Energy from Forest Biomass: Potential Economic Impacts in Massachusetts

Prepared for:
Massachusetts Division of Energy Resources
and
Massachusetts Department of Conservation & Recreation

Massachusetts
Sustainable Forest
Bioenergy Initiative

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December 2007

Executive Summary

The regional economic impact analysis is one task of the Massachusetts Sustainable Forest Bioenergy Initiative, a multifaceted study of biomass energy potential in Massachusetts. The economic impact study looks specifically at impacts in the 5 western counties of the Commonwealth, where biomass energy development would likely occur.

The Massachusetts biomass resource is larger than currently used, and several Commonwealth industries would benefit from closer outlets for wood residue disposal. Biomass energy is effectively carbon neutral. Renewable Portfolio Standards (RPS) in Massachusetts and neighboring states provide a financial incentive to construct new wood chip burning power plants. Such plants will likely be small by fossil-fuel standards, and may increasingly produce both useful heat and electricity, though at present are most likely to produce only electricity. Plants will likely be sited in areas with good road access for wood chip deliveries, and near existing high-voltage electrical networks.

The study develops and describes a scenario of 165 MW of new biomass electricity generation facilities (as well as some smaller heat-only plants) by 2015, supplying an annual 1,300 GWh of renewable energy. This production would provide about 19% of the projected 2015 renewable electricity demand in Massachusetts, Connecticut, and Rhode Island. Generating this energy would require an estimated 1.7 million green tons of woody biomass per year. This fuel source is available from a combination of existing wood residue and increased utilization of in-forest wood residue within the Commonwealth, and from adjacent counties in neighboring states.

Using an IMpact Analaysis for PLANning (IMPLAN) input-output model, the study estimates economic impacts of building new biomass energy facilities in Massachusetts, compared to a business-as-usual scenario that assumes facilities contributing to the region's RPS demands are built elsewhere. The model suggests an on-going total annual output increase of $57 million in the five-county area, with an associated 440 new jobs. Impacts of an additional $22 million in new annual output and 153 new jobs would occur in the rest of the Commonwealth. Besides the on-going operating effects, initial construction of biomass energy facilities as described would create a total of $214 million new output and 1,898 jobs per year for five years in the five-county area, as well as $56 million new output and 346 new jobs per year for five years elsewhere in Massachusetts. Thus in addition to achieving renewable energy goals, development of biomass energy holds substantial economic promise.

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Purpose and Scope

The Massachusetts Sustainable Forest Bioenergy Initiative is a multifaceted study of biomass energy potential in Massachusetts, assessing the possible extent and impacts of expanding bioenergy use, as well as assessing possible obstacles. Activities of the initiative include, among other things, researching potential biomass supply and processing methods, researching sustainable biomass harvest levels and impacts on forest health, developing a strategic plan for establishing biomass supply infrastructure, and outreach to foresters and loggers. The Initiative is managed by the Massachusetts Division of Energy Resources with the Department of Conservation and Recreation and is funded by grants of $495,000 from the U.S. Department of Energy and $245,000 from the Massachusetts Technology Collaborative, Renewable Energy Trust.

In Initiative subtask 1.3 we conduct an economic impact analysis, comparing a scenario with new biomass generating facilities located in Massachusetts to a scenario without those facilities (with the same facilities likely built elsewhere to fulfill regional RPS requirements). Our study estimates how this increased use of biomass might impact total output, investment, and employment in the Commonwealth. This report describes the basis, assumptions, and findings of that analysis, and reviews similar studies that have been conducted elsewhere.

As energy utilization is the major source of anthropogenic greenhouse gas emissions and associated global warming, renewable, carbon-neutral electricity is currently of much interest. Yet other than hydroelectricity, renewable energy has not been a significant contributor to most modern economies, and societal impacts of sustainable energy use are not completely understood. Significantly different impacts also accrue from different renewable sources such as solar, wind, and biomass. This study is part of an effort to better understand the potential of one renewable, biomass used as a solid fuel for generating electricity. Unlike most renewables, biomass generation requires a supply of operating fuel, the creation of which requires significant amounts of capital and labor on an on-going basis. Thus we expect that biomass energy use will have notable economic impacts in the regional economy.

General Considerations

The reforestation of New England in the 20th century provided a large volume of available woody biomass, widely distributed throughout the region. While the sustainable harvest and accessibility of this biomass supply in relation to potential renewable energy demand is a key long-term question, wood chips are clearly abundant at present. Indeed in the recent past, there has been significant concern about how to absorb the surplus supply of wood chips created by pulp mill closures and increased land clearing for development (Morris 1995; Innovative Natural Resource Solutions and Draper/Lennon

Inc. 2002). Securing viable outlets for low-grade wood residue is important to both the logging industry, which generates low-grade wood from thinning and forest-stand improvement, and to wood-processing industries like sawmills, which must dispose of significant quantities of waste as inexpensively as possible.

While wood was historically an important energy source almost everywhere, and is still significant in much of the world, in the United States wood is typically considered an uneconomical energy source. A key limitation of biomass fuel is its bulk—compared to coal (the other solid fuel), wood chips have about three times the volume for a given amount of potential energy (Harris, Adams et al. 2004). Thus compared to coal, and indeed compared to almost any other combustion fuel, biomass is expensive to handle and move, and cost of transportation looms large in assessments of financial viability. A separate technical paper of the Initiative looks in detail at the dependence of wood chips on non-renewable diesel fuel for transportation (Timmons, Viteri Mejía et al. 2007), but does not find that dependence to be extreme, suggesting that labor and equipment costs may be more important to the economics of wood supply than the cost of diesel fuel.

The distributed nature of the wood fuel source and the relatively high cost of wood movement suggest that in general, wood-chip burning power plants will be relatively small and dispersed. Yet the other major influence on plant size is economies of scale in plant operation: larger plants generally use less labor, operate at higher efficiencies, and have lower costs per kWh generated than smaller plants. In practice, the trade off between the plant and transportation efficiencies has resulted in optimum plant sizes of 40-50 MW capacity (Black & Veatch Corporation 2004; Harris, Adams et al. 2004; Kingsley 2007). At this size, a typical plant will draw wood chips from an area defined by a maximum 75-minute one-way truck driving time, or about a 60-mile radius if goods are transported at an average speed 48 mph in every direction (Kingsley 2007). But at 50 MW, such plants are still small compared to fossil-fuel fired stations, which can be ten or twenty times larger (Black & Veatch Corporation 2004). Thus the relatively small plant size dictated by the costs of moving wood chips is a significant factor in the cost of biomass electricity.

In spite of these economic challenges, biomass in general and wood in particular are currently receiving new attention based on two key attributes: 1) unlike fossil fuels, wood can be indefinitely renewable (if sustainably harvested), and 2) when wood harvest and wood growth rates are equal, there is no net emission of carbon: CO_2 resulting from wood combustion is reabsorbed in new tree growth, and renewable protocols typically consider biomass to be carbon neutral (Regional Greenhouse Gas Initiative Model Rule 2007) . Thus replacing fossil-derived energy with biomass can reduce greenhouse gases and mitigate global climate change.

Current demand for biomass-generated electricity in New England is driven, in part, by Renewable Portfolio Standards (RPS) now in place in Massachusetts, Connecticut, and Rhode Island. RPS requires utilities to purchase increasing amounts of renewable-based electricity. Standards for Massachusetts, Connecticut, and Rhode Island range from 3% of electric sales today in Massachusetts and Rhode Island to as much as 10% in Rhode

Island in 2015 (Table 2). RPS are implemented through the sales of Renewable Energy Certificates (RECs), issued for each megawatt hour of eligible renewably generated electricity. Generation need not take place in the state where electricity is consumed, as long as generation practices meet consuming-state standards for RPS eligibility. Other initiatives aimed at curbing global warming, such as carbon caps or taxes could similarly increase demand for biomass energy.

Massachusetts currently has only one operating biomass electricity plant, Pine Tree Power in Fitchburg (16 MW), though a number of other plants operate in New England. Public Service of New Hampshire's 50 MW Schiller plant opened in 2006 in Portsmouth, just north of the Massachusetts border, and permits are being sought for a 50 MW plant in Russell, Massachusetts.

