landowner's Who Harvest Timber

Our analysis so far has attempted to determine the maximum operable land base, which we have defined as the land that would be harvested at much higher prices. In order to provide more perspective on how much of this land might be accessed, we need to incorporate the assumptions of our High-Price Biomass scenario (biomass stumpage prices averaging $20 per green ton). How do these owners value their nontimber amenities and at what prices would they be willing to become active players in the timber market? Would these price levels be sufficiently compelling to bring all of these lands into production?

The prices required to increase harvests significantly on private lands in Massachusetts are outside the range of recent historical experience. This is obvious from the remarkable stability in harvest levels that we have seen in Massachusetts over the past two decades. In order to assess whether this harvest stability is simply the result of limited price variation or the fact that landowners are insensitive to price swings, we have examined the relationship between timber prices (a weighted index of real red oak and white pine sawtimber stumpage prices) and harvest volumes (sawtimber harvests according to FCPs).

From 1994 to 2005, observations on prices and volumes are tightly clustered and somewhat random: the average absolute deviation from the mean is only 5% for prices and 6% for volumes. However, a much different story emerges over the last few years. From the average of 2003–2005 to 2009, planned sawtimber "harvests" fell about 30%, while real prices dropped 60%. This would suggest a price elasticity of timber supply of about 0.5, a result that is consistent with the conventional wisdom that short-run timber supply is inelastic. Of course, this calculation is merely suggestive of ownership behavior because of the quality of the data and the limited sample size.[44] Furthermore, there is no possibility to consider asymmetric behavior and to evaluate whether landowners would respond in a similar fashion if prices rose sharply.

While this result is interesting, one must also be cautious in extrapolating the conclusions much beyond the historical range: in this scenario, we are considering prices and potential landowner income that is far above historical levels. Over the 2000–2006 period, an average harvest on private lands generated about $400 per acre.[45] If we assume that 20 tons of biomass are harvested on an acre with stumpage prices of $1 per green ton, then per-acre income would rise by $20, or by only about 5%. However, if biomass prices jump to $20 per green ton,

[44] We should underscore this point by recalling that the FCP data report only planned harvests, not actual harvest volumes.

[45] We calculated this value by assuming a harvest of 2 MBF and using a weighted average of median red oak and white pine stumpage prices for western Massachusetts from 2000–2006 (University of Massachusetts Amherst, 2008).

landowners could now earn an additional $400 per acre, thus doubling their income on a per-acre basis.

As biomass stumpage prices increase, we would expect that many of the owners in the operable land base would move to take advantage of the opportunity to earn more income. However, landowners possess a complex set of objectives and it is difficult to say how high prices would need to rise to induce all landowners in the operable land base to harvest biomass. It seems likely that the response would be mixed at $20 per green ton: the financial incentives would likely be too compelling for many to ignore; on the other hand, they are probably not adequate to attract many landowners who place high value on the nontimber benefits of owning forests and are not focused on timber revenue.

A final consideration in making a realistic assessment of the response in biomass harvests to higher prices, particularly in the near term, is the limitations of the labor and logging infrastructure. These would need to expand dramatically to achieve much higher harvest levels and this is another development that would be at odds with recent trends. In assessing the ramifications of this from the perspective of biomass supply, the concern is that harvesting costs may need to rise sharply to attract investment in this sector: this could mean reduced stumpage prices that would mitigate the supply response, or an increase in delivered wood prices that would choke off demand. We would anticipate that harvesting and transport costs would subsequently retreat with increasing competition and new investment in harvesting machinery and equipment.

3.2.4.4 A Forecast of Forest Biomass Supply with Higher Biomass Stumpage Prices

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. It is worth noting that $20 per green ton is equivalent to prices of about $50 per cord and $100 per MBF (International ¼" log rule).

While is a good deal of uncertainty associated with many of the assumptions in this analysis, we believe that developing this forecast provides useful guidance while demonstrating many of the important factors at work. Following the presentation of the results, we provide some sensitivity analysis to key assumptions along with some discussion of the conclusions.

This projection is predicated on the following key assumptions:

- One half of the original harvest footprint of 22,300 acres continues to be managed as it has been in recent years. The same volume of sawtimber and other industrial roundwood will be harvested and no logging residues are harvested for biomass because the economics do not justify such low-volume operations. (As in the previous scenario, the pulpwood produced in this "original" share of the harvest is still assumed to be consumed in this end-use market, although it could easily be diverted to biomass fuel at the assumed price levels.)
- One half of the "original" 22,300 acres receive silvicultural treatments that include whole-tree biomass harvesting.[46] With the introduction of whole-tree harvesting on these acres, trees formerly harvested for other industrial markets are now chipped for biomass. Sixty-five percent of sawtimber tops and limbs are harvested for biomass.
- Of the remaining acreage available annually (20,500 acres, or 42,800 minus 22,300), one half is assumed to be drawn into production for whole-tree biomass harvests. The same amount of sawtimber is removed as on other lands, but all other roundwood harvested is used for biomass.
- For whole-tree biomass harvests, 25 green tons are cut per acre as higher prices increase the harvest intensity of "lower-value" wood. Of this volume, 10% of all material is left on the site for ecological reasons (equivalent to 1/3 of tops and limbs).

Projections for this High-Price Biomass scenario are shown in Exhibit 3-12, with the land classified as "½ Current" (land harvested as in recent years) and "Bal WT" (the balance of land harvested with whole-tree harvesting). Removals per acre average 21.8 green tons in ½ Current, compared to 46.8 green tons in Bal WT; removals per acre average 38.2 green tons statewide, as more acres are brought into production and harvested more intensively than in the Low-Price Biomass scenario. Total forest biomass fuel harvested averages 32.4 green tons per acre in Bal WT, resulting in an average of 21.3 green tons per acre for all private lands in Massachusetts. On the acres where biomass is harvested, 31.0 green tons come from whole trees, while only 1.4 green tons consist of residues from sawtimber harvests.

46 As noted in our previous scenario, this assumption is consistent with an electric power demand scenario and can be easily modified for thermal or CHP demand. The main difference would be that if loggers do not use whole-tree methods, then tops and limbs would be excluded from the harvest volumes.

Exhibit 3-12: Biomass Supplies Available from Massachusetts Private Lands under the High-Price Biomass Scenario

Annual Rates, 2010–2025 (Green Tons and Acres)				
	Current	High Biomass Prices		
	Harvest	½ Current	Bal WT	Total
Area Harvested (acres)	22,300	11,150	21,400	32,550
Wood Removals	Green Tons per Acre			
Industrial Removals	21.8	21.8	12.3	15.5
Roundwood Harvest	17.1	17.1	10.1	12.5
Logging Residues Generated	4.7	4.7	2.2	3.1
Left on Site	4.7	4.7	0.8	2.1
Harvested for Biomass Fuel	0.0	0.0	1.4	0.9
Whole-Tree Biomass Removals	0.0	0.0	34.5	22.6
Whole-Tree Harvest	0.0	0.0	31.0	20.4
Logging Residues Left on Site	0.0	0.0	3.4	2.3
Total Removals	21.8	21.8	46.8	38.2
Total Biomass Harvest	0.0	0.0	32.4	21.3
Wood Removals	000's of Green Tons			
Industrial Removals	485	243	263	506
Roundwood Harvest	381	191	216	406
Logging Residues Generated	104	52	48	100
Left on Site	104	52	17	69
Harvested for Biomass Fuel	0	0	31	31
Whole-Tree Biomass Removals	0	0	737	737
Whole-Tree Harvest	0	0	664	664
Logging Residues Left on Site	0	0	74	74
Total Removals	485	243	1,001	1,243
Total Biomass Harvest	0	0	694	694

Notes: 'Current Harvest' is a projection assuming that commercial harvests continue at average levels of the past several years and there is no additional harvesting for biomass. With the High-Price Biomass scenario, one half of acres of the 'original' footprint are assumed to be managed in the same way as in the Current Harvest Projection ('½ Current'), and balance of the acres are assumed to be managed more intensively using whole-tree harvesting techniques ('Bal WT').

