



April 21, 2010

Greenfield District Heating
c/o Lynn Benander at Co-op Power
3 Grinnell Street
Greenfield, MA 01301

RE: Feasibility Study of a Biomass District Energy Project in Greenfield,
Massachusetts

Dear Ms. Benander:

BERC is pleased to provide the enclosed pre-feasibility study for a district biomass energy project in town of Greenfield, Massachusetts. The findings show that installing a biomass district energy system could be feasible and beneficial to the town. The report also provides recommendations for next steps in further studying the feasibility of a biomass district energy system, and we would be pleased to assist in moving the project forward.

We have greatly appreciated the opportunity to collaborate with Greenfield District Heating. If you have any questions or require any additional information, please do not hesitate to call.

Sincerely,

A handwritten signature in black ink, appearing to read "Chris Recchia", is written in a cursive style.

Christopher Recchia
Executive Director

Encl.

FEASIBILITY STUDY

Feasibility Study of a Biomass District Energy Project in Greenfield, Massachusetts

Prepared for:
Greenfield District Heating
c/o Lynn Benander at Co-op Power
3 Grinnell Street
Greenfield, MA 01301

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I. EXECUTIVE SUMMARY

A steering committee for the town of Greenfield, Massachusetts, referred to as the Greenfield District Heating (GDH) was formed in 2008 to consider the logistics of providing a district heating system for the downtown area. GDH requested the Biomass Energy Resource Center (BERC) prepare a preliminary feasibility study to assess the costs and benefits (economically, socially, and environmentally) of installing a district system. A district heating-only system was the primary focus with consideration also given to a combined heat and power (CHP) facility, as well as a purchase heat agreement with a proposed neighboring biomass electrical energy plant.

District Heating System

The system under consideration would link a central woodchip-fired energy plant to a network of underground heat distribution pipes that connect to residential and commercial buildings in Greenfield's downtown area. Under the district heating concept individual building owners purchase their heat from a modern and highly efficient central biomass system instead of operating and maintaining their own boilers and furnaces. The hot water is transferred into a meter station and then into the building's existing heating system with monthly billing based on actual Btu usage rather than the cost of the input fuel.

The study also examined the option of producing electricity at the district energy plant using CHP technology. There are various methods for producing CHP, the most common being to use the woodchip boiler to generate high-pressure steam that will run a turbine and generator to make electricity. A low-pressure steam line can be extracted from the turbine to heat water for the town hot-water distribution. BERC considered this form of CHP when completing the cost analysis.

Following discussions with GDH, BERC chose two sample sites for energy plant placement, one owned by the town in the study district and one outside of the downtown area that would need to be purchased.

BERC considered six options in its study. Maps of these options are presented in Appendix A. Three study areas were chosen for evaluation in this study. Study Area 1 falls within the boundary of Pierce/Beacon St., High St., Main St., and Chapman St.; Study Area 2 falls within the boundary of Silver St., High St., Main St., and Chapman St.; and Study Area 3 falls within the boundary of Silver St., High St., Main St., and Conway St. While BERC considered three specific districts for this project, there are numerous district configurations that could be delineated within the town. It is important to note that the analyses were conducted for a full-system buildout, assuming that the entire district energy system would be built at the same time with all customers who might be served connected at the start. In reality, the financing and implementation would be staged over a few years and conducted in multiple phases. The analyses provided here should give a general idea of the energy demand and the economics that could be expected for a range of distribution network configurations and technology options. Biomass district energy project developers can plan a distribution network configuration that could both minimize project costs and reduce the inconvenience to the public during construction.

Currently, residents of Greenfield are paying an average of \$2.50 per gallon of oil. Considering a fossil fuel inflation rate of 4.75 percent annually, and with a minimum three-year timeline by the time this project likely starts operation, the cost of oil should theoretically rise to \$2.74 per gallon. At that price, no option presented here will result in favorable economics. If the project does not commence until oil prices rise to \$3.10 per gallon, the economics for Greenfield’s district energy system look favorable. Therefore, all of the analyses were run using an oil price of \$3.10 per gallon.

Sustainable Wood Supply

BERC also studied the sustainable wood fuel supply for Greenfield where within in a 50-mile procurement area, more than 1.3 million green tons of wood are grown annually that can be harvested on a sustained-yield basis. After taking into account the firewood, pulp, and other market demands, there is an estimated annual surplus capacity of slightly more than one million green tons of low-grade wood within the total procurement area. If the Greenfield energy plant consumes between 9,000 and 24,000 green tons annually, there is currently ample supply of low-grade wood to fuel this facility in a sustainable way.

Recommendations and Next Steps

When oil prices rise to \$3.10 per gallon or higher, Option I will have the most favorable economics for Greenfield. A summary of costs and benefits is provided in the table below:

	Option I	Option II	Option III	Option IV	Option V	Option VI
Boiler Size (MMBH)	33	72	83	72	77	n/a
Wood Requirement (tons/year)	9,321	20,492	23,695	20,616	21,993	n/a
Total Capital Cost	\$23,421,878	\$57,539,881	\$67,827,056	\$59,605,448	\$63,745,827	\$49,625,322
Grant (30%)	\$7,026,563	\$17,261,964	\$20,348,117	\$17,881,634	\$19,123,748	\$14,887,597
Borrowing (50%)	\$11,710,939	\$28,769,941	\$33,913,528	\$29,802,724	\$31,872,914	\$24,812,661
Equity (20%)	\$4,684,376	\$11,507,976	\$13,565,411	\$11,921,090	\$12,749,165	\$9,925,064
Year 1 System Revenue (\$) Heat	\$1,962,984	\$4,147,315	\$4,758,081	\$4,147,317	\$4,147,317	\$4,147,317
Year 1 System Revenue (\$) Electricity	n/a	n/a	n/a	n/a	\$0	n/a
Year 1 System Cash Flow	\$26,296	-\$283,166	-\$414,308	-\$395,712	-\$461,539	-\$651,568
Payback on Equity 20% (year)	13	16	17	17	18	16
Payback on Total Investment 100% (year)	17	19	20	20	20	18

BERC recommends that system administrators meet with stakeholders and visit existing district heating projects in the United States and Europe. A more detailed engineering-level study should be completed to provide a final analysis of this project.

II. INTRODUCTION

Project Overview

Greenfield District Heating has requested the Biomass Energy Resource Center prepare a preliminary feasibility study indicating the logistic and economic viability of installing a biomass-fueled district energy system to provide thermal energy to residences and businesses in the downtown area. This study includes six assessments: three involve building a biomass thermal energy plant in the downtown area to supply heat to customers within three different project boundaries; two involve building a biomass plant just outside of the downtown area to supply either thermal energy or combined heat and power to the town with the idea of potentially providing this energy to nearby Turners Falls in the future; and the last involves purchasing waste heat from a proposed biomass electrical energy plant located outside of the downtown area.

This preliminary feasibility study: compares various fuels available to consumers in the town of Greenfield; provides rough estimates of project costs, including initial capital and ongoing operation and maintenance; evaluates potential funding mechanisms and options; and gives a preliminary assessment of the economic feasibility for all identified energy options. The results presented here will inform the decision to further evaluate a district energy system for the town of Greenfield at the engineering level.

Town of Greenfield

The town of Greenfield, located in the western part of the commonwealth of Massachusetts, is home to over 18,000 residents, Bay State Franklin Medical Center, an industrial park, and a downtown commercial district, just a few of the important stakeholders in the community. As a town that built itself upon the gifts of the Connecticut River, providing a source for trade and hydro power, the community is now working to reconnect to their natural environment and focus on greener alternatives.

Greenfield District Heating (GDH)

Greenfield District Heating (GDH), formed in 2008 by members of the Greenfield Redevelopment Authority, Co-op Power, Sandri Companies, Franklin Community Development Corporation, the Franklin Regional Council of Governments, and the Co-op Power Franklin County Sustainable Biomass Working Group, is considering a district energy plant and the appropriate infrastructure for Greenfield. GDH has begun Collaborative Community Planning and Conflict Prevention training and has already taken steps to inform and gain support from the community. Where feasible, the district energy plant has the possibility to include co-generation for parts of the town.

Biomass Energy Resource Center (BERC)

The Biomass Energy Resource Center (BERC) is a national nonprofit organization based in Montpelier, Vermont. Its mission is to achieve a healthier environment, strengthen local economies, and increase energy security across the United States through the development of sustainable biomass energy systems at the community level. BERC uses its expertise in institutional and community-scale wood-energy systems to assist industries, schools, institutions, and others in

initiating and constructing biomass projects for their heating and power needs. In the short time since its inception in 2001, BEREC has established itself as a national leader in biomass heating and power generation using sustainable forest and agricultural resources.

Scope of Work

The following is an explanation of the work performed for this pre-feasibility study:

Data Collection

Using data published in GGEC's Greenfield Energy Audit, BEREC collected information on the characteristics and specifics of energy demand for industrial, commercial, and town buildings in the town of Greenfield. Also, BEREC gathered data on residential energy requirements using geographic information system (GIS) data points. Such data included fuel prices, residential square footages, and street lengths. These were used as key inputs in the pre-feasibility assessment.