In principle, the wood resource could be more efficiently utilized by plants built to utilize the low–grade waste heat. When wood is burned to generate steam for electricity generation, more than 2/3 of the potential energy in the wood is lost as waste heat. Some studies have suggested that new plants be located on sufficient land to allow co-development of industries which can utilize a plant's waste heat; in New England, greenhouses were identified as the most likely such user, with aquaculture, wood-drying kilns, and wood pellet manufacturing also being possibilities (High 1997). Through district heating systems, wood burning power plants might also distribute waste heat for space heating applications. Smaller facilities such as schools might build cogeneration facilities that use the thermal output for heating buildings, selling surplus electricity back to the electric grid. Such arrangements are more common in other countries, e.g. Denmark (Moller 2003). At present, policy instruments such as the RPS do not provide sufficient incentive to make most such developments financially attractive in the United States, nor is the equipment needed for small-scale wood-chip fired cogeneration completely commercially mature. But given the possible efficiency gains, use of waste heat from biomass electricity generation is likely to become more important in the future.

Given that biomass sources are dispersed over the landscape, most wood chips travel on trucks, which are well adapted to hauling short distances from differing points of origin. Thus good road access to plants is critical. A 50 MW plant operating at full capacity might get 70 truckloads delivered per business day, requiring 140 daily truck trips. This also suggests that 50 MW power plants will not be popular near residential areas, schools, etc., and that location in new or existing industrial areas with good access directly off major roads is most likely. Capital costs will also be minimized when plants are located close to existing high-voltage electricity grids (which would otherwise need to be constructed, at potentially high cost and time for permitting, and creating potential to generate public opposition).

Thus the current situation in Massachusetts suggests potential for biomass energy development: the biomass resource is larger than currently used, and other industries would benefit from closer outlets for wood disposal. Biomass energy is effectively carbon neutral, and Renewable Portfolio Standards provide a financial incentive to construct new wood chip burning power plants. Such plants will likely be small by fossil-fuel standards, and may increasingly produce both useful heat and electricity, though at present are most likely to produce only electricity. Plants will likely be sited in areas with good road access, near existing high-voltage electrical networks.

Literature Review: Woody Biomass Energy

Writing in 1988, Zerbe noted that 2.7 quads (3.7%) of U.S. energy was derived from biomass, that biomass potential had been calculated as high as 27% of U.S. total use, but that "the United States will not attain more than 5.5 percent (4 quads) in the foreseeable future... without a comprehensive plan to significantly increase research and production." Zerbe's prediction was not far off: in 2006 biomass supplied 3.2 quads or 3.2% of U.S. energy (Energy Information Administration 2007).

Biomass is humanity's original fuel, and has a long commercial history as well. Zerbe (1988) recounts U.S. growth in biomass use during the 1970s and 80s. In the lumber and pulp industries, for example, a combination of tighter air pollution regulations and higher oil prices in the 1970s caused facilities to start burning their own waste for useful energy (having previously just incinerated waste). In 1972, 21.3% of the U.S. paper industry's energy came from oil, but by 1986 this had dropped to 8.5%. Natural gas use declined similarly. The first modern non-forest products industrial boiler was installed in Alabama in 1975, and a number of others followed.

It has also long been known that biomass energy yields local economic benefits: Zerbe cites a Minnesota study's finding that each dollar spent on biomass energy results in $1.50 of additional economic activity, compared to only $0.34 for each dollar spent on oil. Yet most of the impediments to biomass utilization cited by Zerbe in 1988 are still true today: "harvesting biomass fuels is costly, combustion efficiencies are below those for fossil fuels, and emission control is in its infancy, and gasification and liquefaction technologies are ripe for improvement". While some of these issues are inherent in biomass utilization, some are not. Zerbe notes that "with lower oil prices... public support [for biomass] diminished" and development of the technology slowed.

Among the advantages of biomass energy recounted by Bergman and Zerbe (2004) are of course renewability and CO_2 near-neutrality—with biomass transportation accounting for about 5% net carbon emissions.

Bergman and Zerbe note that biomass fuel prices range widely, depending on wood residue availability and demand. In some areas, chip prices have been near pulp prices, at least for small-scale usage. At the power plant scale, Bergman and Zerbe cite Vermont prices for the Ryegate and McNeil power plants, for which whole-tree chips have been acquired for $12 to $20 per ton over the last 15 years. Harvesting costs are typically assumed to be $7-$10 per ton, chipping $4 per ton, stumpage about $1, and the balance in trucking. At $20 per ton, chip energy costs about $2.16/MMBtu (assuming 9.25 MMBtu/green ton), slightly more than coal at perhaps $2/MMBtu (assuming $50/ton and 25 MMBtu/ton). Yet capital costs for woody biomass plants are high, ranging from 50-

200% more than for similar-sized fossil fuel plants (Bergman and Zerbe 2004). And our current study suggests that chip prices will be significantly higher than $20 per ton.

Bergman and Zerbe describe the various uses of biomass energy—heat, electricity, both—and range of scales at which the fuel can be used. At the power plant scale, they note average U.S. size is 20 MW capacity, with larger plants ranging to 50 MW or more. Chips are normally sourced in about a 50-mile radius from a plant. The McNeil and Ryegate plants both operate at about 25% overall efficiency (electric energy generated/potential energy in chips), somewhat lower than typical coal plants. Woody biomass may also be mixed with coal in a practice called cofiring, with biomass substituting for up to 10-15% of coal. This practice of course reduces total emissions and carbon impacts of coal combustion.

As part of a feasibility assessment for woody biomass energy use at Dartmouth College, an environmental studies class there compiled a brief history of the New Hampshire biomass electric industry (2006). Based on legislation (and electricity purchase contracts) enacted in 1984, New Hampshire constructed nine biomass electric plants, with a total of 108 MW capacity. These consumed about 1.3 million tons of wood chips per year; the state also produced an additional 2.8 million tons of relatively low-grade wood for the pulp industry. But as electricity from other sources became cheaper in the 1990s, biomass electricity came to be viewed as too expensive. Three of the original nine plants have now ceased operation, and the future of the others is in doubt.

While as noted above, Renewable Portfolio Standards (RPS) in several New England states support an emerging biomass electric industry, the technology used in the older New Hampshire plants does not qualify for most of these programs, and retrofitting to meet new standards may not be economically attractive. Thus it is clear that biomass electricity currently requires some level of public support to exist—support reflecting lower external costs of carbon emissions and other pollution than from fossil fuel combustion. In December 2006 the newly retrofitted (from coal burning) 50 MW biomass-fired Schiller station at Portsmouth, New Hampshire went on line. This station was designed to meet Massachusetts and Connecticut RPS requirements, and derives income from both the sale of Renewable Energy Certificates (RECs) and MW-hours of electricity.

Earlier biomass electric plants around the U.S. also suffered from several problems, as reviewed by Wiltsee (2000). Typical problems included unreliable fuel supplies or prices; problems with fuel supply storage areas and fuel delivery systems; limited ability to change fuel specifications as necessary; and plant locations that increased chip transportation costs or caused other logistical problems. New biomass plant technology has corrected many of these problems, though some are inherent in the fuel source.

For the 20 biomass electric plants Wiltsee (2000) reviewed, plant sizes ranged from 10-79.5 MW, with a mean size of 37.7 MW. Capacity factors ranged from 19% to 106%, revealing a range of usage patterns—some plants were operated to provide base loads, some to provide peak loads. A typical heat rate was about 14,000 Btu/kWh, or a thermal efficiency of about 24.4% (again, electric energy generated/potential energy in chips).

Huyler (1989) studied the logging industry in New England a few years after construction of wood chip burning power plants had taken place in the late 1970s and early 1980s. At the time there was considerable debate about the impact of the new wood chip power industry on the New England forests: while some thought the new markets for low-grade wood could enhance overall forest quality, others feared it would lead to bad forest management and overcutting. Huyler's study included interviews with loggers, landowners, and others involved in the forest industry, and aimed to both discover production patterns in the emerging chip industry, as well as opinions about forest impacts.

Sixty-four percent of operators whom Huyler surveyed ran chipping operations 201 to 250 days per year, and an additional twenty-four percent operated more than 250 days. For 52% of the loggers, chipping made up one-half their total logging work. Ninety-two percent of loggers also produced sawlogs, and 56% also produced pulpwood. Thirty-two percent of those surveyed produced more than 4,000 tons of chips per month during their busiest months. In terms of forest management, Huyler found that while some clearcutting for wood chips was taking place, this was minimal: areas clearcut were usually less than 20 acres, and most of these were done to permit development. In response to the statement "the overall post-harvest quality of stands entered has improved significantly as a result of fuelwood chipping operations", 72% of loggers strongly agreed and 20% mildly agreed; only 4% disagreed. Thus at least from a logger's perspective, biomass electricity improves New England's forests. Subtask 4.1 of the Massachusetts Sustainable Forest Bioenergy Initiative looks more closely at impacts on forests, and at sustainable harvest levels of woody biomass in the Commonwealth.