As shown in Exhibit 3-12, this scenario results in 694,000 green tons of additional biomass produced for bioenergy from private lands in Massachusetts. This represents an increase of about 510,000 green tons from our Low-Price Biomass scenario: approximately 1/3 of the additional material comes from increased harvesting of "low-value" timber and the diversion of wood formerly harvested for non-sawtimber industrial uses to biomass; the remaining 2/3's comes from new land that is brought into production. This estimate is intended to represent an upper limit for biomass fuel production in Massachusetts, given the biophysical availability of wood and our assessment of how landowners might respond in a situation with much higher biomass prices. We think this scenario provides a reasonable representation of biomass supply over the medium term with biomass stumpage prices near $20 per green ton (as noted earlier, this analysis does not account for logging and infrastructure constraints that may restrict harvesting in the near term).

There are, of course, many uncertainties in this scenario and thus some sensitivity analysis to key assumptions is important. One crucial assumption is the harvest intensity with higher stumpage prices. Our scenario shows total timber removals averaging 47 green tons an acre for harvested acres that include biomass production. This is more than twice the current average harvest of about 22 green tons per acre. Nevertheless, with biomass stumpage prices of $20 per green ton, bioenergy plants could compete for most timber on a typical stand and could probably consistently outbid lumber producers for Grade 3 sawtimber. If we raise per-acre biomass removals from 35 green tons to 50 green tons (total removals increase to 62 green tons per acre), then the biomass harvest would increase from 0.7 million tons to 1.0 million tons. A further biomass increase to 60 green tons per acre would increase the forest biomass harvest to 1.2 million tons.

Another important assumption is the percentage of operable area that is harvested at higher prices. If we increase the additional area that is brought into production from one-half to two-thirds (from 10,250 acres to 13,667 acres), then the total biomass harvest would increase to about 800,000 green tons. On the other hand, if all acres were brought into production (20,500 additional acres), then the total biomass harvest from private lands would increase to 1.0 million green tons.

Relaxing some of our assumptions increases harvest estimates to 800,000 tons and above. In order to acknowledge these key uncertainties, we have summarized our results as a range from 650,000 to 850,000 green tons. Estimation of the upper end of this range is not scientific, but simply reflects our judgment of the uncertainty in these estimates and the likelihood that harvests could be higher. Importantly, it is a reminder to use caution in using these harvest levels as point estimates.

To put these results in perspective, we have looked to the literature for estimates that may provide useful comparisons of the timber supply response. The response of harvest levels to prices is commonly measured as the timber supply elasticity. For statistical reasons, harvest response to income is not comparable to harvest response to prices. Nevertheless, a few comments on timber supply elasticities are useful. Most econometric studies have found timber supply to be very inelastic for non-industrial private ownerships. In fact, a meta-analysis indicated that of the 19 relevant studies that were reviewed, seven did not find a significant relationship between harvests and prices, that is, prices do not affect harvest decisions (Beach et al., 2003). The study also concluded that there often was not enough information in this research to compute supply elasticities (some were binary choice models). In spite of all the work and research that has been done over the past two decades on this topic, the default value for the supply elasticity that frequently appears for non-industrial private landowners is 0.3, which seems to date from Adams and Haynes (1996).

In our scenario, we have assumed that biomass stumpage prices increase to $20 per green ton. With our price and harvest assumptions, per-acre incomes about double. The High-Price Biomass scenario also shows a 50% increase in acres harvested. If we consider the landowner decision variable to be how many acres to harvest, then our results suggest that a 1% increase in income results in a 0.5% increase in harvest activity. As we have said, this 'elasticity' cannot be directly compared with the timber supply elasticity; however, in terms of first-order approximations, both are inelastic suggesting that the behavior assumed for Massachusetts landowners is not inconsistent with previous research.

3.2.5 POTENTIAL BIOMASS SUPPLY BASED ON FOREST GROWTH

Previous studies of potential biomass supply in Massachusetts (reviewed in Appendix 3-A) have considered supply to be the maximum volume of low-value wood that could be harvested without reducing timber inventories below current levels. It is useful to compute this estimate to see how it compares with our estimate of biomass supply in the High-Price Biomass scenario. This also provides information as to whether our estimate is "sustainable" when using the criteria that harvests do not exceed net growth and that biomass harvests can be maintained at the same level for the foreseeable future.

The calculation of the total "sustainable" volume of biomass that can be harvested in Massachusetts depends critically on how the land area is defined and how net growth is estimated. While there are a variety of ways to make these calculations, here we follow the methodology used by Kelty et al. (2008). We define the land area as the size of the operable land base on private lands, which we have derived to be 1,071,000 acres in the previous section. For the growth rate, we use data from Chapter 5 on the average annual growth of unmanaged "mature" stands in all cover types. The average annual increase in the volume of above-ground live trees over the next 50 years is 1.3 green tons per acre. Thus, the long-term average annual growth (net of mortality) in Massachusetts would be 1.4 million green tons per year. Finally, if we reduce this estimate by 36% to account for timber that would be expected to be consumed as sawtimber (again following Kelty et al., 2008), average annual biomass availability would be 900,000 green tons per year.[47]

The upper end of our estimate of biomass supply of 850,000 green tons per year in the High-Price Biomass scenario is within the range of what would be considered "sustainable" based on the rule of harvest not exceeding growth, and thus would not result in a reduction of timber inventories across the operable land base. However, our sensitivity analysis of biomass supplies showed some projections as high as 1.2 million green tons per year which would exceed 'sustainable' annual volumes as we have defined them here.

The discussion of sustainability in this context raises two important theoretical issues. One issue concerns the approach of calculating 'sustainable' growth rates using initial inventory levels and fixing the time horizon in the future.[48] The majority of the timber inventory in Massachusetts is over 60 years old, and given the shape of the timber yield curves, average timber growth rates are decelerating over time. As a result, the longer the future time span that is selected, the lower the average 'sustainable' growth rate. We have selected 50 years in parallel with the analysis by Kelty et al. (2008). However, the simple fact that our starting year is 2010—compared to the base year 2000 used by Kelty et al. (2008)—changes the growth trajectory enough to reduce our "sustainable" growth levels compared to their results.

47 Note that this approach provides a "ballpark" estimate and does not attempt to adjust for logging residues and similar details. Estimates of biomass availability from previous studies using the "forest-growth" approach are discussed in Appendix 3-A.

48 Another approach that is commonly used but beyond the scope of this study is to evaluate the volume of wood that could be produced if the forests of Massachusetts were brought into fully regulated management under optimal rotation ages. Such an approach would likely lead to a higher estimate of long-term timber and biomass supply.

The second theoretical issue concerns scale: there is no simple answer to the question of how to define the appropriate land base. If all forest land in Massachusetts were included, the total land area would jump to about 3.0 million acres and average timber growth would be about 4.0 million green tons per year. Using this theoretical approach, it would be feasible to harvest wood much more aggressively on operable private lands due to the ongoing increase in timber inventories on public lands and private lands that are not being harvested.