Heating Requirement Calculation

Total heating needs were quantified on an hourly, weekly, monthly, and yearly basis based on the current energy use data collected. These energy demands were used to calculate system capacity and estimate total annual fuel consumption for the proposed Greenfield district energy system.

Heating Fuel Comparison

Two fuels available to the town of Greenfield were compared: heating oil and woodchips. The average current price for heating fuels was collected and compared on a Btu basis.

Available and Appropriate Technologies Identified

Once the various system capacities were calculated, commercially available technologies to meet the respective energy loads were identified. BEREC contacted several vendors of these systems to procure product information and used its knowledge base and experience in evaluating each option, including an assessment of how each of these technologies can be utilized to meet Greenfield's energy requirements. Preliminary estimates in terms of initial capital costs and cost of fuel, operation, and maintenance were also collected.

Site Assessment

BEREC and the steering committee evaluated the space available for a new energy plant. Any potential air-quality permits required for a biomass district energy plant were also identified and basic recommendations on permitting were given in this report.

Fuel Supply Assessment

This study included a preliminary quantification of the low-grade wood available for woodchip fuel within cost-effective delivery range of downtown Greenfield. The study included an estimation of sawmill residues and forest inventory and growth surrounding the town. Pricing information was also collected for available low-grade wood. Recommendations in this report include a protocol for a general fuel-procurement strategy and a list of potential fuel suppliers.

Economic Analysis

A proprietary cost analysis tool for district energy systems, developed by BEREC, calculated the financial feasibility of the system. The tool is used to evaluate the relative costs and revenues generated by a district system using key inputs and assumptions from Greenfield's data, including required heat load, current cost of heating fuels, and estimated project cost.

Final Written Report

This report summarizes the study, its conclusions, and the next steps for moving the project concept forward. Recommendations have been made for the conceptual design of the district energy system options, including: plant location and construction, fuel storage requirements, necessary fuel handling equipment, distribution piping, and energy transfer stations. Upon completion and submission of this final report, BEREC staff will make a return trip to Greenfield for a follow-up meeting to present these findings and recommendations.

Methodology

BEREC staff attended a series of public meetings with the GGEC to explore the idea of heating downtown Greenfield with a biomass district energy plant. Together, the group outlined a preliminary area for the heating district from which BEREC would develop its recommendations, including, if necessary, alteration of the optimal district boundaries. BEREC collected available information from the Greenfield Energy Audit, published in June 2009, and available GIS data. In this effort, the GGEC proved to be an invaluable resource and assisted in the initial phases of data collection.

For the preliminary phase of the pre-feasibility study, the square footage data of the entire district under consideration for connection to the heating plant was acquired using the latest GIS data.

Approximate thermal energy demand was calculated by collecting actual data from downtown municipal buildings. For residential buildings, an average fuel use multiplier, based upon total heating degree days for Greenfield, was applied to the square footage to estimate the demand. Total thermal energy demand for the buildings in Greenfield was quantified on an annual, hourly, and peak-hourly basis.

Based on the projected heat load within the proposed district, a recommended capacity for the Greenfield district energy plant was calculated and all available technology options for the recommended capacity of the project were identified.

There are several commercially available biomass boilers covering a range of costs, quality, and biomass feedstocks. Vendors of boilers and relevant system components were contacted to obtain technical specifications and cost estimates.

To determine the availability and pricing of low-grade wood supply within cost-effective delivery range of Greenfield, BEREC interviewed potential woodchip suppliers and used in-house tools and data to calculate the total amount of woodchips available.

Preliminary estimates in terms of initial capital costs and cost of fuel, operation, and maintenance are provided in this report. The costs and revenue streams for each option were evaluated, and cash flow and simple payback periods were calculated.

The report provides preliminary cost estimates and a preliminary assessment of the economic feasibility of each.

This report contains the following:

- An overview of the socio-economic and environmental benefits of biomass energy
- An overview of district energy concepts
- Analyses of the town of Greenfield's thermal energy demand
- An assessment of current and projected fuel usage and costs in Greenfield
- An assessment of current and projected local biomass fuel availability and costs
- An overview of modern and commercially available emissions reduction technologies
- An overview of the regulatory climate surrounding biomass heating systems
- An overview of funding opportunities
- Projected costs of installing and operating a biomass district energy system
- A financial feasibility analysis of each option identified
- Conclusions and recommended next steps

III. DISTRICT ENERGY OVERVIEW

Systems and Technology

District energy systems use one or more central plants to provide thermal energy to multiple buildings. In a district energy system, insulated underground pipelines distribute thermal energy from the central plant to each of the buildings connected to the network. The heat distribution piping, typically thin-wall welded steel with integral foam insulation and plastic jacketing, is designed to be direct-buried at a depth of about three feet. Pipes are placed in pairs, with supply pipes delivering hot water from the plant and return pipes carrying lower-temperature water back to the plant to be reheated. Each customer building is served by a pair of lateral pipes from the supply and return mains. Generally, these pipes enter the basement to connect to the building's heating system. The central plant utilizes variable speed pump controls to minimize the amount of electricity used in the pumping process. In this way district energy systems can be an efficient form of municipal infrastructure, similar to public water or sewage systems.

District energy systems can employ a wide variety of fuels, including biomass, which is the fuel source being considered for the Greenfield district energy system. A typical district energy system consists of the following subsystems:

- Thermal energy generation - the boilers where the thermal medium, steam or hot water, is produced
- Thermal energy transmission and distribution – the pipelines which deliver the thermal energy medium (steam or water) from the production sources to the network of users
- Customer interface – the integration of thermal energy at the user's (customer's) location, also known as an Energy Transfer Station (ETS)

Each connected building will employ an ETS. The connections for a building with hot water heat (baseboard, radiators, unit heaters, or fan coil units), will include system controls for space heat. Hot air furnaces will require a water-to-air coil installed in the main heating ducts. Fossil fuel space heaters need to be removed and replaced with baseboard hot water for room heating. This study assumes that the modifications required within the buildings (beyond the ETS) will be done by the facility owners before they are connected to the district energy network and hence that cost is not included as part of the project.

On a residential building scale, the ETS will be compact and can be floor or wall-mounted. The ETS includes a heat meter, which measures how much heat is taken out of the system water and transferred to the building. These meters are usually read monthly, similar to water or electric meters, with billing according to consumption.

District energy systems can provide space heating for large office buildings, schools, college campuses, hotels, hospitals, apartment complexes, and other municipal, institutional, and commercial buildings. Systems can also be used to heat neighborhoods and single-family residences.

Advantages of District Energy

A district energy system can provide, in one centralized location, the heat that would otherwise be produced in hundreds or thousands of smaller, individual heating systems. This reduces redundancy, and produces the following advantages for both the system customers and the surrounding community:

Low, Predictable Energy Costs. Higher fuel usage provides access to the lower costs associated with bulk purchasing. Additionally, when a district energy system has access to a locally available fuel source to serve all or a portion of the fuel mix, the cost-stabilizing and economic benefits of district energy are further enhanced. The price of wood fuel is not linked to world energy markets or unstable regions, but is instead determined by local economic forces. For this reason, biomass systems do not experience the price instability of conventional fuel systems, especially in areas close to sources of wood fuels (see “Advantages of Biomass District energy” section below).

Air Quality. Air quality improves—as does community livability—when emissions from a single, well-managed plant replace multiple non-regulated stack emissions from many individual buildings. A large district plant is able to be far more efficient than common residential boilers, thereby creating fewer emissions on a per million British thermal units (MMBtu) basis. In addition, district energy systems are of a size that makes it possible and economically feasible to install best available technology and emissions control equipment that is typically not feasible in individual building heating systems.

Reliable Equipment. District energy systems have an unparalleled record of reliable service. They achieve this by well-managed central plant operation, using multiple fuels, having backup boilers in one or more locations, and having standby power at the central plant.

Reduced Environmental Risks. District energy systems can help to mitigate environmental risks by consolidating the fuel storage to a single or a few locations compared to numerous onsite storage tanks that serve individual buildings. Environmental risks related to conventional fuel storage, including underground and aboveground storage tanks, consist of failing underground tanks which can threaten ground and surface waters, as well as aboveground tanks becoming fire hazards or potentially dislodging in the event of a flood.

Purchase Heat, not Fuel. In district energy systems the customer purchases the actual amount of thermal energy used, as measured by a Btu meter, rather than buying the fuel required by a boiler. Since all boilers waste heat through their chimneys and seasonal inefficiencies, the actual amount of heat energy (measured as MMBtu) required for any given building will be less than is used as purchased fuel in a conventional system. New district heat customers converting from older, inefficient boilers will realize greater returns than those that currently have highly efficient systems.