Literature Review: Biomass Regional Economic Impact Studies

A number of previous studies have examined regional economic impacts of using biomass energy. Benefits for local economies clearly exist; given the unequal geographic distribution of the world's fossil fuel endowment, developing local energy sources means replacing imports to an area. Replaced imports may originate in other regions (e.g. coal) or outside of the U.S. (oil). But utilizing biomass and other renewables also creates more total employment than fossil fuels: a key conclusion of a study analyzing 13 independent reports was that "across a broad range of scenarios, the renewable energy sector generates more jobs than the fossil fuel-based energy sector per unit of energy delivered" (Kammen, Kapadia et al. 2004). The studies reviewed below (several of which are listed in Table 1) detail employment and other economic impacts from different perspectives.

A 1992 study for the Northeast Regional Biomass program looked at total economic impacts of the existing biomass energy industry in the northeastern states (Resource Systems Group and Energetics Inc. 1994). While the study assessed the impacts of several biomass electric facilities, the study was not limited to these: woody biomass used in home heating (cordwood) as well as in commercial and institutional heating was included. The study found that a total of 1.06 million tons of wood was used in Massachusetts in 1992.

The 1992 Northeast Regional Biomass study updated a 1985 effort, and used the same methodology: a "hybrid model", with spending and employment from the biomass industry itself estimated directly, and indirect effects estimated using an IMPLAN model. The study assumed that if biomass were not being used as an energy source, more expensive oil or electricity would be used instead. Thus the effects of biomass cost savings over fossil fuels were incorporated. An estimated $29 million (1992 dollars) was spent on biomass home heating fuel, and $42 million in the commercial/industrial sector. The combination resulted in $74.8 million in direct and indirect economic activity, as well as 1,482 jobs (again from both direct and indirect effects).

A 2004 report on potential biomass energy impacts in South Carolina (Harris, Adams et al. 2004) estimated the impacts of new (rather than existing) biomass use. In this case the scenario examined was for woody biomass replacing coal as a fuel in electricity generation—biomass being a potentially local fuel in South Carolina, while coal is an import. An estimated 20.9 million tons of woody biomass was found to be available on a sustainable basis in South Carolina, from a combination of logging residues, thinnings, scrub wood cuttings, mill residues, and urban wood residue.

A 40 MW plant was identified as the optimum size electric generating facility, and impacts of operating and supplying fuel to a plant of this size were calculated using the Regional Dynamics model. Total economic impact from operations (not construction) was estimated at $10.8 million per 40 MW plant. For comparison, four such plants represent the approximate scenario considered in our current study of Massachusetts; four plants would have resulted in annual economic impacts of $43.2 million. The South Carolina study also noted that biomass electricity is significantly more expensive than current sources: estimated biomass electric production cost was $.084/kWh, compared to coal-based electric futures which at the time averaged about $.039/kWh.

In Pennsylvania, the Community Foundation for the Alleghenies commissioned a 2004 study on the economic impacts of using a number of renewable energy sources in the state (Black & Veatch Corporation 2004). While stand-alone biomass electricity generation was described in the report, the scenario for which economic impacts were calculated included only biomass cofiring at conventional coal plants, the authors believing this approach to be more viable. This is in part because of larger feasible plant sizes: a 500 MW plant fired with 10% biomass cofiring would still have a reasonable size woodshed, while the supply area for a 500 MW biomass-only plant would likely be uneconomic for wood chip transportation (as discussed above). Retrofitting coal plants for biomass cofiring also requires less capital than constructing new stand-alone biomass plants. But note that the economics for the operator of a cofiring plant are only superior if the electricity generated meets RPS criteria, which is not the case in some states. In Massachusetts cofiring is eligible, subject to meeting Massachusetts Department of Environmental Protection emission limits and advanced technology criteria, as provided in the October 2007 revised RPS regulations.

The Black and Veatch scenario assumed a goal of 10% renewable electricity in Pennsylvania, including 21.1% of that coming from cofired biomass, for a total of 1,020 MW of biomass capacity in Pennsylvania by 2015. The analysis compared the cost of generating the renewable portfolio to a business-as-usual case of generating the same amount of electricity from conventional sources. While renewable energy was found to be more expensive, an increase of $1.23 billion in present value over the 20-year study period, the per-unit premium was modest: the renewable mix added only $0.0045 per renewable kWh, or $0.00036 per average kWh. This equates to about $0.29 per month for a typical household electric bill.

Sensitivity analyses looked (among other things) at the impact of a more restrictive RPS that would disallow biomass cofiring. The impact of such a change was significant but perhaps still modest, with monthly household electric bill impact rising to $0.87.

Black and Veatch also used a RIMS II model to assess indirect economic impacts of the RPS scenario. Biomass cofiring was found to have 57% of operating expenditures made in state, with a $92,221 per MW increase in total economic output and $74,354 increase in earnings. Biomass operation created 2.13 jobs per MW capacity, more than any other renewable assessed, given the ongoing fuel requirement. In total for both construction and operation over the study period, the RPS portfolio increased output by $10.1 billion, earnings by $2.8 billion, and employment by 85,167 over the business-as-usual scenario.

Another study by Jensen, Menard, et al (2004) looked at economic impacts of cofiring biomass with coal in the southeastern United States, where 60% of electricity currently comes from coal. The study took a somewhat different approach from others reviewed here, assuming that a hypothetical carbon tax would create new biomass demand, inducing coal-burning utilities to reduce carbon emissions by cofiring some percentage of biomass with coal. Market impacts on biomass prices were then calculated. In different scenarios, biomass demand ranged from 0.56 million dry tons (approximately 0.81 million green tons), supplied at an estimated $21/dry ton (~$14/ green ton) to 31.9 million dry tons (~46.26 million green tons) at $55 per dry ton (~$38/green ton). At this price, agricultural biomass becomes a significant portion of the total.

Economic impacts ranged from an additional $7.4 to $2,255.3 million in total output (direct, indirect, and induced) from operation (not including construction), and 97 to 32,611 new jobs. Thus by attaching various levels of cost to carbon emission, this study shows that biomass use becomes economically feasible, though at quite different levels and prices in the different scenarios, and yielding a wide range of economic impacts.

In 2006, Barkenbus, Menard, et al reviewed the employment impacts in the Tennessee Valley Authority (TVA) region of a possible federal Renewable Portfolio Standard (as opposed to the carbon-tax scenario modeled in the 2004 Jensen, Menard, et al study). TVA has 8.6 million electric customers in Tennessee and portions of 6 other states The study notes that the southeast is the only region of the country in which no state-level RPS have been enacted, and reviews the various challenges associated with achieving renewable targets in this region. Biomass was identified as the renewable most readily

Table 1, Comparison of Economic Impact Studies Reviewed

author	year	application	model	study description	million tons green biomass	operating impact on total output (millions)	total jobs impact	output impact per ton biomass	jobs per million tons biomass
Resource Sys. Group	1994	all: cordwood heating, etc.	IMPLAN	impact of existing wood heating industry in MA (includes impact of savings over fossil fuels)	1.1	74.8	1,482	70.6	1,398
Black and Veatch	2004	wood chip-coal cofiring	RIMS II	meeting 10% RPS in PA, 50% in-state biomass supply, 1999 dollars	9.3	94.1	2,173	10.1	234
Barkenbus, et al	2006	wood chip-biomass crop-coal cofiring	IMPLAN	meeting 10% RPS in TVA region (most biomass assumed to be agricultural)	6.8	na	8,256	na	1,214
Harris, Adams, et al	2004	wood chip electricity	ReDyn	impact per 40MW plant in SC	0.4	11.8	107	27.0	268
current study, total MA impact	2007	wood chip electricity	IMPLAN	impact of 165 MW of new biomass electricity generation in MA	1.7	113.0	774	66.5	455

Notes: Values not expressed in constant dollars. Research questions, models, and methods in the different studies are not completely comparable.

deployable in the southeast, again in cofiring with existing coal-burning power plants. The study assumes that 15% is the maximum biomass cofiring rate, and that cofiring at this maximum level will be optimal for the utilities.