3.3 BIOMASS SUPPLY FROM PUBLIC LANDS IN MASSACHUSETTS

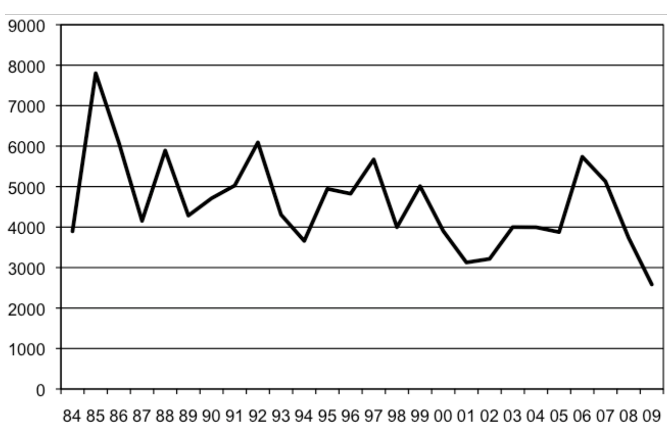
This section considers the availability of forest biomass supply from harvesting on public lands in Massachusetts. We first review estimates of historical harvest levels on all public lands and then explore these in more detail by major agency. These trends are then used to develop projections of commercial timber harvests for public lands for 2010–2025.

Using this background and perspective, we provide two forecasts of biomass supply from public lands that are consistent with our Low-Price Biomass and High-Price Biomass scenarios. As discussed previously, these are projections of incremental biomass production and do not include biomass chips that may already be counted in historical wood production totals.

3.3.1 HISTORICAL HARVEST ESTIMATES

As noted earlier, we have obtained data on Forest Cutting Plans (FCPs) for public sector lands for the period from 1984 to 2009. Exhibit 3-13 shows the number of acres targeted for harvest on public lands according to these plans. There is a general downward trend in these data: the annual average for 2005–2009 was 4,300 acres, significantly less than the average of 5,600 acres in 1984–1988.

Exhibit 3-13: Acres Planned for Harvest on All Public Lands, 1984–2009



We have assembled planned harvest data by public agency for 2001–2009 in several tables that follow. Exhibit 3-14 provides annual averages of the number of acres to be harvested, along with timber harvests of sawtimber (MBF, International ¼" rule), pulpwood (cords), and fuelwood (tons).[49] During this nine-year period, state lands accounted for an annual average of 3,092 acres, or 79% of the public area to be harvested. City and town lands accounted for 811 acres per year, or 21% of the total. The "Other" category was less than 1% of the total and consists of occasional harvests by the University of Massachusetts and the Army Corps of Engineers.

Exhibit 3-14: Summary of Forest Cutting Plans for Public Lands in Massachusetts

Area and Volumes, Annual Averages, 2001–2009				
	Acres	**MBF**	**Cords**	**Tons**
DCR, State Parks & Recreation	1,490	4,884	4,030	2,470
DCR, Water Supply Protection	1,454	4,873	5,069	6,766
Fisheries & Wildlife	148	465	502	450
Cities & Towns	811	2,789	2,033	1,804
Other	30	137	75	388
Total Public Lands	3,933	13,148	11,709	11,877

Harvest rates on a per-acre basis are presented in Exhibit 3-15. Among the major groups, the harvest intensity for sawtimber was very consistent, ranging from 3.2-to-3.4 MBF per acre; these compare with harvest rates of 2.0 MBF per acre on private lands. "Pulpwood" harvests averaged 3.0 cords per acre and 'fuelwood' harvests averaged 2.9 green tons per acre.

Exhibit 3-15: Summary of Forest Cutting Plans for Public Lands in Massachusetts

Harvest per Acre, Annual Averages, 2001–2009			
	MBF	**Cords**	**Tons**
DCR, State Parks & Recreation	3.3	2.7	1.7
DCR, Water Supply Protection	3.4	3.5	4.7
Fisheries & Wildlife	3.2	3.4	3.0
Cities & Towns	3.4	2.5	2.2
Other	4.5	2.5	12.8
Average, All Public Lands	3.3	3.0	3.0

Per-acre harvest rates have all been converted to a green ton basis in Exhibit 3-16. Excluding the "Other" group, sawtimber harvests average 17 green tons per acre, while the total harvest per acre

49 As noted earlier, "pulpwood" is sometimes referred to as "cordwood" and likely contains a combination of wood that will be shipped to pulp mills and processed for fuelwood. Fuelwood includes both residential fuelwood that will be cut and split and wood that will be processed into biomass chips.

ranges from 25-to-30 green tons. Thus, sawtimber has accounted for 56% to 67% of the wood harvested from public lands.

Exhibit 3-16: Summary of Forest Cutting Plans for Public Lands in Massachusetts

Harvest in Green Tons per Acre, Annual Averages, 2001–2009				
	Sawtimber	Pulpwood	Fuelwood	Total
DCR, State Parks & Recreation	16	7	2	25
DCR, Water Supply Protection	17	9	5	30
Fisheries & Wildlife	16	9	3	27
Cities & Towns	17	6	2	26
Other	23	6	13	42
Average, All Public Lands	17	7	3	27

3.3.2 TIMBER HARVEST PROJECTIONS FOR 2010—2025

As with timber harvest projections for private lands, historical trends provide the starting point for this assessment. Our next step was to review the 15-year Forest Resource Management Plans for state forests, several of which have already been approved. Finally, we contacted representatives from each of the three main state divisions—State Parks & Recreation, Water Supply Protection, and Fisheries and Wildlife—to review historical cutting levels and discuss their expectations for harvests in the future.

On the basis of our review and discussions, it appears that historical averages for 2001–2009 probably provide the best estimate of acres to be treated and timber harvest volumes over the next 15 years. Information from some of the individual Forest Plans suggest that acres and harvests could be higher than we have observed historically, but it seems more likely that there will be some downward adjustments to reflect the recommendations of the Forest Futures Visioning Process (2010). There will, no doubt, be other adjustments to harvest areas and to harvest intensity and silvicultural treatments, but we do not anticipate that these will be significant enough to alter our assessment of future biomass potential.

With regard to the issue of biomass harvesting, there are at least two key factors that distinguish our analysis of potential supplies from private versus public lands. First, private landowners have the flexibility to be much more responsive to market forces and can adjust the acreages they choose to harvest as well as their silvicultural treatments. In contrast, public lands are subject to a wider array of objectives and planning issues and it is more difficult for these plans to be modified in response to changes in market demand and prices. Second, the harvest of tops and limbs will not be permitted from public lands if new management guidelines suggested by the Forest Futures Visioning Process are adopted.

Thus, once management plans have been established on public lands, undergone public scrutiny, and been officially approved by the responsible agency, it is more difficult to increase harvests in response to potential new demand from bioenergy plants. However, while the volume of wood to be harvested may be pre-determined, the ultimate disposition of the wood is not—planned harvests of pulpwood and residential fuelwood might be diverted to biomass fuel depending on demand conditions and relative prices.

3.3.3 LOW-PRICE BIOMASS SCENARIO

The economics of biomass production on private lands in Massachusetts suggest that in order to obtain sufficient volumes to furnish bioenergy plants and make logging operations profitable, it is necessary to harvest some combination of cull material, small trees, and low-grade sawtimber: the harvest of whole trees generates the volume that makes it economic to enter the stand for biomass production. Once that process is underway, then tops and limbs from industrial roundwood harvests can also be harvested for biomass.

Given the various constraints associated with harvests on public lands, we find that there is not likely to be any increase in biomass production above the levels that are already being produced for the market. (There are no estimates of the volume of biomass chips produced from public lands historically, but it is known that whole-tree biomass chips account for much of the 'fuelwood' volume that is reported in tons on the FCPs.) There are several key reasons for our assessment: 1) we are not anticipating an increase in the total volume of wood harvested on public lands; on average, future annual harvest levels are projected to be about the same as during 2001–2009; 2) we are not anticipating any diversion from previous end-use markets (pulpwood, for example) because of the assumed low-price levels for biomass stumpage; 3) restrictions on the removal of tops and limbs mean that logging residues from industrial roundwood harvesting will not be available.