Building owners may realize a number of financial benefits from district energy. These include:

- Direct savings by avoiding the capital equipment expenses for replacement of fuel tanks and boilers, and the time and expense of yearly maintenance;
- Time savings in price-shopping and negotiating yearly contracts with fuel suppliers;

- Stabilized heating costs, since district heat pricing is less impacted by fluctuations in fuel prices;
- Simplified building operations and reduced building maintenance costs;
- The increased availability of space; i.e. the space that had been used for the boiler and can now be used for other purposes;
- Reductions in risk of fire, carbon monoxide poisoning, and other combustion-related hazards. In a district energy system, combustion happens centrally, not in individual buildings, significantly reducing risks in the buildings that are recipients of the district heat. In addition to making buildings safer, this reduced risk of combustion-related hazards may reduce fire insurance and liability premiums to homes and businesses in the district;
- Reduced risk of power outage or other “down-time.” District systems have back-up systems as well as fuel stockpiles. As a result the risk of interruption in heat supply to customers is minimal. Even when the district energy system needs to shut down for short periods of time, the retained heat in the system is sufficient to provide continuous heat to the customers. As a result, the individual customer does not need to worry about having heat during a power outage.

What is Biomass?

Biomass is any biological material that can be used as fuel. Biomass fuel is burned or converted in systems that produce heat, electricity, or both heat and power. Woodchips, wood pellets, and other low-grade wood wastes are the major type of biomass fuel. Other common biomass fuel sources are agricultural crop residues and farm animal wastes.

Advantages of Biomass Energy and Biomass District Energy Systems

There are numerous environmental and socio-economic advantages of using sustainably procured biomass fuel for energy production instead of fossil fuels, such as heating oil or propane. Several benefits to using biomass energy are listed below, followed by a more in-depth discussion of some of the most compelling reasons to choose biomass energy.

- Increased flexibility and reliability over other energy sources;
- Low heating fuel price escalation (biomass fuel prices have historically escalated at a slower rate than fossil fuel prices);
- Support of local fuel supply will lead to increased economic opportunity in the region and state;
- Support of local economies will contribute to the overall fiscal health of the community through additional purchases, jobs, and an increased tax base; and,
- Decreased susceptibility to interruptions in fuel supply.

Dollars Remain in the Local Economy. Unlike fossil fuels that come from outside the region, wood fuel is a local and regional resource. The businesses associated with wood supply (logging operations, trucking companies, and sawmills) tend to be locally owned and operated, retaining profits in the regional economy. These activities contribute to the federal, state, and local tax base. Conversely, most fossil fuel dollars leave not only the local community, but the country. Fuel

supply is increasingly an issue of national security, especially for places that rely heavily on heating fuels during much of the year.

In Europe, where district energy is far more commonplace than in the US, an Austrian study completed in the Styria Region¹ showed how the use of biomass energy directly impacted their community. When heating with oil, 25 cents of every dollar left the region, and 59 cents of every dollar left the county entirely, leaving Styria with only 16 cents of each dollar. However, when they switched to locally sourced wood, 52 cents of every dollar stayed in Styria, 48 cents stayed in Austria, and no money left the county.

More Local Jobs. Conventional energy systems require labor in fuel extraction, processing, delivery, operation, and maintenance as well as in system construction and installation. Fossil fuel supply is based on energy resources outside the community, thus, all jobs associated with extraction and processing are outside the local and regional economies. By contrast, jobs associated with biomass fuel extraction, processing, fuel transportation and distribution, and reforestation are all within the local and regional economies, and provide direct support to the forest products industry and agricultural sectors.

In the same Austrian study as mentioned previously, it was shown that just nine jobs were created from the use of fossil fuel heating, whereas 135 jobs were created as a result of biomass district energy.

Combustion of biomass for energy instead of fossil fuels has a positive impact in moderating global climate change. Carbon dioxide (CO₂) buildup in the atmosphere is a significant contributor to global climate change. Fossil fuel combustion takes carbon that was locked away underground (as coal, crude oil, and gas) and transfers it to the atmosphere as CO₂. However, when biomass is combusted it recycles the carbon that was already in the natural carbon cycle. Consequently, as long as the fuel is harvested sustainably and locally, the net effect of burning biomass fuel is that no new CO₂ is added to the atmosphere, with the exception of carbon emissions from the relatively small amount of fossil fuel used in harvesting, processing, and transporting the wood. Avoiding use of fossil fuel for heat (and electricity) mitigates climate change further by eliminating the release of sequestered carbon.

Enabling support for the local forest products industry and practicing quality forestry. With only developed markets for the best trees, forests are often “high-graded” or harvested to remove only the highest grade wood. Markets for low-grade wood can help create new incentives for quality forestry and preserve current land use practices. Harvesting the low-grade trees can help improve the forest quality over time through sustainable forestry practices.

Biomass comes in many forms—any plant or animal-derived material can be considered biomass. Wood fuels historically came from either sawmill or timber harvesting residues. These residues were viewed as by-products of the forest products industry. In today’s market, the demand for wood fuel has surpassed the supply of industry by-products. Wood fuel for the project can be harvested from local forests, which will improve the market for low-grade wood needed to practice

¹ Waldverband Steiermark; Regionalenergie Steiermark

quality forestry—with only markets for the best trees, forests are often “high-graded” or harvested to remove the best and leave the low quality trees behind. Markets for low-grade wood help create a new incentive to remove the low-quality trees and help improve the forest quality over time.

Purchase Heat not Fuel. In district heating systems, the customer purchases the actual amount of thermal energy used—as measured by a Btu meter—rather than the fuel required by a boiler (i.e., energy output rather than fuel input). Since all boilers waste heat through their chimneys and seasonal inefficiencies, the actual amount of heat energy (measured as millions of British thermal units, or MMBtu) required for any given building will be less than is used as purchased fuel in a conventional system. New district heat customers converting from older, inefficient boilers will realize greater returns than those that currently have highly efficient systems.

Building owners may realize several financial benefits from converting to district heating, including:

- Direct savings by avoiding capital equipment costs of replacing fuel tanks and boilers, and the time and expense of yearly maintenance
- Time savings in price-shopping and negotiating yearly contracts with fuel suppliers
- Stabilized heating costs since district heat pricing is less impacted by fluctuations in fuel prices
- Simplified building operations and reduced building maintenance costs
- Available space previously used for the boiler that can now be used for other purposes
- Reductions in risk of fire, carbon monoxide poisoning, and other combustion-related hazards. In a district energy system, combustion happens centrally—not in individual buildings—significantly reducing risks in buildings in the system. In addition to making buildings safer, this reduced risk of combustion-related hazards may reduce fire insurance and liability premiums to homes and businesses in the district
- Reduced risk of power outage or other “down-time.” District systems have back-up systems and back-up power sources as well as fuel stockpiles. The risk of heat interruption is almost nil as a result. Even when the system must shut down for short periods, the retained heat in the system is sufficient to provide continuous heat. As a result, the individual user does not need to worry about not having heat or hot water during a power outage

Low, Predictable energy cost. Higher fuel usage provides access to the lower costs associated with bulk purchasing. Additionally, when a district energy system has access to a locally available fuel source, such as locally grown biomass, to serve all or a portion of the fuel mix, this further enhances the cost-stabilizing and economic benefits of district energy. The price of wood fuel is not linked to world energy markets or unstable regions, but instead determined by local economic forces. For this reason, biomass systems do not experience the price instability of conventional fuel systems, especially in areas close to sources of wood fuels.

IV. ASSESSMENT OF TOTAL HEATING DEMAND IN GREENFIELD

Total Area

Three study areas are presented in this study (see Appendix A for maps of each area and option).

Study Area 1 (the basis of Option I) is formed within the boundary of Pierce/Beacon St., High St., Main St., and Chapman St. This boundary was selected because it has the highest population density, thereby necessitating less pipe length, while including the large heating loads of Baystate Franklin Medical Center, Greenfield Middle School, and the Teen Center. In this area is the potential for approximately 860 residential connections plus three commercial connections, totaling two million square feet of heated space. In order to connect each customer, the system requires nearly 37,900 linear feet of pipe.

Study Area 2 (the basis of Options II, IV, V, and VI) is formed within the boundary created by Silver St., High St., Main St., and Chapman St. This boundary was selected because it has a high population density and also stops short of the train track running between Chapman St. and Wells St. The additional permitting needed to bury lines beneath a train track is costly and the work is far more labor-intensive. This area has the potential for approximately 2,000 residential connections plus five larger commercial connections, totaling 5.3 million square feet of heated space. In order to connect each customer, the system requires 111,000 linear feet of pipe.

Study Area 3 (the basis of Option III) is slightly larger with the western border located on Conway St. This boundary accommodates a greater number of heating customers. In the area is the potential for approximately 2,460 residential connections and five commercial connections, totaling over 6.5 million square feet of heated space. This system will require nearly 135,000 linear feet of pipe to connect each customer.

Heating Load

The heat load is the total heating demand of the buildings in the proposed area. Over half of the residential customers in Greenfield use oil for their heating purposes; roughly 40 percent use natural gas. This study only considers oil customers, which account for 51 percent of the town², because natural gas is too cheap to make the switch to wood fuel affordable. Additionally, town buildings and schools which heat primarily with oil and are within the study area boundaries were added into the heat load calculation.

This study assumes that 85 percent of current oil users will participate in the district energy system, which then brings the total percentage of town users to 43 percent. Based on these assumptions, Study Area 1 could potentially displace 0.7 million gallons of oil annually; Study Area 2 could displace 1.4 million gallons of oil annually; and Study Area 3 could displace 1.6 million gallons of oil annually.