The study calculates that 19.7 billion renewable kWh would be needed to satisfy a 10% RPS. Of this, the authors conclude that only 77% could feasibly be generated in the TVA region, the balance being purchased through RECs. The study projects that 49% of the total RPS requirement would come from biomass (representing 6.8 million tons), though they calculate that only 13% of the total would come from woody biomass. The balance would come from agricultural sources, primarily switchgrass grown as a dedicated energy crop.

Annual employment (operations) impacts of all renewables in this scenario are estimated to be 2,229 jobs directly, and 16,291 jobs total including indirect impacts. Biomass-generated electricity is estimated to create 1,681 jobs directly, and 8,256 in total. The study notes that positive impacts on rural employment are one of the primary attractions of an RPS in general, and of the large dedicated-energy-crop approach in particular.

Basis for the IMPLAN Model

We use an IMPLAN input-output model to estimate total economic impacts of expanded wood chip energy use in Massachusetts. Specifically, the model examines a 2015 scenario of 165 MW of new electric generating capacity: two 50 MW plants, two 25 MW plants, five 3 MW combined heat and power (CHP) plants, as well as twenty-five new 5 MMBtu/hr (~1.5MW) heat-only plants. Assumptions behind the number, scale, and type of wood-chip burning plants proposed for the model are explained below.

Many variables enter into the scenario development, for which a number of values are unknown and unknowable. Thus the projected scenario is not intended to be a prediction, but rather to provide a rational and transparent basis for the economic impact assessment. Potential impacts can then be scaled up or down as appropriate to correspond to different assumptions and scenarios.

We chose a 2015 scenario because it represents the earliest realistic construction date for the facilities envisioned, though construction of the facilities to be modeled is not assured.

Demand for biomass electricity in 2015 could plausibly grow to the total electric capacity of 165 MW proposed for the model. Demand depends on a number of variables, shown in Table 2:

- total electricity consumption in states with RPS; estimates provided are from ISO New England (2006). Retail electric sales are totals less transmission and distribution losses, assumed to be 9%. Sales of electricity by municipal utilities are excluded from the RPS in Massachusetts (14%) and Connecticut (5.8%).

Table 2, New England Total Electric Demand, RPS, and Biomass Electric Demand

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
ISO New England Total Demand Projections, GWh										
Connecticut	34745	34800	35270	35885	36515	37195	37845	38365	38865	39350
Massachusetts	61500	59980	60720	61660	62630	63690	64640	65490	66300	67095
Rhode Island	8615	8690	8775	8900	9065	9235	9410	9540	9670	9800
Projection less transmission and distribution portion @ 9%, GWh	31618	31668	32096	32655	33229	33847	34439	34912	35367	35809
	55965	54582	55255	56111	56993	57958	58822	59596	60333	61056
	7840	7908	7985	8099	8249	8404	8563	8681	8800	8918
Total electricity sales less muni load, GWh										
Connecticut (5.8% muni)	29784	29831	30234	30761	31301	31884	32441	32887	33316	33732
Massachusetts (14% muni)	48130	46940	47519	48255	49014	49844	50587	51252	51886	52509
Rhode Island (0% muni)	7840	7908	7985	8099	8249	8404	8563	8681	8800	8918
Renewable Portfolio Standards (RPS)										
Connecticut (Class I only)	2.00%	3.50%	5.00%	6.00%	7.00%	7.00%	7.00%	7.00%	7.00%	7.00%
Massachusetts	2.50%	3.00%	3.50%	4.00%	4.50%	5.00%	5.50%	6.00%	6.50%	7.00%
Rhode Island	n/a	3.00%	3.50%	4.00%	4.50%	5.50%	6.50%	7.50%	8.50%	10.0%
RPS, GWh										
Connecticut	596	1,044	1,512	1,846	2,191	2,232	2,271	2,302	2,332	2,361
Massachusetts	1,203	1,408	1,663	1,930	2,206	2,492	2,782	3,075	3,373	3,676
Rhode Island	n/a	237	279	324	371	462	557	651	748	892
TOTAL GWh CT-MA-RI	1,799	2,690	3,454	4,100	4,768	5,186	5,610	6,028	6,453	6,929
Biomass portion of RPS (Grace & Corey, 2002)	19.0%	23.6%	28.4%	33.0%	31.7%	30.3%	29.0%	29.0%	29.0%	29.0%
Biomass electricity required, GWh	342	635	980	1,353	1,510	1,573	1,627	1,748	1,871	2,009
MA portion of RPS electric demand		52%	48%	47%	46%	48%	50%	51%	52%	53%
assumed MA generation, % of total NE market		65%	65%	65%	65%	65%	65%	65%	65%	65%
MA-generated biomass electricity, GWh		413	637	879	981	1,023	1,057	1,136	1,216	1,306
Biomass electric capacity @ .9 CF, MW		52.4	80.8	111.5	124.5	129.7	134.1	144.1	154.3	165.7

- specific RPS levels in each state; the Connecticut figures include energy only from class I sources (new sustainable biomass). Massachusetts figures assume RPS continues to grow at 0.5% per year after 2009 (which must be legislatively approved). Note that all RPS are subject to legislative change.

- the portion of the RPS supplied by biomass; wind, solar, hydro, etc. also provide renewable electricity. Figures used for biomass are from an analysis of likely renewable sources used to meet the RPS standards (Grace and Cory 2002), an update of an earlier report (Smith, Cory et al. 2000). The authors estimate the RPS biomass portion will climb as high as 33% in 2009, then start to decline as other sources like wind become more prominent. Figures for 2006, 2009, and 2012 were provided; percentage after 2012 was assumed to be constant.

- the portion of that biomass electric supply located in the Commonwealth; we assume this figure to be 65%, i.e. that 65% of all the RPS demand in Massachusetts, Connecticut, and Rhode Island would come from Massachusetts sources. This is likely an upper bound estimate, as the Massachusetts portion of the 3-state renewable electric demand is about 50%.

Thus the demand projection includes many assumptions, which if changed, could significantly alter the projected 2015 demand for biomass electricity. Yet based on the assumptions above, as calculated in Table 2, 165 MW of capacity appears to be a rational basis for an economic model.

For our scenario we assume the 165 MW of capacity to be provided by:
- two 50 MW plants
- two 25 MW plants
- three 5 MW combined heat and power (CHP) plants

Plants of 50 MW are likely near the optimal scale for producing commercial electricity, as discussed above. Yet the Renewable Energy Certificate (REC) market may still allow profitable electricity generation at smaller scales, particularly if smaller plants are co-located with heat-using industries (e.g., greenhouses). Such cogeneration is also more likely at smaller plant scales.

The three 5 MW combined heat and power plants represent a relatively new but promising area for biomass utilization. Since as noted above, the technology in this area is not fully mature, and the economics are not fully known, we assume only a small number of such plants for our scenario. The best prospects for CHP plants are likely industrial facilities that have year-round demand for process heat, and which can thereby achieve high capacity utilization.

Though the current number of chip-based heat-only plants is small, and at current fuel prices the financial incentives to build new plants are not strong, we also propose including 25 such plants (5 MMBtu, ~1.5 MW) in the biomass utilization scenario.

Again, including these in the scenario reflects the economic impacts of this kind of biomass use, which may have policy implications (Vermont, for example, provides a 75% subsidy of the capital cost of converting schools to wood chip energy).

The total new biomass fuel demand in Massachusetts from electric facilities as well as new heating plants is projected to be 1.7 million green tons per year (Table 3). Sustainable supply levels and sources are discussed in more detail below. This amount of biomass energy is equivalent to about 646,000 tons of coal (at 25 MMBtu/ton).