Thus, while there is already some production of chips on public lands, we do not project any significant increase in biomass supplies beyond recent levels.

3.3.4 HIGH-PRICE BIOMASS SCENARIO

It is likely that biomass supplies from public lands would become significant in response to a large increase in biomass stumpage prices. In this scenario, biomass stumpage prices are assumed to increase to $20 per green ton in response to higher demand from bioenergy plants. As we have noted, if the higher demand originates from electric power plants, higher electricity prices will be needed for wood-fired utilities to remain in operation. For thermal and CHP plants, it is likely they could afford wood at these prices and remain profitable.

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. We do not expect that forest management plans on public lands would be modified to increase the total volume of material that could be harvested on designated logging sites.

In this scenario, incremental biomass production from public lands is estimated as follows: 1) about 4,000 acres will be harvested each year; 2) all of the pulpwood harvested—7 green tons per acre—will now be chipped for biomass; 3) half of the fuelwood harvested—1.5 green tons per acre—will also be chipped for biomass (it is known that much of the reported fuelwood volume is already consumed for biomass fuel so we have assumed half simply to recognize this phenomenon). Thus, 'new' biomass supplies from public lands would total 34,000 green tons per year (4,000 acres x 8.5 tons/acre).

We have assumed that the removal of tops and limbs will not be acceptable under new silvicultural guidelines for state lands. We should note that if the removal of logging residues were permissible, this would further increase biomass supplies by about 17,000 green tons, thus bringing the total from public lands to approximately 50,000 green tons per year.

We should point out that our scenarios reflect relatively light harvests on state lands relative to the volume of timber grown each year. In these scenarios, timber inventories on state lands continue to rise, resulting in rising levels of carbon storage. If the political winds on harvesting shift, these policies could be modified so that much more biomass is harvested from state lands. However, we think that such a scenario would have low probability because of the state's mandate to balance a wide array of timber and nontimber objectives.

3.4 SUMMARY OF FOREST BIOMASS SUPPLIES IN MASSACHUSETTS

The volumes of biomass available from private lands and public lands for our two scenarios are summarized in Exhibit 3-17. Importantly, we should re-emphasize that these data represent the incremental volumes of biomass that we project could be supplied in response to expanded demand from new bioenergy plants, and thus would be available to furnish these facilities.

Our Low-Price Biomass scenario was designed to evaluate the potential supplies of forest biomass that might be produced if there was an expansion in demand from bioenergy plants. This analysis was motivated by the assumption that if the increase for demand originates from wood-fired electric power plants, they will not likely be able to pay much more than the current price of $30 per green ton without significant increases in real electricity prices; thus, given the harvesting and transport costs, there is little value left for stumpage. This same volume of wood could be utilized by thermal and CHP plants—they could pay more for stumpage than the $1–$2 per green ton that we have assumed, but would not need to until demand increases to higher levels.[50] On private lands, income from biomass production is not adequate to justify bringing more land into production and biomass volumes will be limited to increasing the harvest intensity on sites already being logged for sawtimber. On public lands, we do not anticipate an increase in the incremental volume of biomass production: planned harvest volumes are not likely to be modified in response to increased biomass demand, and low biomass stumpage prices will not provide the economic incentives to divert timber from current uses to biomass chips.

[50] There are several reasons (including administrative, logistical, and transport costs) that may lead some facilities to pay higher prices for biomass stumpage in their own timbershed, rather than purchase biomass from other locations where stumpage may be available at lower cost.

Exhibit 3-17: Summary of Forest Biomass Fuel Supplies for 2010–2025

Low- and High-Price Biomass Scenarios 000 Green Tons per Year		
	Low-Price	High-Price
Private Lands	150–250	650–850
Public Lands	0	35
TOTAL	150–250	685–885

Note: Some estimates are rounded for this table.

In our High-Price Biomass scenario, total "new" forest biomass supply increases from 150,000–250,000 green tons per year to about 650,000–850,000 green tons per year. We have postulated that increases in demand from bioenergy plants drive biomass stumpage prices up to $20 per green ton, and prices in energy markets are high enough so that electric power, thermal, and CHP plants can compete for this wood. The large volume increase from private lands occurs primarily because much higher income levels provide incentives to bring more timberland into production. Public lands are also assumed to yield more biomass as relative prices cause timber to be diverted from pulpwood markets to biomass markets.

3.5 BIOMASS SUPPLY FROM NON-FOREST SOURCES IN MASSACHUSETTS

Our study has focused on biomass supplies from forest biomass sources, which include the harvesting of whole trees (including thinnings, cull, pulpwood, and low-grade sawtimber) and logging residues. These are sometimes classified as primary sources (see, for example, the *Billion-Ton Study*, Perlak et al., 2005). Wood from land clearing from development is also considered to be a primary source of wood biomass fuel in the taxonomy of the *Billion-Ton Study*. The potential volume from this source is evaluated below.

There are two other important general sources of non-forest biomass material that should be mentioned. Secondary sources ("mill residues") include any wood residues generated in the processing of logs (mill residues from sawmills, veneer mills, etc.) or lumber (manufacturing residues, from furniture, pallets, etc.). It appears that most secondary-source material is already being fully utilized in Massachusetts, and this is consistent with recent trends that show significant inflation in their prices. Tertiary sources (often referred to as "urban wood") include all other wood material and consists mainly of municipal solid waste, construction and demolition debris, and wood from landscaping and tree care. Tertiary material may potentially be a source of substantial volumes of biomass that could provide feedstock for new bioenergy plants and this source is briefly discussed below.

3.5.1 LAND CLEARING AND CONVERSION

According to a report by Mass Audubon (2009), forest land clearing and conversion averaged 4,700 acres per year from 1999 to 2005. Forest land clearing and conversion was reported at much higher levels in the previous three decades, but there are numerous inconsistencies between these data and independent data on building and construction. In addition, the new techniques and methods used in the 2005 survey (involving computer imaging and digitization) provide much finer resolution and greater accuracy in measuring land areas cleared. Given that average building permits in 1999–2005 were similar to the average levels of the past 20 years, we have assumed that recent levels of land clearing and conversion represent a reasonable estimate of land clearing for 2010–2025.

We have not been able to identify any information that would allow us to track the volume and disposition of the wood removed from these lands. It is probably safe to assume that higher-value sawtimber material is cut and sold, whereas the fate of the low-value material is much harder to predict.

Given the lack of information on these land clearing and conversion operations, it is not feasible to provide a rigorous quantitative projection of biomass supply from these sources. However, we can provide a framework for understanding the important parameters in evaluating this supply—this framework can then be used to demonstrate the biomass potential from land clearing. The potential increase in biomass supply from this source over the next 15 years will depend on: 1) the relative size of the land area cleared (future versus history); and 2) the relative rates of biomass recovery between the two periods. As noted above, we have assumed that land clearing will remain at the recent historical level of 4,700 acres per year. Thus, any increase in biomass production will require an increase in biomass recovery rates.

In order to demonstrate the potential biomass supply from land clearing, two important assumptions are necessary. The first concerns removals of sawtimber and other high-value timber for industrial products: we assume that the economics always justify harvesting this material first and for this example we assume that it accounts for an average of 36% of standing timber volume. The second assumption is the initial stocking levels of lands to be cleared and we assume that an average acre has 100 green tons of wood (this is less than the average shown in Exhibit 3-7 which applies only to stands of mature timber). Thus, the maximum volume of wood that could have been harvested for biomass in each year of the historical period—as well as in the forecast period—would be about 300,000 green tons (4,700 acres x 64 tons/acre).