² Statistic taken from the Greenfield Energy Audit completed in June 2009 by the Greening Greenfield Energy Committee.

Load Coincidence Factor

An additional factor in sizing a boiler for a district system is the percentage of the total maximum capacity that will be required by the system. The load coincidence factor is the quotient of the simultaneous peak heat demand by a number of customers, and the sum of the usually non-coincident individual peak demands by these customers in the same period of time. In other words, not all facilities on the system will be on-line and requiring their maximum demand at any given time. The load coincidence factor attempts to define what percentage of the total load would likely be required at any given time. In the preliminary technical analysis, it is assumed to be 85 percent.

V. DISTRICT ENERGY TECHNOLOGY - WOODCHIP DISTRICT HEATING

This centrally located district energy plant will deliver hot water to customers via insulated underground supply and return piping. As previously discussed, an ETS will be installed for each customer that is connected to the grid.

The following chart shows the tonnage of woodchips per year (at 40 percent moisture content) necessary to supply enough energy to meet the heating demands of the customers.

Table 1: Amount of Woodchips Required for Each District Energy Option

	Amount of Woodchips
Option I	9,321 tons
Option II	20,492 tons
Option III	23,695 tons
Option IV	20,616 tons
Option V	21,993 tons
Option VI	n/a ³

Technology Description

Technology for thermal energy includes a biomass combustion chamber (furnace) and boiler, a biomass gas turbine, and biomass gasification. Based on BERCC's review, a semi-automated woodchip combustion system was considered for Greenfield. This mechanical equipment for the system will be fully automated; however, the fuel will be stored on on-grade slabs which will require operators to use a tractor to manually move the woodchips into the hopper. The system can generate thermal energy as steam or hot water. While consideration was given to using high-pressure steam technology, hot-water distribution is recommended because it is more efficient for delivering heat over long distances (there are considerably lower heat losses from piped hot water compared to piped steam) and the cost of hot-water distribution piping is lower than for steam piping. A hot-water system is also safer and less expensive to operate than steam. A more detailed description of woodchip technology is given in Appendix B.

Also included in this study is the consideration of a combined heat and power (CHP) system. There are several technology options for woodchip CHP. The most commonly used method is to use the woodchip boiler to generate high-pressure steam that will run a turbine and generator to make electricity. The low-pressure steam can be extracted from the turbine to heat water for the town hot-water distribution.

Another option is to install a woodchip boiler and an Organic Rankine Cycle (ORC) system to generate electricity. The ORC system uses a thermal oil loop to generate electricity at lower temperatures than high-pressure steam generators. The captured heat from the ORC system will then heat water for distribution to the district energy network. Advantages of the ORC system include better efficiency than the steam turbine system and lower staff-time requirements, since this

³ This option includes purchasing waste heat from an off-site electrical power-generating biomass plant. No additional woodchips will be required for this option.

is a low pressure application that will not require 24/7 operator attention. The additional cost of an ORC system was not considered in this study, but members of the steering committee should evaluate both of these options before coming to a final decision. These technologies are described in greater detail in Appendix C.

Plant Siting

The steering committee chose two sample central locations for the district energy plant. The first is located between Davis St. and School St., and the second is located on the corner of Norwood St. and Federal St. The first site is owned by the city (currently the site of a school administration building), so the land will not need to be purchased. The second site will require the purchase of land. Upon further review, using the second site is not cost effective in any configuration and therefore was not considered further in this report. Options I, II, and III all consider using the Davis St. sample site for heating plant placement.

For Options IV and V, the proposed plant location is located northeast of the city off of Bernardston Rd. See Appendix A for proximal building sites.

Conceptual System Design

Heating Plant Building

The size of the heating plant building will depend on the number of customers it will serve as well as the type of district energy it will provide. For Option I, which provides heating only to Study Area 1, the building will need to be 9,000 square feet. For Options II/ IV and III, which provide heating only to Study Area 2 and 3 (respectively), the building will need to be 13,000 square feet. Option V, which will require more room to include the CHP system, will be roughly 17,000 square feet. The size of the building in Option VI is not discussed here as it will not belong to the town. A detailed layout of the new energy plant should be designed in consultation with the selected equipment vendor(s) and prepared by an engineering team before moving this system design concept further.

Stack and Emissions Controls

A stack must be installed on the district energy plant to effectively disperse any emissions in order to ensure minimal impact on air quality in the surrounding area. In the engineering phase of the project, a dispersion modeling study will determine the appropriate height and location of the stack, accounting for weather patterns, local topography, neighboring facilities, and wind direction.

BERC is committed to recommending the best available emissions control technologies at each site. BERC recommends that the Greenfield district energy plant install a baghouse (in addition to the standard cyclone) to control particulate emissions. The combination of the cyclone and baghouse is typically the best combination of emissions control technology appropriate to a system of this size and is proven effective in controlling fine particulates. Depending on the design and vendor of the baghouse, it may range in size from 9 feet by 4 feet to 7 feet by 7 feet, with a height of 24 to 30 feet. The detailed layout of the new heating plant should include space for the recommended emissions control equipment and the appropriately sized stack.

VI. SYSTEM ORGANIZATION AND FINANCING

Public–Private Partnerships

There are few US examples of community-scale biomass district energy systems, but a wealth of examples from Europe and other countries that can be adapted to work in the US. In regions of Europe, especially, biomass district energy has grown to be the predominant method of community heating. Communities, therefore, have the option to seek out partners in the nonprofit, for-profit, and governmental sectors here and abroad to help understand and implement district energy systems.

Among companies and organizations in the non-profit sector, BEREC and the International District Energy Association (IDEA) are two of the most prominent resources for communities interested in exploring the concept of biomass district energy. In the commercial sector there are yet more partnership options, including: district energy companies, energy developers, utilities, engineering firms, energy services companies (ESCOs), and performance contractors. In order for a municipality to develop a project it may be necessary to form a partnership with one or more such entities from the nonprofit and for-profit sectors.

While these companies can offer expertise, local partnership and leadership is important to ensure that the project fits the community’s needs and circumstances—from feasibility to financing, construction, start-up, and future operation.

Sources of System Capital

There are many potential sources of capital to build a district energy system, and any system is likely to put together a finance package using a number of different sources. While the recent economic down-turn has crimped the financial and credit markets, it has opened up new funding opportunities through the American Recovery and Reinvestment Act (ARRA), and the interest in alternative energy options is high for certain investors. A broad outline of potential funding sources includes:

- Equity investment by: users of the system, municipality itself; private and non-profit partners; and private investors
- Grants and tax credits from state or federal agencies or other sources
- Loans through: the municipal bond market (revenue bonds or general obligation bonds); commercial bank loans from local or other banks; loans from federal, state, or other public-sector sources (such as USDA Rural Development)

Grant Opportunities

For Massachusetts’ sustainable energy projects, Sustainable Energy Economic Development has been the guiding light to funding opportunities and grant monies. “Since 2004, SEED has made 15 awards, totaling \$4.9 million. Seven of the companies have received significant funding from private investors after SEED closing. The SEED companies currently have a total known valuation

of \$237 million and support 150 jobs in Massachusetts.”⁴ However, as of 2008 SEED was transitioned into the Massachusetts Clean Energy Center, which is discussed in the Policy Framework section.

Loan Sources

There are numerous low-interest and other loan sources that could be used for district energy. Commercial loans may be available from one or a consortium of banks. District energy systems, which have been well-established and seen as low-risk in Europe for decades, are a new concept in the United States. In the current economy, it is unknown how commercial lenders will view community district energy loan applications. Local banks may be more interested in supporting these projects on the basis of local economic development and stimulus to the local economy. Banks may be incentivized by federal low-interest loan and loan guarantee programs available from a number of federal agencies, including USDA Rural Development, or through advances for community and economic development through the Federal Home Loan Bank available for its member banks.

If a community wishes to promote the district energy system, it may use its bonding authority by issuing ‘general obligation’ bonds or revenue bonds. General obligation bonds are backed by the full faith and credit of the municipality, and revenue bonds are issued on the strength of the project finances and repaid from them. The Emergency Economic Stabilization Act passed in the fall of 2008 includes a new category of tax credit bonds called “Qualified Energy Conservation Bonds” (QECCBs). QECCBs are expected to perform as no-interest bonds for the end user. The bondholder will receive federal tax credits in lieu of traditional interest.

QECCBs can support a variety of energy conservation and possibly renewable energy purposes including capital expenditures for publicly owned buildings and certain demonstration projects. QECCBs could possibly be used as a finance source for district energy projects. As a new federal program, the applicability of QECCBs will not be certain until the IRS issues rules, and ownership structure may affect a project’s eligibility

In addition to the traditional loan sources described here, there are constantly evolving less-traditional and new approaches that could be creatively combined in innovative ways to finance the debt portion of the capital requirements of the project. Current non-traditional loan sources should be evaluated at the time that funding for the project is being acquired.