Table 3, Estimated Wood Chip Demand

Chip burning power plants	
MW electric capacity to be modeled	165
plant capacity factor	90%
annual GWh/MW capacity	7.9
MMBtu/GWh	3,413
annual MMBtu/MW capacity, net	26,908
plant efficiency	28%
annual MMBtu/MW capacity, gross	96,100
MMBtu heat content/ton chips	9.25
tons chips/MW capacity	10,389
annual tons wood chips required	1,714,222
Heat only plants	
new MMBtu capacity	125
tons/year/MMBtu plant capacity	250
tons of wood chips/year used	31,250
new tons per year	1,745,472
current tons/year (Pinetree Fitchburg only)	180,000
total tons/year	1,925,472

Constructing and operating 165 MW of new biomass electricity generation (and 25 smaller heat-only plants) is then compared to a “business as usual” alternative. Given the existence of the RPS in Massachusetts, we assume that renewable electricity to meet the RPS will be generated in some way. Possibilities include meeting the RPS in Massachusetts from other renewable sources, or meeting the same demand from approved renewable sources outside of the Commonwealth. Given the state of development for other renewables, and that we have already assumed that over 2/3 of the RPS electricity would be supplied by non-biomass sources (Table 2), we think the outside-of-Commonwealth scenario is more realistic. Thus the economic model compares the difference between having 165 MW of biomass electricity generation built in Massachusetts, to the same capacity built in other states, with those states garnering any economic rewards that may accompany biomass energy development.

Plant Capital Costs

A significant amount of the initial impact of new biomass generation is from expenditures on new plants. Plant construction costs are difficult to estimate, in that all plants are to some extent custom built, with varying prices, and the price/size relationship is not linear (smaller plant have higher costs per megawatt of capacity). Nor is construction cost information necessarily in the public domain. For the model we use a construction costs estimate of $2,154,950 per megawatt of generation capacity (Table 4). This figure is the mean of numbers from four sources: average of estimates from a biomass industry consultant, average of estimates from biomass industry developer, and two different estimates cited in Harris et al (2004). All figures are adjusted to constant 2006 dollars using the Consumer Price Index (CPI). For the new biomass-based heating plant to be modeled, we use an estimate of $175,000 per MMBtu, a figure obtained from an industry consultant.

Table 4, Estimated Plant Construction Costs

Source	$/MW (2006 dollars)
Kollmer, average of 3 scenarios in New England	2,800,000
Kingsley, average of two studies in New England	1,708,893
Harris, estimate for South Carolina	1,707,570
Harris, estimated for Wisconsin cited	2,403,335
mean $/MW	2,154,950
(Black & Veatch range: $2,000,000-$2,500,000)	

Based on these construction cost estimates, the modeled 165 MW of new electrical capacity and 125 MMBtu of thermal capacity would result in construction budgets of $377 million in the Commonwealth. These expenditures would clearly not occur simultaneously, and for modeling purposes we assume that they will be spread out evenly over five years. We also expect that generating plant equipment investment will be purchased from outside of Massachusetts. For all other goods and services related to construction, standard IMPLAN regional-purchase coefficients are used to gauge (regional) in-state and out-of-state purchases.

Plant Operating Costs

A major expense of biomass plant operation is of course biomass fuel. Quantity of fuel required is relatively predictable. In New England, mixed, green wood chips of the quality and moisture content used in power plants typically contain about 9.25 MMBtu of gross energy potential (Kingsley 2007). We assume plants operate at 90% of rated capacity (or perhaps more accurately, aim to operate at 90% capacity). From experience at the more-efficient existing biomass plants (Wiltsee 2000), we use a figure of 28% overall efficiency in conversion of wood chip energy to electrical energy. From these figures we then calculate biomass plant wood demand to be 10,389 tons per MW of biomass capacity per year, or 1.7 million additional tons of wood chips annually for the 165 MW scenario to be modeled (Table 3, above).

Establishing the cost of this wood chip fuel for biomass plants is more difficult. New Hampshire has 6 biomass electricity plants that were constructed in the 1980s, and operated steadily from 1995-2006 (with the exception of one plant that closed in 2002). Average prices in the state during that time, as reported in the New Hampshire Timberland Owners quarterly market report, and expressed in constant 2006 dollars, ranged from $16.84 per ton (4th quarter 2002) to $27.40 per ton (2nd quarter 2006) averaging $21.37 per ton over the entire period.

Thus there is variation in market prices even during periods of relatively constant demand. And clearly, the biomass supply curve is also upward sloping. At the low end, wood chips enter the market as waste products from land clearing, tree trimming, etc., as well as waste from sawmills and other wood processing facilities. In the absence of significant demand, i.e. *without* biomass energy markets, prices net of transportation may approach zero. For this study we assume that all wood residue products are currently utilized, and that increasing the wood chip supply requires additional raw material from the forest, in Massachusetts or adjacent states. While this may also be waste-quality wood—treetops, low-grade trees, etc.—extracting this material from the forest, processing it into chips, and transporting it to market all require significant and increasing inputs of labor, equipment, and fuel. Thus the marginal cost of providing wood chips rises with the quantity supplied, and the market price should in theory reflect that marginal cost.

We anticipate, then, that wood chip demand created by the envisioned 165 MW of new Massachusetts biomass electric capacity will have a significant impact on wood chip prices in the Commonwealth. Thus a separate part of the Initiative, subtask 3.1, looks in detail at the Massachusetts wood chip supply curve. Preliminary results suggest the chip price should be approximately:

- $18.00 per ton for the first 500,000 tons supplied
- $18.50 per ton for 500,000 – 700,000 tons
- $18.50 per ton plus $1.00 per ton for every 100,000 tons over 700,000

Based on these estimates, new demand of 1.7 million tons, and an existing demand of about 180,000 tons per year from the Pinetree Fitchburg plant, estimated wood chip price is $30.75 per ton (at this price per ton, and using the other assumptions in our model, wood cost/kWh is $0.04; thus cost of wood clearly has a significant impact on the price of biomass electricity). Total new fuel expenditures are calculated to be $54.6 million (split between chip production and chip transport costs); this figure is used in the IMPLAN analysis.

Besides fuel, other important plant operating expenses include labor, supplies and services, utilities, maintenance, and property taxes. For breakdown of these costs we use estimates from a report on New Hampshire power plants by Innovative Natural Resource Solutions and Draper/Lennon Inc. (2002) shown in Table 5, and adjusted to 2006 dollars. Since the 2002 report estimated operating costs for 15 MW plants, and such costs are not linear (plants of a 40-50 MW scale will have lower average operating costs) we use a scale factor of 0.6 to reduce the per-MW costs from the 2002 report. This results in a total operating cost projection similar to known costs of larger-scale plants.

Table 5, Estimated Plant Operating Costs

		50MW scale factor for payroll, supplies, and maintenance:	0.6	
		per MW @15MW size	per MW @ 50MW size	2006 dollars
payroll	975,000	65,000	39,000	43,680
property taxes	225,000	15,000	15,000	16,800
supplies and services	400,000	26,667	16,000	29,867
maintenance	350,000	23,333	14,000	26,133
utilities	425,000	28,333	28,333	31,733
TOTAL	2,375,000	158,333		148,213
			total @ 50MW	$ 7,410,667
source: Innovative Natural Resource Solutions (2002) for 15 MW plant in NH				

In addition to capital expenditures and direct fuel and operating expenses, supplying wood chips for 165 MW of new biomass electric capacity will require significant secondary investments and expenditures, for example in wood chip harvesting and processing. We assume that the necessary chipping equipment and harvesting equipment are purchased from outside Massachusetts. For all other aspects of logging firms' operational expenses we rely predominantly on IMPLAN's pattern of intermediate input requirements for *Logging* to provide appropriate estimates for these. We also check IMPLAN figures against figures for these expenditures from several sources.

The basic configuration and productivity of harvesting crews is based on case studies by Kingsley (2007) and Westbrook, Green, and Izlar (2006). Chipping crews are assumed to be additions to normal logging crews, though felling, skidding, and delimbing, expense are assigned to chips in proportion to the total weight of timber harvested. Crews are assumed to be using feller-bunchers to harvest trees, grapple skidders to remove whole trees from the forest to a landing, stroke delimbers, knuckle-boom loaders to handle tops, and horizontal chippers. Chips are blown into 30-ton capacity tractor-chip van rigs, and driven directly to biomass power plants.

Labor dedicated to chipping includes only one crewmember who operates the knuckle-boom loader and chipper simultaneously, and two truck drivers who ferry chips to biomass plants. Time is also added for 1.5 employees, attributable to additional felling, skidding, and delimbing labor used in chip production (in addition to just producing saw logs). Each such 4.5 person crew has an estimated production of 180 tons of chips per day (Westbrook, Greene et al. 2006; Kingsley 2007). With five working days per week and operating 48 weeks per year, each crew can produce 43,200 tons of chips annually. Thus the required new supply of 1.7 million tons of chips will require 24 such chipping crews, employing in total approximately 109 people (Table 6).