At this stage, it is easy to see the importance of the recovery rate. If biomass demand increases due to the expansion of bioenergy plants, then we would expect that there would be an increase in the percentage of material from land clearing that would be chipped and used for biomass fuel. Although it is not possible to quantify historical recovery rates, we can demonstrate the potential magnitude of this biomass source by considering the impact of different recovery rates. A recovery rate of 30% would imply that 90,000 green tons of material was collected and utilized. Each increase of 10% in the recovery rate would add an additional 30,000 green tons to the supply base, so at 70%, the total volume of supply available would be 210,000 green tons.

While the disposition of wood from land clearing sources is not known in 2000–2005[51], it is highly probable that if demand increases significantly for bioenergy uses, a greater share of this wood would be recovered and shipped to these markets. Logistics and economics will govern how much biomass can be recovered from land clearing. The kinds of machinery used, the harvesting methods, and the end-use markets for this wood will vary depending on the size of the parcel being cleared and other site-specific factors. The price of biomass delivered to a bioenergy plant will also be a critical factor in determining how much biomass is actually recovered, as will transport costs and tipping fees when the option is sending the material to a landfill.

The potential volume of wood that could be generated from land clearing in 2010–2025 will depend critically on the current disposition of this wood. If current recovery and utilization are low, the incremental volumes available in the future could be substantial. At the extreme, one might consider the increase in volume to be as much as 120,000 green tons if recovery rates were to increase from 30% to 70%. Conversely, if current recovery rates are higher due to tipping fees and competing uses, 'new' biomass from these sources in the future would be reduced accordingly. A final consideration is the possibility that this material in being 'underutilized' in current markets. That is, if wood is chipped and used in landscaping primarily because it is a good economic option compared to disposal, it is possible that some of this wood could be diverted to bioenergy in situations where that might become a higher value use.

3.5.2 TREE CARE AND LANDSCAPING SOURCES

Among the tertiary sources mentioned above, the most significant is wood from tree care and landscaping sources. This wood is often referred to as "urban wood" which is somewhat of a misnomer because it includes wood not only from tree care in urban areas, but also wood from tree care from sources such as county parks and recreation areas and maintenance of electric power lines. The term can also be confusing because it is not always clear whether it includes 'urban waste' such as construction debris.

A literature review conducted in 2002 indicated that tree care/landscaping sources accounted for 1.0 million tons (42%) out the total available supply of 2.5 million tons of non-forest wood biomass

51 The startup of the Schiller plant in Portsmouth, New Hampshire in 2006 makes the comparisons going forward more problematic. The plant consumes about 500,000 green tons of wood per year and has ready access to wood from land clearing in eastern Massachusetts (where most land clearing in the state occurs).

in Massachusetts (Fallon and Breger, 2002). However, given the difficulties in estimating this volume (noted in the report), this estimate is perhaps best used to suggest that the potential from these sources may be substantial and worthy of further investigation (importantly, the carbon profile of this material is generally similar to logging residues and thus very favorable compared to that of harvesting standing trees). Problems in measuring supplies from these sources may be attributed to: 1) the actual generation of this material is difficult to estimate; 2) it appears that wood from land clearing may be included in this estimate; 3) little is known about the current disposition of these materials, although some broad generalizations are possible such as more than half of the material in the Northeast is 'managed on-site'; and 4) the economics of recovering this material are quite variable due to the wide variety of sources from which it is generated.

3.6 BIOMASS SUPPLY FROM NEARBY STATES

The outlook for how much wood is available to furnish an expansion of bioenergy capacity in Massachusetts is certainly not complete without considering potential wood supply and demand from the surrounding region. State boundaries mean little in the wood biomass market, as demand, supply, and prices are determined on a regional basis. New bioenergy facilities in Massachusetts would have access to wood from nearby states, while, at the same time, new bioenergy facilities in nearby states would have access to wood supplies in Massachusetts.

There are a number of ways to gain some insights into this issue. Our strategy is as follows. Given the objectives of this study, we have focused most of our effort on a detailed analysis of forest biomass fuel supplies within Massachusetts. It is not possible to use the same approach for the Massachusetts timbershed, so we assess the potential of this region by putting it in perspective relative to Massachusetts. Among the key features that we compare are: timberland areas, timberland inventory, timber growth rates, landowner characteristics, and forest products output. We have defined the timbershed as the counties which border Massachusetts: the distance across these counties is similar to the maximum that biomass could be economically transported to bioenergy plants located in Massachusetts.

Once estimates of 'new' biomass supply potential are developed for the border counties, the question remains as to where this wood will be consumed. This will depend on many factors including local demand, permitting requirements for new energy facilities, who builds first, transportation costs and infrastructure. In the last section, we discuss the implications of these factors for future wood flows to—and from—Massachusetts.

This section thus addresses two central questions:

- How much incremental biomass supply is available in the border counties?
- How much of this supply is likely to be shipped to new bioenergy plants in Massachusetts?

3.6.1 TIMBERLAND AREA AND TIMBER INVENTORY

Timber inventory is an obvious place to start in considering the border counties' potential contribution in meeting future demand from Massachusetts bioenergy plants. In Exhibit 3-18, we show the timberland areas and timber growing stock inventories in Massachusetts and in the major counties that border Massachusetts.[52] These FIA data indicate that timberland areas in the border counties are nearly 30% greater than those of Massachusetts. The conclusion is the same using the growing stock data.

Also noteworthy is that Massachusetts has a much higher share of public land (30%) than the border counties (an average of 19%, ranging from 28% in the Vermont and Connecticut sub-regions to only 5% in New York's three counties). Thus, when private lands only are considered, timberland areas and timber volumes in the border counties are about 50% greater than those in Massachusetts. This distinction is important because harvesting regulations for biomass fuel are generally more restrictive on public lands than on private; for example, in New Hampshire, whole-tree harvesting is prohibited on National Forest lands.

Exhibit 3-18: Timberland Area and Growing Stock Inventory in Massachusetts Timbershed, 000 Acres and Million Green Tons; 2008

	Area			Inventory		
	Total	**Private**	**Public**	**Total**	**Private**	**Public**
Massachusetts	2,895	2,026	869	207	146	62
Border County Total	3,712	3,018	694	262	212	50
New Hampshire (3 counties)	1,075	938	137	81	70	11
Vermont (2 counties)	755	543	212	57	43	15
New York (3 counties)	747	708	38	46	43	3
Connecticut (4 counties)	983	709	274	69	49	19
Rhode Island (1 county)	152	120	33	10	8	2
Combined Total	6,607	5,044	1,563	470	358	112
Border Counties ÷ Mass.	1.28	1.49	0.80	1.27	1.46	0.81

Source: FIA On-line; volumes converted from original units assuming 30 green tons per 1000 cubic feet. Note that 2008 is the nominal date for the survey data, but the data were compiled from annualized surveys and thus reflect an average of data collected over the period 2004–2008. (cont.)

County List: New Hampshire: Cheshire, Hillsborough, Rockingham; Vermont: Bennington, Windham; New York: Rensselaer, Columbia, Dutchess; Connecticut: Litchfield, Hartford, Tolland, Windham; Rhode Island: Providence

52 Data on growing stock volumes significantly understate the volume of biomass available because of the availability of wood from non-growing stock sources, notably cull trees, tops and limbs. However, our analysis is focused on relative levels—not absolute volumes—and this omission has little effect on our conclusions.