⁴ <http://www.masstech.org/SEED/>

VII. POLICY FRAMEWORK

The following are key players in Massachusetts' renewable energy strategy:

Massachusetts Technology Collaborative

The Massachusetts Technology Collaborative (MTC) is the state's economic development agency for the innovation economy and renewable energy. The agency is working to enhance the state's economic competitiveness, strengthen its high-tech industry clusters and harness local, clean energy resources. MTC operates as a catalyst at the intersection of industry, academia, and government to create new economic opportunity and a cleaner environment for Massachusetts⁵. From the beginning, MTC has studied federal research and development funds in an effort to increase the amount of federal funding for Massachusetts projects. Upon gaining recognition for being a dependable source for funding opportunities, MTC created the Renewable Energy Trust to help find solutions for the Commonwealth's energy strategy.

Renewable Energy Trust

The Renewable Energy Trust works to provide environmental and economic benefits to the people of the Commonwealth of Massachusetts. Their mission is to promote clean energy technologies and create a market platform upon which they may operate. Currently, their projects seem to focus on wind, solar, and hydro projects for individuals, businesses, and communities. However, as their focus is to foster the growth of emerging markets, this Trust may still play a vital role in biomass technology for Massachusetts.

Massachusetts Clean Energy Center

As of November 2009, the Renewable Energy Trust merged with the Massachusetts Clean Energy Center, thereby "establishing the Clean Energy Center as the primary agency responsible for growing the Massachusetts clean energy industry."⁶ The Center works to offer grants for clean, renewable energy projects, support the clean energy sector, invest directly in Massachusetts companies (both new and existing), promote training programs to foster a green workforce, and allow companies access to capital resources for growth.

⁵ Agency Overview- Massachusetts Technology Collaborative. <http://www.masstech.org/agencyoverview/historybest.pdf>

⁶ Keough, Robert. "Governor Patrick Signs Law Consolidating State Support For Clean Energy". 2009, Nov. 25. http://www.mass.gov/?pageID=eoeepressrelease&L=1&L0=Home&sid=Eoeea&b=pressrelease&f=091125_pr_cec_mret&csid=Eoea

VIII. ENVIRONMENTAL IMPACTS

Air Emissions from Woodchip Boilers

As the number of biomass heating systems in facilities increases, there is increased concern about the emissions from biomass systems and air quality.

The emissions from wood-fired boilers are different from emissions from natural gas, propane or oil boilers. A number of these components are air pollutants and are discussed below. Boiler emissions are typically measured in pounds of pollutant per million British thermal units (one million British thermal units is the amount of heat energy roughly equivalent to that produced by burning eight gallons of gasoline, or 121 lbs of dry woodchips).

All heating fuels— including wood—produce particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NOx), and sulfur dioxide (SO₂) in varying amounts. Burning wood in a modern and well-maintained woodchip boiler, for example, produces more particulate matter than burning oil, but less SO₂ than oil. Emissions rates are given in the table below (in lbs per MMBtu) for woodchip and oil boilers.

Table 2: Woodchip Boiler versus Oil Boiler Emission Rates (in lbs/MMBtu)⁷

	PM10	CO	NOx	SO ₂	TOC	CO ₂
Wood Pellet Boiler (Test Report)⁸	n/a	0.51	n/a	0.272	n/a	n/a
Woodchip Boiler	0.1	0.73	0.165	0.0082	0.0242	Gross 220 (net 0)
Oil Boiler	0.014	0.035	0.143	0.5	0.0039	159
Propane Boiler	0.004	0.021	0.154	0.016	0.005	137
Natural Gas Boiler	0.007	0.08	0.09	0.0005	0.01	118

Modern wood systems emit more SO₂ than natural gas, but have less than two percent the SO₂ emissions of fuel oil. Wood and fuel oil combustion have similar levels of NOx emissions. All fuel combustion processes produce carbon monoxide (CO). The level produced by wood combustion depends very much on how well the system is tuned. Wood combustion produces significantly more CO than oil. This, in addition to PM, is a good reason to make sure the facility is fitted with the best available controls and that the stack is tall enough to disperse any remaining emissions away from ground level. However, CO emissions from burning wood are of relatively minor concern to air quality regulators, except in areas like cities that have high levels of CO in the air from automobile exhaust.

Volatile organic compounds (VOC) are one component of total organic compounds (TOC), another pollutant of concern. VOCs are a large family of air pollutants, some of which are

⁷ Without emission control equipment with the exception of PM10; the PM10 is given after emissions moved through a baghouse. Emissions given on a heat input basis.

⁸ Emissions rates, given in pounds of pollutant per MMBtu, were provided by Resource Systems Group in a report titled, *Air Pollution Control Technologies for Small Wood-fired Boilers* (2001). These emissions rates characterize wood fuel in general, with a specific focus on woodchips. The emissions from wood pellets may differ from the emissions rates given here.

produced by fuel combustion. Some are toxic and others are carcinogenic. In addition, VOCs elevate ozone and smog levels in the lower atmosphere, causing respiratory problems. Both wood and oil combustion produce VOCs – wood is higher in some compounds and oil is higher in others. VOC emissions can be minimized with good combustion practices.

In terms of health impacts from wood combustion, particulate matter (PM) is the air pollutant of greatest concern. Particulates are pieces of solid matter or very fine droplets, ranging in size from visible to invisible. Relatively small PM, 10 micrometers or less in diameter, is called PM₁₀. Small PM is of greater concern for human health than larger PM, since small particles remain airborne for longer distances and can be inhaled deep within the lungs. Particulate matter exacerbates asthma, lung diseases and increases mortality among sensitive populations.

Fine particulates (PM_{2.5}) are increasingly a concern as they are known to increase health-related problems as compared to the larger particulates. Although not a great deal is known about PM_{2.5} emissions from wood boilers, we do know there are effective pollution controls available.

Control Devices for PM

As described above, fine particulate matter is the pollutant of greatest concern with regard to wood systems. Even with the climate change benefits of wood energy, the PM_{2.5} issue needs to be considered as the regulatory framework is changing. The National Ambient Air Quality Standard for PM_{2.5} has recently been changed, with the standard becoming tighter. The region of Greenfield, Massachusetts is expected to be in compliance with the revised standards based on EPA designations. The AP42 uncontrolled PM emission factor (EPA accepted measurement of emissions) is 0.29 lb/MMBtu for wet wood, which can be reduced to 0.20 lb/MMBtu by installing a mechanical collector. Some uncontrolled small wood-fired boilers of modern design with a gasifier or staged combustion have uncontrolled emission rates of between 0.1 and 0.2 lb/MM Btu.

Currently, the four most common air pollution control devices used to reduce PM emissions from wood-fired boilers are mechanical collectors (cyclones and core separators), wet scrubbers, electrostatic precipitators (ESPs), and fabric filters. Such devices can reduce PM emissions by 70 to 99.9 percent.

Multicyclones

Multicyclones, or multiple tube cyclones, are mechanical separators that use the velocity differential across the cyclone to separate particles. Cyclones are less efficient collectors than multicyclones because a multicyclone uses several smaller diameter cyclones to improve efficiency. Overall efficiency ranges from 65 percent to 95 percent but multicyclones, like cyclones, are more efficient in collecting larger particles and their collection efficiency falls off at small particle sizes. The AP42 lists multicyclone controlled emission rates that indicate a control efficiency of 73 percent for PM₁₀ when the uncontrolled emission rate is 0.71 lb/MMBtu. The resulting multicyclone controlled emission rate is 0.19 lb/MMBtu. When the uncontrolled emission rate is as low as 0.1 to 0.2 lb/MM Btu the overall control efficiency will be lower. Some combustion units could meet an emission level of 0.1 lb/MM Btu with a multicyclone.

Electrostatic Precipitators (ESP)

ESPs are widely used for the control of particulates from a variety of combustion sources including wood combustion. An ESP is a particle control device that employs electric fields to collect particles from the gas stream on to collector plates from where they can be removed. There are a number of different designs that achieve very high overall control efficiencies.

Control efficiencies typically average over 98 percent with control efficiencies almost as high for particle sizes of one micrometer or less. Overall ESPs are almost as good as the best fabric filters. Two designs were considered for smaller boilers: a dry electrostatic precipitator and a wet electrostatic precipitator. The systems are basically similar except that wet electrostatic precipitators use water to flush the captured particles from the collectors. The advantage of dry systems is that they may have a lower capital cost and reduced waste disposal problems. Wet systems may be less expensive to operate and are probably slightly more efficient at capturing very small particles that may include toxic metals. An expected increase in capital costs will result from installation of an ESP versus a baghouse depending on system size and availability.

Fabric Filters or Baghouses

With the correct design and choice of fabric, particulate control efficiencies of over 99 percent can be achieved even for very small particles (one micrometer or less) by fabric filters or baghouses. The lowest emission rate for large wood-fired boilers controlled by fabric filters reported is 0.01 lb/MMBtu. Operating experience with baghouses on larger wood-fired boilers indicates that there is a fire risk, due to caking of the filters with unburned wood dust. It is possible to control or manage this risk by installation of a mechanical collector upstream of the fabric filter to remove large burning particles of fly ash (i.e. “sparklers”).