Based on equipment cost figures from the USDA Forest Service (2005) and Brinker et al (2002), we estimate the machinery needed to equip each such crew would cost approximately $1.5 million (Table 6). Based on depreciation rates from the same sources, and the total tonnage of chips required, we estimate an annual equipment depreciation and replacement expenditure across all crews of $5.4 million.

The projected wood chip fuel demand could potentially be met from several different supplies: from existing wood residue of land clearing, sawmills, etc., in Massachusetts that currently gets shipped out of state for lack of in-state markets; from chipping low-quality trees and tree tops left in the forest after current or new Massachusetts logging; and from chipping of the same kinds of logging debris in adjacent states. Of these sources, only chipping of forest waste in Massachusetts represents new economic activity in the Commonwealth. We estimate that approximately 60% (1.0 million green tons) of the new wood chip demand could be supplied in this way (Table 7), and use this as an assumption in the economic impact analysis below. Note that this is an upper-bound estimate, so that maximum potential economic impacts are calculated. The remaining 40% (0.7 million green tons) of new demand could be supplied by a combination of currently generated wood-waste in western Massachusetts (0.3 million tons, estimated in subtask 3.1) and from wood residue and new harvest in adjacent counties (10.1 million tons, also estimated in subtask 3.1).

One question in assessing the sustainable supply of Massachusetts wood chips is the meaning of sustainable—most would likely assume this to mean a harvest at no more than the rate of growth. Yet the appropriate stocking level is also a question. By some standards, the current forest is overstocked, and some areas would benefit from thinning, or harvesting at levels greater than net growth. Current stocks are much lower than in pre-settlement times, though, and others would argue that harvest should be less than net growth. Additional questions are how much of the net growth is economically retrievable at the projected fuel price point, and how much is ecologically retrievable given the need to follow harvesting methods that maintain ecosystem health. Subtask 4.1 of the Initiative looks at ecological limits of sustainable biomass supply in greater detail.

The 1.0 million tons of assumed new chip supply from western MA represents 51% of the estimated ecologically sustainable chip harvest level from Massachusetts forests, as established in subtask 4.1. This does not include any potential contributions from dedicated biomass energy crops (e.g. switchgrass), which could augment the supply.

Table 6, Selected Wood Chip Production Inputs and Employment Impacts

PRODUCTION HOURS							
hours per day	8						
days per week	5						
weeks per year	48						
production hours per year	1,920						
TOTAL PRODUCTION							
tons chips/day	180						
truckloads per day	6						
average tons per hour	23						
tons chips per year	43,200						
EQUIPMENT	feller-buncher	grapple skidder	stroke delimber	knuckle-boom loader	chipper	container truck	TOTAL
number	1	1	1	1	1	2	
price each	239,008	178,500	355,500	181,030	580,000	138,000	
source	Brinker	Brinker	USDA	USDA	USDA	USDA	
year	2002	2002	2005	2005	2005	2005	
adjusted to 2006 dollars	267,689	199,920	366,165	186,461	597,400	142,140	
chip portion	50%	50%	50%	100%	100%	100%	
total capital	133,844	99,960	183,083	186,461	597,400	284,280	1,485,028
useful life	4	5	5	5	5	8	
residual amount	20%	20%	20%	20%	20%	20%	
annual depreciation	26,769	15,994	29,293	29,834	95,584	28,428	225,901
maintenance % of depr.	100%	100%	90%	90%	75%	60%	
annual maintenance	26,769	15,994	26,364	26,850	71,688	17,057	184,722
LABOR							
man hours/machine hr.	1	1	1	1	-	1	
man hours/production hr.	0.5	0.5	0.5	1.0	-	2.0	4.5
EMPLOYMENT IMPACTS							
new chips required	1,745,472						
portion from new MA chipping	60%						
chip production per crew	43,200						
total crews required	24						
logging/chipping jobs	61						
trucking jobs	48						
total jobs	109						

Table 7, Portion of New Chip Demand Supplied by New MA Chipping

	western MA	notes
Growth, stems	2,262,774	Kingsley 2007
sawlog portion of stem growth	40%	Kingsley 2007
Stem growth net of sawlogs	1,357,664	
top growth as percentage of stem growth	29%	Kingsley 2007
Growth, tops	656,204	
Total potential chip supply	2,013,869	sum stem growth and top growth net of sawlogs
harvestable portion	50%	assume not all growth harvestable
Total available chip supply	1,006,934	new chipping portion only
Projected demand	1,714,222	based on 165 MW capacity plus heating plants
Potential portion of supply from core counties	59%	

IMPLAN Results and Sensitivity Analysis: Overview

The main purpose of this study is to measure the economic impact of biomass development on a 5-county region, and for the Massachusetts economy as a whole. The 5-county region encompasses the four western Massachusetts counties – *Berkshire, Franklin, Hampshire and Hampden*, and the central Massachusetts county – *Worcester*. This analysis considers these counties in aggregate. It is not the purpose of this study to identify which counties will eventually site new biomass-fired generating plants, or to identify where forest resource harvesting and chipping activities would occur. The goal is to obtain an estimate of regional *jobs, labor income,* and *sales,* created by the various aspects of developing woody-biomass supply, investment in chip-burning generation facilities, and their subsequent operating and maintenance requirements. As mentioned above, the time perspective is for complete build-out of generating plants, anticipated for 2015.

Initial Economic Potential of Biomass Development

This impact evaluation (similar to the Harris, Adams, et al study (2004) cited in the literature review) focuses on how different types of spending—related to forest-based chip production and to the construction and operation of chip-burning generation plants—is tied to *within- region* labor and businesses providing the necessary (capital) goods and services. The more that construction or operating and maintenance budgets *procure* locally, the greater the economic impact. This analysis does not include effects on the energy end-user, as might arise from potential changes in the price of electricity, since the existence of a Renewable Portfolio Standard is taken as a given. Implicitly the analysis does include an *import substitution effect* whereby the region recaptures a *leakage* of dollars expended on fuel inputs for traditional electricity generation (e.g. coal) by developing a locally produced chip supply. Table 8 portrays how specific components of the biomass initiative translate into *direct* economic effects.

The investment (logging capital and plant capital) required for implementing biomass generation will not generate any economic impact for the 5-county region or the state as a whole since these capital goods are manufactured outside of Massachusetts. However all the additional labor (related to construction, on-going forest operations and generating plant operations) will be satisfied within the 5-county region meaning additional labor income for households in the study region. Similarly the non-labor, non-capital budgets for forestry operations, plant construction, and eventual plant operations create requirements for supplies and services to fulfill the annual production requirement (of chips, of facility construction, and of energy outputs). Many of these requirements will generate new business for local area firms. The extent to which this occurs is determined in large part by the propensity of local firms (by specific type of industry activity) to meet local demand for specific products—in a regional economic impact model this is characterized by a set of *regional purchase coefficients*.

The next section provides a brief description of the *input-output* (I-O) economic modeling approach and its role in translating the *direct* economic effects into a set of *multiplier* effects that support additional economic activity for the region under study.

Input-Output Modeling and Impact Estimation

Regardless of how the direct economic effects of a project or policy are stated (e.g. payroll or jobs or sales) they in turn have the potential to generate subsequent rounds of economic activity through:

- ***Indirect economic effects -*** the economy-wide effects on business activity for off-site suppliers to the directly affected businesses. This can include production, distribution, and transportation for suppliers of goods and services.

- ***Induced economic effects*** – household-generated consumption of food, clothing, shelter and other consumer goods and services, as a consequence of the payroll change (emanating from employment changes) of the directly affected businesses and their suppliers.

The sum of the *direct, indirect,* and *induced* economic effect equals the ***total economic effect*** stated in various metrics—jobs, output (sales), labor income. The *indirect* and *induced* effects (also referred to as *multiplier effects*) are measured using an input-output framework for describing inter-industry transactions. A calibrated (year 2004 data) modeling system of all counties in Massachusetts was licensed from IMPLAN[1] to measure the multiplier effects of the biomass energy scenario. The IMPLAN (IMpact Analysis for PLANning) model is now the most widely used input-output economic modeling system in the United States, with a client list of 500 public and private agencies, including several federal agencies and numerous state agencies. It utilizes U.S.