3.6.2 TIMBER GROWTH

When interpreted strictly from a biophysical standpoint, there is a large volume of 'excess' wood available in both Massachusetts and the border region in the sense that forests are growing more wood than is being removed through harvesting and mortality. Here we compare the potential of the border counties to Massachusetts on the basis of relative rates of timber growth. We should emphasize that relationship between net growth and removals is not a measure of supply; it only speaks to how much timber could be harvested without reducing inventory levels.[53]

There are a number of ways of measuring and evaluating timber growth. Ultimately, the key variable of interest is how much additional wood will become available in different regions. As noted above, we are primarily interested in private inventories because biomass harvesting is subject to fewer restrictions and owners tend to be more responsive to market forces.

Most often, this growth has been evaluated by comparing net growth (gross growth less mortality) and removals. This relationship would be an excellent metric (it essentially defines inventory accumulation at any point in time) were it not for the poor quality of the data on removals. Furthermore, issues of data accuracy have become more of a concern in recent years due to the new annualized survey procedures that have been adopted by the Forest Service. For example, the sampling error for removals in 2008 is 45% in Massachusetts and 31% in New Hampshire. At the county level, the sampling error for removals is so large as to make these data effectively meaningless.[54]

Although any approach will encounter problems with accuracy due to sample size and sample frequency issues, we believe that comparing inventory levels over time is a better method for evaluating growth trends. The primary reason is statistical in that standing inventory can be measured on each plot that is surveyed each year. Likewise, with regard to components of change in the FIA data, net growth is much more reliable than data on removals. Since we are interested in small areas, we have also combined private and public inventories for this comparison because sampling errors for areas and inventories increase significantly for separate ownerships.

3.6.2.1 Growth per Acre

When all lands (private and public) are considered together, timber growth rates in Massachusetts are similar to the border region on per-acre basis. In Exhibit 3-19, average stocking levels are shown along with two sets of growth rates. The data on net growth per acre (gross growth less mortality) are derived by dividing net growth (as reported directly by FIA data) by the area in each region. The data indicate that growing stock timber inventories in Massachusetts are increasing at an average rate of 1.6 green tons per acre. The average growth rate in the border counties is essentially the same (1.5 green tons per acre), spanning a range of 1.2–1.8 green tons per acre.

The second set of growth data is derived by calculating the annual rate of change in per-acre stocking levels using FIA data between the 2004–2008 inventory/area surveys and the surveys from 10-to-15 years ago. This is a more inclusive measure of timber accumulation on an average acre by accounting for not only net growth and mortality, but also removals. These data also show very little difference between Massachusetts and the border counties—timber inventory volume is increasing at an average of about 0.8–0.9 green tons per acre, and with the exception of Rhode Island, the border counties are clustered around this number.

According to the above data, timber volume per acre is increasing at very similar rates throughout the area we have defined as the Massachusetts timbershed. These similarities reinforce the idea of using relative land areas as a measure of potential supply. Thus, if timberland use and ownership were to remain the same over the next 15 years, the potential contribution of the border counties areas—from a growth perspective—would be about 50% greater than Massachusetts (based on the private timberland area).

Exhibit 3-19 Stocking Levels and Inventory Growth for Growing Stock

All Timberlands (Private + Public), Green Tons per Acre			
	Stocking	**Net G**	**Inv Δ**
Massachusetts	71.7	1.6	0.8
Border County Total	70.7	1.5	0.9
New Hampshire (3 counties)	74.9	1.3	0.7
Vermont (2 counties)	76.1	1.2	0.7
New York (3 counties)	61.1	1.8	1.0
Connecticut (4 counties)	70.0	1.8	1.0
Rhode Island (1 county)	65.9	1.2	2.4

Notes: See Exhibit 3-18 for county definitions. Net G is net growth per acre: the net growth volumes are taken directly from FIA data for 2008 and divided by area for 2004–2008 (Exhibit 3-18). Inv Δ is a more inclusive measure of volume change on an average acre and accounts for net growth, removals and mortality; it is calculated as the change in stocking levels over the last 10-to-15 years (depending on the date of the previous inventory).

53 Even if a forest is not adding new wood each year, it still has the potential to contribute to biomass production; biomass supplies can come out of existing stocks, not growth. From a carbon standpoint, a forest that has matured to the point that the yield curve has leveled off (net growth = mortality) may be a preferred source of material.

54 Data for 2008 for timber removals in 12 Massachusetts counties show: no removals recorded in 7 counties, sampling errors of 100% or greater for 3 counties. For the 13 selected counties that are adjacent to Massachusetts, there were no removals recorded in 2 counties, sampling errors of 100% or greater for 4 counties, and the minimum sampling error for the remaining 7 counties was 53%. The reason for the poor accuracy is that removals are a rare event given the sampling methodology; for example, in Massachusetts, about 120 plots were re-measured in 2008 (20% of the 600 plots in the sample) and with about one percent of timberlands harvested in Massachusetts each year, that means that one would expect to find, on average, only about six plots with harvest activity every five years.

3.6.2.2 Total Volume Growth

Does the conclusion change when we adjust overall inventory growth for historical land use changes? There are two aspects of land-use change to consider: 1) shifts in total timberland area over time; 2) shifts from private to public ownership. For the border counties as a whole, the change in total timberland area has been negligible (a decrease of less than 1% from the earlier inventory years). However, over this same time frame, there has been a large shift from public to private ownership: approximately 20,000-to-25,000 acres per year have shifted into public ownership according to FIA data (as noted earlier, there are inconsistencies in these data due to measurement errors and sampling errors and their accuracy has been disputed). Thus, while the total increase in timber inventory was about 2.6 million green tons per year in the border zone, the increase in *private* timber inventories was only 0.9 million green tons per year, while inventories on *public* lands increased by 1.7 million green tons per year.

When measured on a comparable basis, private timber inventory volume in Massachusetts has increased at a rate of about 1.1 million green tons per year. Thus, in the important area of private timber inventory growth, the data suggest that inventories in Massachusetts are increasing at rates similar to those in the surrounding counties. From this perspective, the border countries lose the 50% advantage that we observed when considering growth rates on a per-acre basis.

Of course, there is no *a priori* reason to assume that land use changes will continue at the same rates as in the recent past. Good arguments can be made that future shifts from private to public lands could accelerate or proceed more slowly. In any case, it does seem clear that a serious assessment of biomass fuel availability in the border counties should consider an in-depth analysis of land-use changes in the region. To the extent that significant reductions in private timberland will continue, this would likely have an important influence on potential supplies from the surrounding region.

3.6.3 THE FOREST PRODUCTS INDUSTRY AND REGIONAL HARVESTING

Another possibility for assessing the relative importance of the border counties is to consider harvesting levels given that the greatest potential for biomass (at least in the near term) comes from integrated harvesting with higher-value industrial roundwood. Logging residues—generally considered to be a prime source of biomass fuel—will be directly proportional to the amount of industrial roundwood harvested. Perhaps more importantly, areas that already have a significant forest industry may be good candidates for biomass fuel harvests through additional cutting of low-value timber, or possibly because forest industry intensity is a good indicator of timber availability and underlying landowner attitudes.

For this overview, we have used TPO data because they have the appropriate concepts at the county level (Exhibit 3-20). These data indicate that production in the border counties is about three times that in Massachusetts; thus, from the vantage point of current harvesting activity, the border counties show a lot more promise as a source of biomass than Massachusetts. The table also shows an index which compares the intensity of harvests in the different areas—this is calculated as roundwood harvests divided by total timberland acres, and is indexed to Massachusetts = 1.0.