BERC recommends the installation of a cyclone and baghouse combination at the Greenfield district energy plant. The cyclone is generally included as part of the standard manufacturer supplied equipment. A cyclone and properly sized stack are usually sufficient to keep air emissions below current state permitting thresholds. BERC recommends the additional installation of a baghouse to biomass systems in community settings because of the particular vulnerability of certain populations to health impacts from fine particulates released by wood combustion. The use of these advanced controls also ensures the project is serving as a model demonstration of the best system possible. The cost of both a cyclone and baghouse has been included in the economic analyses presented here.

BERC is actively engaged in this on-going discussion and will continue to recommend changes in combustion techniques and pollution control options as appropriate based on the state of the scientific information.

Stack Height

Wood system chimneys at this size range emit virtually no visible smoke (the white plume of vapor on cold days is condensed water). Nevertheless, all but the very best wood burning systems, whether in buildings or power plants, have significantly higher PM emissions than do

corresponding gas and oil systems. For this reason, it is necessary to use a stack with a height that will effectively disperse any remaining emissions into the air and reduce ground-level concentrations of PM (and other pollutants) to ensure acceptable levels are maintained.

Woodchip System Air Quality Permitting

Greenfield will need to submit a construction permit application for an Air Pollution Control permit for the district energy plant. The permit should be secured before the project scope is finalized, and certainly before any purchase heat contracts are issued.

The permit will clearly identify certain scoping issues such as required stack height and required air pollution control equipment. Having the permit will also allow the Greenfield district energy plant to include the permit conditions (and request emission rate guarantees) in their scope of work in the bid packages sent to potential boiler suppliers. The permitting process can take approximately four months from the time that the agency receives a complete permit application until the time that the permit is issued.

Appendix J provides details on the air quality operating permit.

Climate Change and Biomass Energy

Global climate change is one of the most pressing environmental challenges of our time, and the major cause of climate change is emissions of carbon dioxide (CO₂) from burning fossil fuels such as oil, natural gas, propane, coal, and gasoline. Woody biomass is considered a carbon-neutral fuel by both the US Department of Energy and the US Environmental Protection Agency, even when considering the fossil fuels used in production and transportation of wood fuel. One of the most important environmental benefits of using sustainably harvested wood for energy in place of fossil fuels is its positive impact in moderating long-term global climate change.

Fossil fuel combustion takes carbon that was locked away underground (as crude oil, gas, or coal) and transfers that carbon to the atmosphere as new CO₂. When wood is burned, on the other hand, it recycles carbon that was already in the natural carbon cycle, which is recaptured through sustainable forest growth. Consequently, the net long-term effect of burning wood fuel is that no new CO₂ is added to the atmosphere—as long as the forests from which the wood came are sustainably managed. For this reason, heating with wood is a powerful tool for an institution, business, or community interested in meaningfully addressing climate change through its energy use.

By burning approximately 1,615,647 million gallons of oil (as is the amount of oil displaced in Option III, the largest of the six options) at 22 pounds of atmospheric CO₂ emitted per gallon of heating oil, the buildings in the study area contribute over 18,000 tons of carbon dioxide to the atmosphere annually (for space heating; this does not include emissions from electrical production). If these buildings were to instead connect to a wood-fired district energy plant, net CO₂ emissions for heating would be reduced by 75-90 percent (depending on how much the plant has to rely on back-up fossil fuel boilers).

IX. ASSESSMENT OF AVAILABLE WOOD FUEL SUPPLY

Biomass comes in all shapes and sizes. This section focuses on woodchips as the primary fuel for the Greenfield district energy plant and discusses the various types and grades of woodchips, their overall quality as a boiler fuel, the availability and pricing from different sources, and general recommendations for securing the necessary volumes.

The Fuel Procurement Area

At the scale of wood consumption being considered here, wood fuels would likely be procured from within a fifty-mile radius around the energy plant. A fifty-mile radius was drawn around Greenfield, Massachusetts to begin to determine the area from which wood fuels would be sourced for this project. Limiting haul distances will keep delivery costs down, and so a drive-time analysis was also conducted. The counties surrounding the Greenfield plant that were well within both a 50-mile and 90-minute drive time radius were considered to be the procurement area from which wood fuels would be sourced. These counties were Berkshire, Franklin, Hampden, Hampshire, and Worcester, Massachusetts; Cheshire, New Hampshire; and Windham, Vermont. Once the procurement area is identified, this becomes the study area for the wood fuel assessment. Counties in Connecticut were not included.

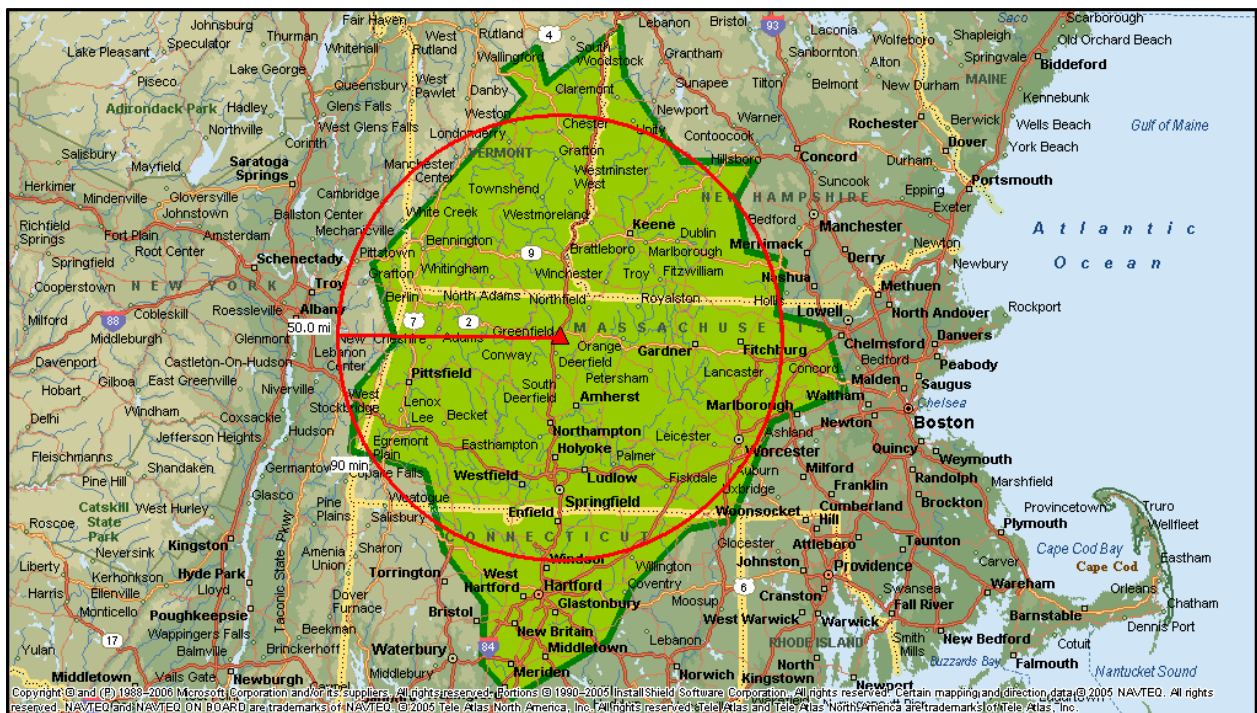


Figure 1: 50-mile radius around Greenfield, Massachusetts indicating the area from which wood fuels could potentially be sourced.

Wood Fuel Sources Overview

Woodchips have historically been almost exclusively a by-product of timber harvesting in the woods, lumber production at sawmills, and clean wood waste recycling efforts from communities. In recent years increased market demand for chips as fuel and decreased sawmill activity has prompted a gradual shift toward woodchips sourced as a commodity wood fuel harvested directly from the forest rather than a by-product produced from higher value wood harvesting and processing.

Whole-tree Harvesting



Figure 2: Examples of Whole-tree Harvesting

Commercial harvesting of sawlogs and pulpwood removes the main stem or bole of the tree from the woods and leaves the tops and limbs either scattered in the woods near the stump or in a large pile at the log landing. Whole-tree harvesting—mechanized harvesting where entire trees, as opposed to just the log, are dragged (skidded) from the stump to the central log landing—requires the tops and limbs be removed and piled at the log landing. This leftover wood can be chipped into biomass fuel commonly known as whole-tree chips. In some cases entire trees, not just the tops and limbs, are fed to the chipper to also produce whole-tree chips. It is common practice for the wood to be chipped in the woods at the log landing into box trailers which are transported directly to large users like biomass power plants and pulpmills that are equipped with trailer tippers to unload the chips from the box trailers.

Stem Only Harvesting



Figure 3: Examples of Stem Only Harvesting

Timber harvesting can be performed where only the merchantable roundwood is removed from the stump to the landing or roadside—meaning once the tree is felled it is de-limbed there at the stump leaving the tops and limbs scattered in the woods. Stem only harvesting can be conducted using manual cutting and processing (logger with chainsaw and skidder) or can use Cut-to-Length equipment (mechanized harvester and forwarder).