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[1] IMPLAN MIG, Stillwater, MN

Commerce Department ("National Income and Product Accounts") data on inter-industry technology relationships (also known as input-output structural matrices), countywide employment and income data from the Bureau of Economic Analysis (BEA) and Bureau of Labor Statistics (BLS), and its own industry and county-specific estimates of local purchasing rates ("regional purchase coefficients"). It is enhanced over most other input-output models in that it also includes coverage of public sector activity (government functions), the self-employed economy, and consumer activity (reflected in its "social accounting matrix"). The industry detail is at the level of 509 industries, and is based on categories of the US Bureau of Economic Analysis (BEA), which correspond to 2 to 5 digit groups in the North American Industry Classification System (NAICS).

This modeling approach is amply suited for this evaluation since there is no expectation for a change in electric prices or the region's general price level as a result of estimated parameters describing biomass development. If there is a single limitation to conducting economic impact evaluation within modestly budgeted studies, it is that currently there are no *multi-regional* input-output systems[2] available (though IMPLAN MIG may have a tool available soon). Decision-makers also have an interest in knowing how the 5-county biomass initiative creates economics impacts *elsewhere* in Massachusetts. Ideally a two-region input-output model would be used (the 5-county biomass area as region_1 and *rest of State* as region_2), the direct effects entered into region_1, and impacts for region_2 arising as unfulfilled supply requirements and portions of household spending spillover to the *rest of State*. There would then be a potential subsequent cycle of impact generation for region_1 from the spillover stimulus felt in the *rest of State*.

In absence of this multi-regional modeling functionality the results that follow for the *rest of State* are arrived at by modeling the direct effects shown in Table 8 in a state-level model (which has adjustments to the key industries involved in the biomass development, adjustments necessary to mimic the 5-county economic structure) and subtracting the total economic impacts that result using the 5-county model.

Estimated Economic Impacts from Biomass Development

Construction of wood chip fired plants is assumed to occur over a 5-year interval and the first year of operation for all plants is anticipated by 2015. The first set of results incorporates the assumption that 60% of the required wood chips would be sustainably produced in the 5-county region. Table 9 portrays the total economic impacts that result for the 5-county region. With the exception of the construction-related impacts, all results should be interpreted as occurring annually.

The total job impacts for the 5-county region accrue to other business segments beyond those sectors directly involved in chip production and power generation. Figure 1 shows additional jobs for the 5-county economy by major sector, and Figure 2 shows how the

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[2] A different class of economic impact model with multi-regional modeling feedbacks is available for significantly more money and offers computable general equilibrium properties.

Table 8, *Direct* Annual Economic Effects of Developing Biomass Generation in W Massachusetts

Component	**Sales (mil.)**	**Jobs**	**Payroll (mil.)**	**Sourced**
Chip Supply Development				
Forest operations (logging firms)	$22.560	60		*locally*
Chip transport (logging)	$10.23	36		*locally*
Chip transport (contractors)		12		*locally*
Equipment investment	$7.115			***out-of-state***
Biomass Fired Plants				
Construction (over 5 years)	$215.659	2,759 job years	$140.03	*locally*
Equipment investment (over 5 years)	$161.783			***out-of-state***
Annual Operations - labor		67	$7.207	*locally*
Other expenses	$14.476			*locally*

Table 9, Estimated Economic Impact for 5-county W MA region from Biomass Development

		Direct Effect	**Total Impacts_W Mass Economy 2015**		
				mil. 2006$	
			Jobs	**Labor Income**	**Output**
New fuel supply	Logging_Chipping Production (sales)	$22.560	125	$3.944	$27.690
	Trucking services (new jobs)	48	91	$4.240	$11.548
		total	216	$8.185	$39.238
GEN Plant non-fuel OP Expense	Payroll	$7.207	67	$7.207	
	Take-home portion (HH spending)	$4.324	44	$1.648	$4.963
	Other operating expense	$14.476	113	$4.943	$12.838
		total	224	$13.798	$17.801
		total annual O&M related	**440**	**$21.983**	**$57.039**
			accrue over a 5-Year construction phase		
GEN Plant Construction	Construction_labor Payroll	$140.031	2,759	$140.031	
	take-home portion (HH spending)	$87.519	887	$33.369	$100.464
	Arch_Engr Services *Local*	$31.705	546	$29.200	$61.776
	Other development (e.g. other non-facilities Constr.)	$28.620	465	$22.251	$51.795
		total construction phase related	**4,657 job years**	**$224.851**	**$214.035**

Figure 1, Annual Job Impacts for 5-county W MA region from Biomass Development

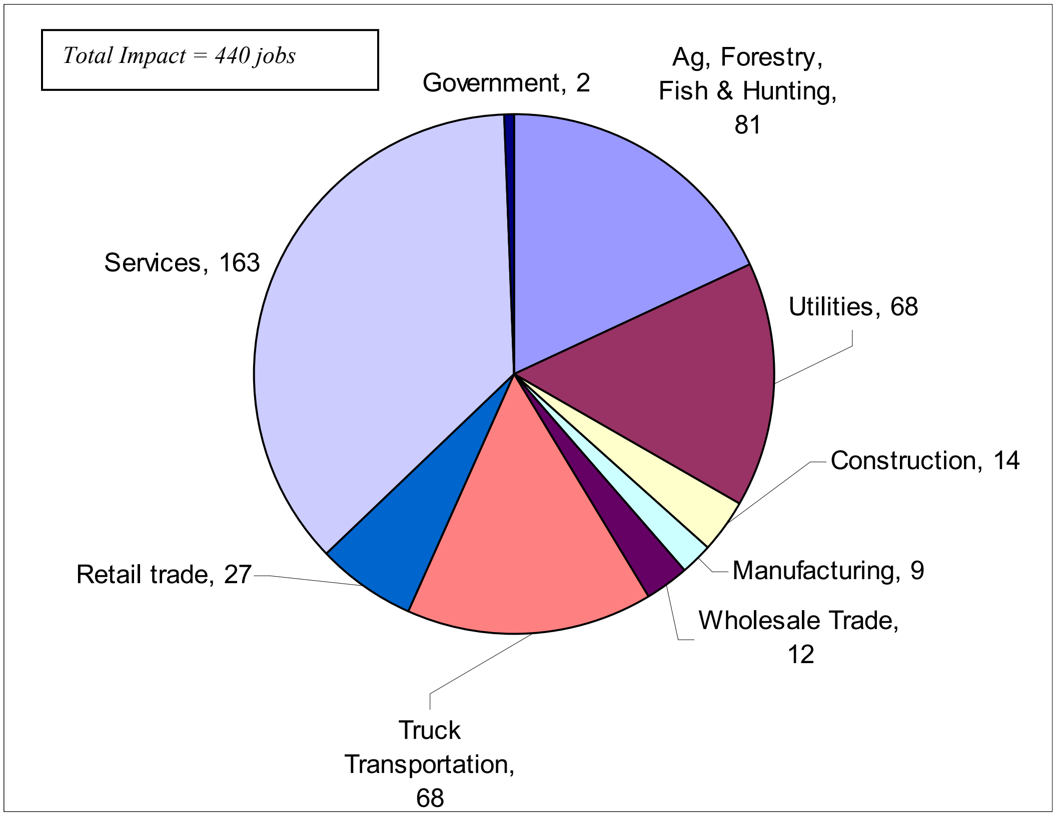
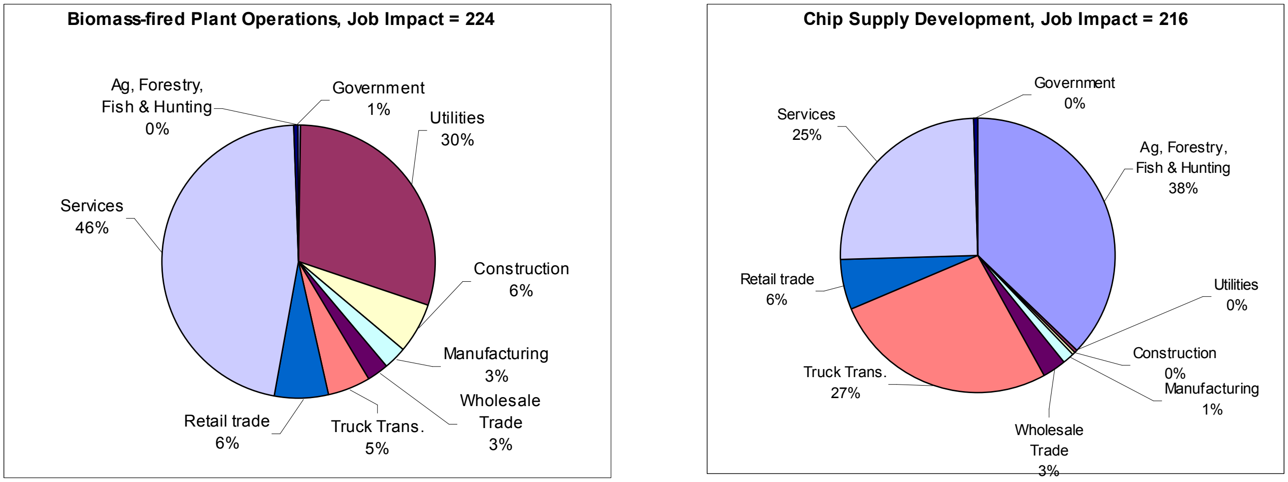