Exhibit 3-20: Industrial Roundwood Harvests in Massachusetts Timbershed, 000 Green Tons and Index; 2006

	Sawlogs	Pulpwood	All Ind.	Cut/Acre
Massachusetts	217	33	254	1.0
Border County Total	605	174	819	2.5
New Hampshire (3 counties)	252	111	387	4.1
Vermont (2 counties)	142	28	170	2.6
New York (3 counties)	92	30	137	2.1
Connecticut (4 counties)	101	6	107	1.2
Rhode Island (1 county)	17	0	17	1.3

Source: Harvest data from TPO. All Ind. is "All Industrial" and, in addition to sawlogs and pulpwood, includes veneer logs, composite products, posts, poles, piling, and miscellaneous. Cut/Acre is an index (Massachusetts = 1.0), measured as All Ind./ Timberland Acres. See Exhibit 3-18 for county definitions.

3.6.4 LANDOWNER CHARACTERISTICS IN THE REGION

Ownership characteristics provide another perspective on future wood biomass fuel availability in the border counties for at least three reasons: 1) the size of forest holdings is generally considered to be highly correlated with the landowner's propensity to harvest timber; 2) the size of forest holdings is of particular importance for biomass fuel because of economies of scale in whole-tree harvesting; and 3) landowner attitudes are important in the decision of whether or not to use their land for commercial timber production.

In Exhibit 3-21, data that address the above issues are presented at the state level.[55] In Massachusetts, the average parcel size for family-owned forest land is 6 acres, while Rhode Island is also 6 acres and Connecticut averages 9 acres per owner. Forest holdings are much larger in New Hampshire and Vermont, where the

[55] We evaluated these data at the survey unit level in New Hampshire and Vermont to focus more directly on the sub-regions of concern. However, there were no obvious differences within the states, particularly given the large sampling errors associated with this survey. We did not consider the data for New York because the three-county area accounts for such a small share of the state's total forest land.

average owner has 19 acres and 36 acres, respectively (although it is likely to be the case that parcel sizes in the border counties are more similar to those in Massachusetts than the state averages would imply). Notably, a significant area of New Hampshire's private forest land (1.3 million acres) is held by non-family owners (average forest holdings of owners in this group are substantially larger). According to these survey data, only 43% of the family forest land area in Massachusetts is held in parcels that are 50 acres or larger. New Hampshire and Vermont are much higher at 64% and 75%, while Connecticut is 48% and Rhode Island is 33%. Importantly, New Hampshire has twice as much family-owned land as Massachusetts in 50+ acre parcels, while Vermont has three times as much land; however, we do not have data on the relative areas for the border county region.

Exhibit 3-21: Attributes of Family Forest Landowners

	MA	NH	VT	CT	RI
Private Lands (000 acres)	2,179	3,646	3,864	1,383	303
Family Forest Owners (000 acres)	1,686	2,358	3,109	898	204
Family Forests, 50 acres or more	729	1,514	2,343	434	68
% of Family Forests, 50 acres or more	43%	64%	75%	48%	33%
Average Size, Family (acres per parcel)	5.8	19.0	35.7	8.9	5.5
Timber production is important*	20%	21%	29%	12%	11%
Commercial harvest in past 5 years	40%	59%	68%	39%	26%
Commercial harvest in next 5 years	20%	29%	39%	9%	11%
% of family forests available given constraints*	32%	43%	57%	20%	21%

Source: National Woodland Ownership Survey, Butler et al., 2008; on-line data.

Notes: 1) Data are state level, not for county sub-regions.

2) The survey asks landowners to rank the importance of producing commercial timber on a 7-point scale from "very important" to "not important." These data show the percentage that ranked production as '1' or '2' on this scale.

3) "% of family forest available given constraints" is taken from Butler et al. (2010) and reflects reductions for biophysical and social constraints, including parcel size and landowner attitudes and preferences.

With respect to timber production, probably the three most important questions asked in the National Woodland Ownership Survey are: 1) how important is timber production?; 2) did you conduct a commercial harvest in the past five years?; and, 3) do you plan to conduct a commercial harvest in the next five years? The results shown in Exhibit 3-21 are much as one might expect: Vermont and New Hampshire owners gave answers that most favored timber production, Massachusetts was ranked in the middle of this group, and Connecticut and Rhode Island owners were least oriented toward timber production.

There appears to be a fairly high degree of correlation between parcel size and landowner interest and willingness to pursue commercial timber harvests. A recent study by Butler et al. (2010) developed a methodology to combine these factors in a manner to eliminate double counting in the presence of multiple constraints. Harvest 'participation rates' from this study are shown on the last line of Exhibit 3-21: Vermont had 57% of family forest land available for harvest (ranking the highest of all 20 northern states); New Hampshire was second of this group with 43% available; Massachusetts had only 32% of land available; Connecticut and Rhode Island were the lowest with only about 20% of land available (and ranked among the lowest of the 20 northern states).

Some question the validity and usefulness of landowner surveys, so it is useful to have additional information from other sources. Participation rates in current use programs provide further insights into the level of interest in forest management and related income incentives. The Chapter 61-61A-61B program in Massachusetts has had limited success relative to its counterparts in New Hampshire and Vermont. In Massachusetts, about 15% of private forest lands were enrolled in this program in 2009 (Massachusetts Department of Conservation, 2009). This is in stark contrast to New Hampshire where about 27,000 landowners participate in the current use program, covering nearly 3 million acres (New Hampshire Timberland Owners Association, 2010). In Vermont, more than 1.6 million acres of forest land were enrolled in their current use program in 2009 (Vermont Department of Taxes, 2010).

Ownership attributes clearly reinforce the patterns shown earlier on the basis of area, inventory and harvesting. The potential for forest biomass fuel from border counties in Connecticut and Rhode Island appears limited. On the other hand, the border counties of New Hampshire, Vermont, and New York are similar in size to Massachusetts (on the basis of timberland area, inventory, and growth) and their forest products industry and industrial roundwood harvests are significantly higher. Furthermore, landowner surveys for New Hampshire and Vermont show family owners in these states to be more supportive of timber harvesting.

3.6.5 SUMMARY OF FOREST BIOMASS SUPPLY POTENTIAL IN BORDER COUNTIES

In order to assess potential forest biomass supplies from the counties surrounding Massachusetts, we have looked at several key measures relative to Massachusetts. The general conclusion from our analysis of timberland area, timber inventory, and timber growth is that private lands in the border counties have the ability to supply about 50% more biomass than Massachusetts.

When the analysis is expanded to account for landowner characteristics and the development of the forest products industry, the potential biomass contribution of border counties becomes more difficult to evaluate. It is certainly the case that New Hampshire, Vermont, and New York would be much more conducive to increased harvesting than Massachusetts based on landowner attitudes and the distribution of ownership by parcel size. This already manifests itself in a much larger forest industry and much higher roundwood production. Thus we are faced we this analytical dilemma: these regions may be more attractive for timber harvesting, but given that more harvesting is now taking place, how much further expansion is likely? Has investment to date put the production in these regions in equilibrium relative to Massachusetts? Are there still more promising opportunities in the border counties? Or are they already approaching production levels that make it more difficult to expand further? Whole-tree harvesting already has a long history in southern New Hampshire for example, suggesting that future increases might be more difficult to achieve and come only at higher cost.

While this issue will not be settled in this analysis, we have made an effort to better understand the situation in southern New Hampshire: it has been suggested that New Hampshire has the most potential for increasing supplies of forest biomass because of its inventory, harvest rates, and favorable stance toward timber production. Our evaluation of recent harvest relationships and price trends is provided in Appendix 3-D. We did not find any obvious pockets of opportunity or expansion possibilities in the southern counties, nor any evidence to support claims that southern New Hampshire may be in an advantageous position to produce more biomass compared to neighboring areas.