Stem only harvesting only extracts roundwood and leaves tops in the woods. While many studies have examined the mechanical and logistical feasibility of a second entry to gather, extract, and process chips from stem only harvests the costs are prohibitively high. The only feasible chipwood from stem only harvesting is smaller diameter and pulp-grade main stems.

Sawmills



Figure 4: Examples of sawmills

The business of sawing round logs into dimensional lumber produces a significant amount of by-product wood. Sawmills produce three main categories of by-product wood—bark stripped from the log prior to sawing, chips produced from the unusable slabs cut from the out curve of the log, and fine sawdust created from the cutting teeth of the saw.

The slabs and off-cuts from lumber production at larger sawmills are typically chipped and shipped to regional pulpmills, biomass power plants, or woodchip-heated institutions. These “mill” or “paper” chips are the best suited for use as fuel in biomass heating systems. Mill chips tend to be the highest quality chips available for woodchip-fueled heating systems. Because logs are debarked before sawing the chips, mill chips are very clean and have relatively low ash content. Mill chips are also commonly screened to remove over-sized stringers and fines. Wasted wood from sawmills is commonly chipped on a continual basis as logs are sawn and chips are blown directly into dedicated box trailers. When the trailers are full they are shipped to the various markets and an empty trailer is set in its place.

Tree Service Companies and Urban Wood Yards



Figure 5: Examples of Tree Service Companies and Urban Wood Waste

There are two main categories of urban and suburban community clean wood waste: tree trimmings (often chipped using mobile equipment) and wood aggregated at yards (pallets, Christmas trees, stumps, etc.).

For the tree trimmings where material is often collected and chipped using mobile equipment there are several activities that yield wood—periodic storm clean-up, removal of dead and diseased trees, and thinning of trees and branches along power-lines. This material is commonly collected and transported in small dump trucks by private tree service companies as well as municipal road crews and public works departments making longer haul distances less cost effective. Chipped tree trimmings are often transported to local wood yards or local farms and in some cases the material is chipped and blown back into the woods along the roads or power-lines.

Clean wood recycling yards are often located in landfills, transfer stations, and composting operations. These wood yards commonly receive untreated wood such as brush, wood pallets, stumps, and Christmas trees. These wood wastes are normally stock-piled at the yard until there is enough on-site volume before using a grinder to reduce the material into chip-sized product. Many wood yards either sell the chips to existing wood-fired power plants, composting operations, or die the chips for ornamental mulch.

Construction and demolition debris is excluded from this category because this material can contain significant amounts of contaminants ranging from metal to toxic chemicals, making it a poor wood fuel.

Chip Yards and Chipmills



Figure 6: Chip yard handling and transport equipment.

Bole chips are produced from low-grade wood or pulpwood. The difference between whole-tree chips and bole chips is that bole chips do not include the branches or foliage. When the trees are harvested the limbs are removed and the slash is left on the ground in the woods or at the log landing (depending on where the tree is de-limbed). While bole chips can make for higher-quality fuel and help forest soil health by returning

a portion of the biomass and nutrients to the soil, they are significantly more expensive than sawmill chips and whole-tree chips which are both by-products. In the past, sawlog prices were high enough that low-grade wood could be extracted at the same time as sawlogs and still be profitable for the logger and pay the landowner stumpage. With recent drops in the sawlog market, however, low-grade wood like pulp, chips, and firewood can no longer rely on subsidized costs—this low-grade wood must pay its own way out of the woods.

Bole chips can be produced by chipping roundwood at the log landing where the wood was harvested, at a remote yard used by the logging/chipping contractor, or at the energy plant's wood storage yard.

Chip yards are usually small basic yards where pulpwood can be stored and periodically chipped using mobile equipment. Chip mills are larger established facilities with stationary equipment that often supply regional pulpmills.

While bole chips are not commonly produced in Massachusetts at this time, there is the potential for greater use of bole chips (and the establishment of chip yards and mills) should a wood heating market develop in the state.

Availability of Residues from Forestry and Processing

Sources of residue wood include those that are forestry-derived, such as whole-tree harvesting or chipped pulpwood, and those that are mill-derived, such as sawmill residues.

Historically, there has been sufficient supply of wood by-products such as sawdust, chips, and bark generated by the forest products industry to meet any wood energy demand and regional pellet production. Over recent years the demand for woodchips has grown dramatically while the by-product supply has decreased due to general downturn in the forest products industry. This procurement area supports only a handful of active sawmills, and many of these businesses are operating at diminished capacity due to the dramatic downturn in the lumber market. In general, the volumes of bark, chips, and sawdust left over from forestry and processing operations have strong existing markets, and relatively firm supply commitments to these existing markets are in place. For the purpose of supplying wood fuel to the Greenfield plant, residue wood from sawmills will not likely be a significant contributing source.

Should the project move forward it is still worth approaching the few sawmills in the area that are willing and able to supply woodchips to the Greenfield plant. Some mills, chipping contractors, and chip brokers listed here may opt to supply closer markets instead of existing markets that are further away, if they are available. Building these relationships at the start can ensure a successful project and reliable supply from these mills.

Wood residues from land clearing activity have historically been a significant part of wood fuel in southern New England. Due to the recent downturn in the economy and the resulting slow down of development and the desire to source wood fuel from local well-managed forests, land clearing-derived fuel was not considered as part of this analysis.

Availability of Low-Grade Wood from Harvesting

Despite the decline in by-product supply of woodchips, logging contractors have encouragingly responded to the recent surge in demand for wood fuels produced as a primary product. Low-grade logs or pulpwood that would historically have gone to regional pulpmills now is a major source of woodchip fuel. While some wood fuel sourced for the Greenfield plant may be by-product material, a majority of the supply will likely come directly from harvesting low-grade wood from regional forestland. Because wood is not infinite in its supply, careful attention must be paid to the question of how much wood is available or we run the risk of growing our wood fuel demand beyond our forests' capacity to supply.

In an effort to better understand the potential capacity of the region's forests to provide increased amounts of wood fuel for wood energy systems, such as the Greenfield plant, the forestland within the procurement area was identified and the current inventory of wood on this forestland was estimated. Several steps were taken:

1. Identify and examine accessible and managed forestland area;
2. Examine the current inventory of wood on the forestland area;
3. Understand the rate of forest growth, building upon existing inventory;
4. Quantify the existing market demand for low-grade wood;
5. Determine any additional forest capacity for additional low-grade wood market demand.

Estimating Accessible and Managed Forestland Area

The seven-county procurement area identified for this assessment is approximately 3.8 million acres in size. While a large percentage of this area is forested, not all forest is classified as timberland. Timberland is defined by the USDA Forest Service as "forestland capable of producing 20 cubic feet of industrial wood per acre per year and not withdrawn from timber utilization." In other words, timberland is forestland that is productive and more likely to be accessible and managed as forestland. This procurement area holds about 2.758 million acres of forestland classified as timberland⁹. About 72 percent of this procurement area is timberland.

⁹ From Forest Service Forest Inventory and Analysis (FIA) program data.

Table 3: Total Timberland in the Seven-County Procurement Area

Counties	Total Area (acres)	Total Timberland ¹⁰ Area (acres)	% Timberland
Franklin, MA	464,000	351,555	76%
Hampshire, MA	348,800	241,397	76%
Hampden, MA	405,760	250,878	69%
Berkshire, MA	605,440	440,021	62%
Worcester, MA	1,010,560	659,789	73%
Windham, VT	510,720	427,555	65%
Cheshire, NH	466,560	386,839	84%
Total	3,811,839	2,758,034	72%

While there is a considerable amount of timberland in this procurement area, not all of it will be accessible or ecologically appropriate for harvesting. A significant amount of the timberland area shown above is not accessible for harvesting due to physical attributes such as slope, elevation, wilderness designation, stream and wetland buffer areas, and key wildlife habitat. Additionally, not all of this timberland is being actively managed for periodic harvesting. Forestland ownership and landowners' objectives will impact access to periodic harvesting on this timberland as well.

To account for these limitations on harvesting, it was assumed that 30 percent of the total timberland shown above is physically inaccessible and ecologically inappropriate for harvesting and further that 30 percent of the accessible timberland is not actively managed. The right hand column of the following table estimates the remaining accessible, ecologically appropriate, and actively managed timberland within the study area using the assumptions described here.

¹⁰ Timberland is defined by the USDA Forest Service as “forestland capable of producing 20 cubic feet of industrial wood per acre per year and not withdrawn from timber utilization.”

Table 4: Total Accessible and Actively Managed Timberland in the Seven-County Procurement Area

Counties	Total Timberland Area (acres)	Accessible & Appropriate Timberland (acres)	Accessible and Actively Managed Timberland (acres)
Franklin, MA	351,555	246,089	172,262
Hampshire, MA	241,397	168,978	118,285
Hampden, MA	250,878	175,615	122,930
Berkshire, MA	440,021	308,015	215,610
Worcester, MA	659,789	461,852	323,297
Windham, VT	427,555	299,289	209,502
Cheshire, NH	386,839	270,787	189,551
Total	2,758,034	1,930,624	1,351,437

While there are about 2.75 million acres of timberland in this procurement area, only 1.9 million acres are accessible and ecologically appropriate for harvesting after accounting for slope, elevation, wilderness designation, stream and wetland buffer areas, and key wildlife habitat. Further, only 1.3 million acres are both accessible and actively managed for harvesting.