Figure 2, Annual Job Impacts for 5-county W MA region by Component



distribution of job impacts differs between *fuel input* development activities and biomass-fired plant operations. In the 5-county western Massachusetts region, chip supply development creates approximately 49% (216) of the additional 440 jobs. The key segments of the 5-county economy to see job increases are *forestry (40%), trucking (27%),* and *services (25%)*. Annual operations of biomass-fired power plants support job growth predominantly in *services (46%)* and the *utilities sector (30%)*. These *largest* job-gaining sectors are mostly explained by the *direct* jobs required to for the envisioned biomass-energy scenario. The gains seen in other industries (*e.g.* retail, wholesale, manufacturing, construction) are evidence of new demand by area households from additional labor income created as a result of the biomass energy development, and the cycles of increased orders for supplies and services which emanate from forest operations and new generating plant operations.

Table 10 shows the results for *rest of State* assuming the provision of the remaining 40% of the required chip supply creates no new economic activity in Massachusetts. These results can be interpreted as follows: for any aspect of biomass development in the westernmost five counties of Massachusetts that does not represent an import from out-of-state (such as the plant capital and specialized logging equipment) there is an opportunity for businesses elsewhere in Massachusetts (but outside the biomass region) to provide goods and services for new generating plants that do not procure 100% in the 5-county economy. Likewise there is an opportunity related to the operating expenses of first-tier suppliers to the biomass activities, as extra household consumer demand that is realized when more loggers and truckers are hired. The larger the economic region is, the greater the ability to meet dollars of demand using *within region* production/services.

Both the construction phase and the annual O&M of biomass activities create added economic impacts (spillovers) for the *rest of state*. With annual operations and maintenance alone the following occurs: for every 2.9 jobs created in western Massachusetts by the biomass undertaking, another 1 job is created elsewhere in Massachusetts; for every $2.50 of labor income created in western Massachusetts, another $1 dollar of labor income is created elsewhere in Massachusetts; and for every $2.60 of output created in western Massachusetts as a result of biomass activities, another $1 in output is created elsewhere in Massachusetts.

Conclusions and Policy Implications

This study establishes a feasible description and scale for a biomass energy industry in Massachusetts: approximately 165 MW of new electric generating capacity, at perhaps four commercial-scale electric generation sites, as well as a number of smaller institutional-scale plants which could provide heating or perhaps both institutional heating and electricity production. The fuel source for this scale of biomass energy use is available from a combination of existing wood residue and increased utilization of in-forest wood residue within the Commonwealth, and from adjacent counties in neighboring states.

Table 10, Estimated Economic Impact Generation for *rest of MA* from the Biomass Initiative, 2015

		***Indirect & Induced* Impacts *elsewhere in* Mass Economy 2015**		
		Jobs	*mil. 2006$*	
			Labor Income	**Output**
New fuel supply	Logging_Chipping Production (sales)	44	$2.908	$10.475
	Trucking services (new jobs)	12	$1.133	$1.390
	total	56	$4.041	$11.865
GEN Plant non-fuel OP Expense	*Take-home portion (HH spending)*	16	$0.897	$1.646
	Other Operating expense	81	$3.861	$8.336
	total	97	$4.758	$9.982
	total annual O&M related	**153**	**$8.799**	**$21.847**
		accrue over a 5-Year construction phase		
GEN Plant Construction	Construction_labor Payroll			
	Take-home portion (HH spending)	275	$23.281	$45.763
	Arch_Engr Services *Local*	40	$6.516	$4.041
	Other development (e.g. other non-facilities Constr.)	31	$4.549	$6.354
	total construction phase related	**346 job years**	**$11.065**	**$56.158**

Besides reducing net carbon emissions, and significantly contributing to the state's Renewable Portfolio Standard, the study finds that biomass energy would provide substantial new economic activity and new employment in the Commonwealth. Using biomass for energy would replace a significant amount of imported energy with a new, local source, generating employment for citizens of the Commonwealth through the construction and operation of biomass energy plants, and especially through the on going harvesting and processing of the wood chip fuel supply.

Using locally available forest resources (that are currently left as logging waste) represents an economic development opportunity. Logging firms, if outfitted with additional equipment, could add a product to their existing forest operations, if a profitable market is established for forest-extracted wood chips. Another opportunity relates to the production of plant capital and logging capital goods that currently would be sourced from out-of-state. To maximize economic development potential, the Commonwealth may want to explore the feasibility of attracting the manufacturers of some of the required equipment for chip production and biomass-fired generating plants.

Given the bulk of biomass fuel, and the expense associated with shipping it, woody biomass will always be sourced as close to biomass energy plants as possible. For the same reason, biomass electric plant scale will likely always be modest compared to the scale of fossil-fuel plants, perhaps an order of magnitude smaller. The demand for renewable energy as expressed by the Renewable Portfolio Standard provides a mechanism (the sale of Renewable Energy Certificates) that makes such small biomass electric plants financially viable. This smaller scale of biomass plants also makes it more likely that waste heat from biomass electricity generation will be utilized (for example in district heating) than is likely with the larger fossil fuel plants; this has the potential to significantly increase overall energy use efficiency.

Though the creation of a Massachusetts biomass energy industry is feasible, and would provide economic benefits, its development is not certain. Utilizing biomass energy at a significant scale requires an extensive working landscape, i.e. forest lands that are available for regular harvest. Since wood chips are essentially a waste product of other logging operations, the Commonwealth must have viable industries for harvesting and using all forest products—lumber as well as residues. Thus, for biomass energy to be successfully developed, Massachusetts citizens and policy makers must support practices and policies that encourage active forest management. Individual landowners must manage their own woodlots, and citizens must support forest management and harvest on public lands. Policy makers must ensure that appropriate regulations are in place to safeguard forest health without precluding appropriate and responsible forest utilization.

Providing Massachusetts with renewable energy will be a significant challenge in the future, and one that will likely require a variety of approaches and technologies. Though biomass cannot provide all of the Commonwealth's energy, it is unlikely that any single renewable energy source can do this. Biomass electricity can be one technology of a renewable energy portfolio, and is one that would provide a significant boost to local economies.

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Appendix I: IMPLAN Model Inputs

Submitted by EDR Group

The following exhibit presents the project-related costs/expenditures (the *direct effect*) which are mapped to appropriate levers within the IMPLAN *input-output* analysis models of the W MA (sub-state) and Massachusetts economies. All dollar amounts represent annual project spending (except those for plant construction, for which a 5-year interval was assumed).

Table A1: IMPLAN Model Levers

Project component	IMPLAN sector	Modeled as	Value
forest feedstock production from W MA	14_Forestry & Logging	Sales	$22.56m
wood chip Delivery	394_ Truck transport Services	new jobs	48
Generating Plants annual payroll	HH institutions median $50-$75k	after-tax take-home pay	$4.32m
Generating Plants annual OP budget after fuel & labor	30_Power Generation	intermediate demand, adjusted to remove fuel coefficients	$14.47m
Facility Construction payroll (5 year interval)	HH institutions median $50-$75k	after-tax take-home pay	$87.52m
Ancillary Construction required (5 year interval)	41_Other new construction	Sales	$28.62m
Facility Design & Engineering (5 year interval)	439_Architect_Engineering Services	Sales	$31.70m

The duplication of the analysis run on the above inputs in the state-level model requires an analyst to adjust—at minimum—the key sectors involved in the direct effects to reflect the structure observed in the 5-county W MA model to avoid aggregation bias issues in the resulting impact results from the state-level system.