Since we have considered the availability of biomass from border counties in relation to supplies from Massachusetts, it is important that we consider these supplies in the context of our two scenarios for Massachusetts. In our Low-Price Biomass scenario, we expect that biomass supplies in Massachusetts will increase as a result of more intensive harvesting using whole-tree harvesting. Given the development that has already taken place in some of the border areas, we would not expect that increased biomass demand at current biomass prices would spur additional harvesting to the same extent that we might see in Massachusetts. However, in our High-Price Biomass scenario, more land is harvested and more timber is harvested from that land. We would expect that this will cause a substantial response in the border counties, just as we expect in Massachusetts. Given landowner characteristics in the region, one might argue that the response in border counties might be greater than in Massachusetts.

Mindful of the numerous uncertainties involved in projecting the potential supply of biomass in the counties bordering Massachusetts, we consider a reasonable "guesstimate" to be 50% more than can be produced within this state. In our Low-Price Biomass scenario, this would suggest the border counties could produce an additional 278,000–428,000 green tons of forest biomass annually. If the High-Price Biomass scenario unfolds, border county supply would jump to an annual average of 1.2–1.5 million green tons.

3.6.6 INTER-REGIONAL TRADE AND IMPLICATIONS FOR BIOMASS SUPPLIES FOR FUTURE BIOENERGY PLANTS IN MASSACHUSETTS

Understanding potential wood biomass supplies in the counties that surround Massachusetts is critically important in estimating biomass availability for bioenergy plants that may get built in Massachusetts. But where will this wood be consumed? It is crucial to consider future demand outside of Massachusetts and possibilities for biomass trade. Biomass produced in the border counties could stay within its home zone for local use, it could flow between sub-regions (from New Hampshire to Vermont, for example), it could flow to the northern areas, or it could flow to Massachusetts. Likewise, wood in Massachusetts is not limited to home use; in fact, with few outlets for wood biomass in Massachusetts currently, biomass chips are now being shipped to bioenergy facilities in New Hampshire.

3.6.6.1 Historical Wood Products Trade

Recent patterns in wood products trade in this region provide some perspective on trade possibilities. Data available on wood trade for New Hampshire, Vermont, Maine, and New York show that the four-state region is a net importer of wood, purchasing 195,000 green tons in 2005. (We caution that the data are for only one year and they do not indicate specifically what is happening with Massachusetts.)

Data for Vermont (Northeast State Foresters Association, 2007b) indicate that Vermont consumed about 400,000 green tons of biomass chips in 2005. Of this total, about 300,000 green tons were imported from other states, while at the same time, Vermont exported 75,000 green tons; thus, net imports were just over half of wood chip consumption.

Based on the limited data that we have on Massachusetts wood trade, it appears that trade between Massachusetts and Vermont has been one-directional, with Massachusetts exporting a small volume of sawlogs to mills in Vermont.

Exhibit 3-22: Wood Trade Among Northeast States, 2005 (000 green tons; does not include international trade)

	Import	Export	Net Imports
New Hampshire	353	820	-468
Vermont	508	630	-123
Maine	1,115	363	753
New York	838	805	33
TOTAL	2,813	2,618	195

Source: Northeast State Foresters Association, 2007a. Original data in cords; converted to green tons assuming 2.5 green tons per cord.

3.6.6.2 Potential Future Trade in Forest Biomass Fuel

One of the advantages of Massachusetts size and shape is that it has access to a large horseshoe of wood as part of its timbershed. However, it is important to recognize that an even larger horseshoe envelops this timbershed, which means that wood available from that area may provide incentives to build bioenergy facilities in the border region, or that wood could flow from Massachusetts to feed plants in that area. Exhibit 3-23 provides a list of facilities that—if built—might potentially compete for the same wood that could provide feedstock to proposed plants in Massachusetts. Plans and proposals change frequently and this list is intended only to be suggestive of some of the facilities—and their size—that are now under consideration in this region. This list does not include facilities that are located overseas, but there is always the possibility that biomass produced in this region could be directed to export markets.

Exhibit 3-23: Proposed Bioenergy Plants that Could Influence Biomass Availability for Massachusetts (Wood Use in Green Tons per Year)

State	Company	Location	Size	Wood Use
MA	Russell Biomass	Russell	50 MW	550,000
	Greenfield Biomass	Greenfield	50 MW	550,000
	Tamarack Energy	Pittsfield	30 MW	350,000
	Palmer Renewable	Springfield	30 MW	*235,000
NH	Clean Power Development	Berlin	29 MW, CHP	340,000
	Clean Power Development	Winchester	15 MW	150,000
	Alexandria Power	Alexandria	16 MW (re-start)	200,000
	Greenova Wood Pellets	Berlin	pellets	400,000
	Laidlaw Energy	Berlin	40 MW	400,000
VT	Vermont Biomass Energy	Island Pond	pellets	200,000
	Brattleboro District Heat	Brattleboro		
CT	Decker International	Plainfield	30 MW	400,000
	Tamarack Energy	Watertown	30 MW	400,000

*Notes: *plan calls for construction and demolition debris as feedstock.*

Two important strategic issues in siting large-scale bioenergy facilities are relevant to this discussion. One is that transportation costs are a significant component of delivered biomass costs and so the location of new facilities should be optimized so that they have access to the most wood within short distances. Thus, plants should be built where there are ample supplies of wood in the 'home' area. This could be analyzed with mathematical optimization models, but the results would probably be of little use due to the large number of other factors that affect plant location, many of which are specific to individual locations and facilities.

A second strategic issue is what has been termed 'first-mover advantage,' which suggests that the facility that starts up first will have a competitive advantage in establishing its network and logistics for wood supply. In addition, the first mover may discourage future investments that would need to access the same timbershed. However, being first does not rule out the possibility that other new facilities that may start later: they may be willing to compete for the same wood due to proximity or the belief that they will be more efficient and thus able to pay more for their fiber.

3.6.6.3 Wood Supplies Available for Massachusetts

How much in the border counties would be available for new bioenergy facilities in Massachusetts? This will depend on how the bioenergy industry in the region evolves and depends on the following:

- How many new facilities will be built and how large will they be?
- Where will they be built?
- When will they be built?

In order to provide some general guidelines, such an analysis might proceed as follows. For economic reasons, it would seem most likely that the majority of wood produced would remain in its home market: it might be reasonable to assign that a 50% probability. The remaining 50% could be shipped to Massachusetts or shipped 'outside' to the facilities in the next ring of border counties. Thus, in this example, the supply of biomass being shipped to Massachusetts from the border region would be 25% of the total available. If the amount of wood available in Massachusetts is X, and the amount available from outside is 1.5X, then Massachusetts could plan on increasing its supplies by 0.375X (or 0.25 * 1.5X).

These numbers can be adjusted to develop some insights into what might represent a reasonable upper bound. Suppose we make the assumption that the amount of 'new' biomass available in the border counties is actually twice that available in Massachusetts (call this 2X). Furthermore, suppose that Massachusetts is able to purchase half of that wood by virtue of location or the timing of establishing new plants and their supply infrastructure. In this case, Massachusetts could increase its supply by X (or 0.5 * 2X), thus doubling the amount available only within the state.

In order to provide some general guidance and indication of the volumes of biomass that could be available from the border counties to supply new bioenergy facilities in Massachusetts, we have assumed that Massachusetts could successfully purchase 50% of the potential incremental production. In our Low-Price Biomass scenario, this would suggest that 140,000–215,000 green tons of forest biomass from border counties could augment the supplies available within Massachusetts. Supplies available from border counties increase to 575,000–725,000 green tons in the High-Price Biomass scenario.

Suffice to say, there is no simple answer to the question of how much biomass might be available from the border counties to furnish new bioenergy facilities in Massachusetts. However, it would seem prudent that each new facility (particularly those with large annual wood consumption) conduct its own feasibility study and carefully establish that the supplies it needs are available and not destined for other bioenergy plants.

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