The 1.3 million acres of timberland that are accessible, appropriate, and actively managed for harvesting now become the footprint for estimating the low-grade wood that could be available annually from the forests for use as biomass fuel.

Forest Inventory and Composition

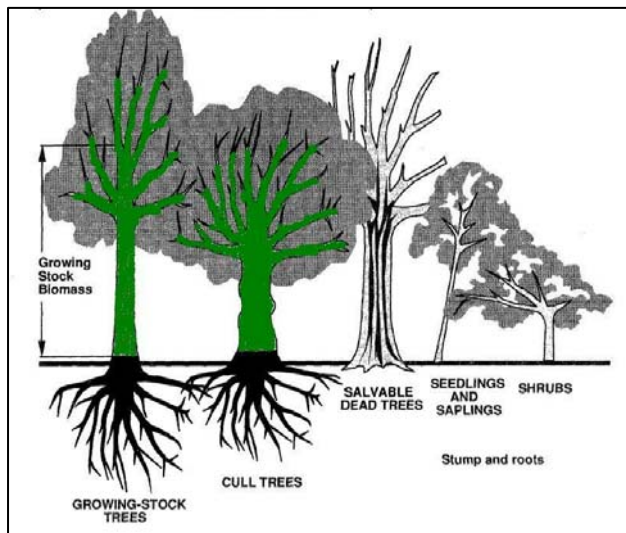


Figure 7: Samples of above-growing growing stock and cull biomass inventory

Estimating both the total inventory on the accessible and actively managed portion of timberland and the portion of inventory that is low-grade wood appropriate for use as wood fuel is one component of quantifying the amount of low-grade wood available annually from within the procurement. The only source of complete forest inventory data is compiled by the USDA Forest Service.

This information on inventory comes from the USDA Forest Service’s Forest Inventory and Analysis (FIA) program, which generates reliable estimates of the condition and health of the forest resource and how it is changing over time. The program uses a statistically designed

sampling method to select hundreds of plots for measurement by field crews and includes plots that were counted in previous inventories. The re-measurements on the same plots yield valuable information on how individual trees grow. Field crews also collect data on the number, size, and species of trees, and the related forest attributes.

For live trees of a merchantable size (five inches Diameter at Breast Height [DBH] and larger) there are two main qualitative categories: growing stock and cull. The term “growing stock” refers to the traditionally merchantable wood contained in live trees greater than five inches, whereas “cull” refers to trees or portions of trees that are rough or rotten and therefore are traditionally un-merchantable, or non-commercial species.

Standing and downed deadwood was not counted due to its value as wildlife habitat and because it does not represent inventory on which new growth occurs. Neither seedlings nor saplings were counted, nor were foliage or below-ground forest biomass such as roots and stumps.

The following tables give the total above-ground forest inventory¹¹, by county, of all live trees in the study area on the portion of timberland that was estimated to be accessible and actively managed as described above. These inventories include both high- and low-grade wood, shown below as growing stock and cull/non-commercial categories, respectively.

Table 5: Standing Inventory on Accessible and Actively Managed Timberland

Counties	Growing Stock (green tons)		Cull and Non-Commercial (green tons)		Grand Total (green tons)
	<i>Bole</i>	<i>Tops & Limbs</i>	<i>Bole</i>	<i>Tops & Limbs</i>	
					<i>Combined Bole and Tops & Limbs</i>
Franklin, MA	5,246,264	483,901	677,184	207,151	6,614,500
Hampshire, MA	4,475,496	337,280	269,126	83,625	5,165,527
Hampden, MA	4,304,404	341,553	291,179	94,305	5,031,441
Berkshire, MA	7,751,071	605,521	1,297,817	373,123	10,027,532
Worcester, MA	8,079,229	724,290	1,201,097	351,223	10,355,838
Windham, VT	5,222,861	475,898	621,120	192,026	6,511,904
Cheshire, NH	7,492,711	683,432	763,404	224,056	9,163,603
Total	42,572,036	3,651,874	5,120,927	1,525,507	52,870,345

¹¹ Total forest inventory of live trees five inches DBH and larger (includes growing stock and cull trees and bole and top & limb wood inventory). This total inventory is then whittled down to a smaller and more appropriate low-grade wood inventory on which net annual growth rates are applied.

In total, there are 52.8 million green tons of standing, live trees (inventory) on the accessible and actively managed timberland within this procurement area.

Net Annual Growth

In addition to determining the amount of standing wood (or inventory) and the forest's composition, knowing how much the forests are growing and what level of harvest can be sustained over time gives a clearer picture of wood fuel availability and the viability of woody biomass energy.

When forests are examined from a broader perspective, wood inventory can be compared to money invested in a bank account that earns interest annually. The total annual growth of trees in a forest is analogous to the interest earned on capital invested. A wise financial investor strives to only spend the annual interest earned each year and not dip into the principal. Forests are the same: sound forest management policy within a state or region limits harvesting to within the amount of annual growth. Continual harvesting beyond the rate of growth, or withdrawing the principal, will reduce the forest inventory at an unsustainable rate.

Rates of forest growth fluctuate widely depending on the age and composition of a forest as well as the site's soil and aspect. For the purpose of this assessment, the net annual growth¹² of new amounts of wood was chosen as the indicator of how much wood the forests of these counties can provide on a sustained-yield basis. An average rate of net annual growth of 2.0 percent was used for this assessment based on the most current forest growth data from the USDA Forest Service¹³. In addition to accounting for the timberland area that is not physically accessible and the timberland area that is not managed and periodically harvested, it would be inappropriate to include high quality trees otherwise capable of yielding merchantable wood for sawlog production. For these reasons, a series of assumptions were used in this wood fuel supply assessment to target a more appropriate amount of wood that could be available for use as wood fuel.

The amount of low-grade wood grown each year on available timberland in this procurement area was estimated using a series of fine-tuned assumptions. For this assessment, it was assumed that:

- the net annual growth rate is 2.0 percent;
- 40 percent of the net annual growth of growing stock bole wood is low-grade;
- 90 percent of the net annual growth of cull bole wood is low-grade; and
- Top and limb wood from the growing stock and cull categories were not included in this estimation¹⁴.

The amount of new low-grade wood growing each year is shown in the table below. It should be noted that these values do not yet account for current levels of harvesting.

¹² FIA defines forest *net annual growth* as "the change, resulting from natural causes, in growing-stock volume during the period between surveys (divided by the number of growing seasons to produce average annual net growth). The simplified FIA formula for net growth is: In-growth¹² + Accretion¹² - Mortality¹² = Net growth

¹³ Further sensitivity analysis will be performed in the full report to examine the impact of minor fluctuations to the net annual growth rate used in this analysis.

¹⁴ Top and limb wood was not factored in this analysis in effort to provide a conservative estimation that encourages this material to be left in the woods to sustain forest productivity over time.

Table 6: Net Annual Low-Grade Growth

Counties	Growing Stock (green tons)		Cull and Non-Commercial (green tons)		Grand Total (green tons)
	<i>Bole</i>	<i>Tops & Limbs</i>	<i>Bole</i>	<i>Tops & Limbs</i>	<i>Combine Bole and Tops & Limbs</i>
Franklin, MA	126,410	-	57,431	-	183,841
Hampshire, MA	87,573	-	25,493	-	113,066
Hampden, MA	94,167	-	23,665	-	117,832
Berkshire, MA	173,365	-	53,598	-	226,962
Worcester, MA	243,202	-	44,233	-	287,436
Windham, VT	167,200	-	33,188	-	200,389
Cheshire, NH	139,292	-	36,097	-	175,389
Total	1,031,208	-	273,705	-	1,304,914

As can be seen in the tables above, more than 1.3 million green tons grown annually on this forested footprint can be harvested on a sustained-yield basis. While this may sound like a large amount of wood, it should be noted that there is significant existing demand for low-grade wood within this region. The next steps are to quantify the existing annual demand of low-grade wood and then determine the remaining quantity that could be available. The following sections discuss this further.

Existing Demands for Low-Grade Wood

The net annual growth presented above does not account for existing levels of harvesting for pulpwood, residential firewood, and woodchips. Massachusetts does not currently track harvesting of wood products at the county level. For the Massachusetts counties current harvesting data were examined from the FIA Program using the Timber Products Output (TPO) database.

Unfortunately, the reliability of these data is suspect. For this reason, BEREC reviewed other data sources including harvest plans submitted to the Massachusetts Department of Conservation and Recreation (DCR). Based on these multiple data sources estimates of low-grade harvest were generated. For Vermont, annual harvest data gathered by the state were used. For New Hampshire, annual harvest data derived from stumpage taxes were used.

Harvest data for pulpwood, residential firewood, and whole-tree chips in the study indicate that approximately 250,000 green tons of low-grade wood is removed annually from timberland in these counties. Current, specific uses and demands for this wood are discussed in a later section of the report.

Net Available Low-Grade Growth

The difference between the rates of annual growth of low-grade wood and the current rates of harvest is the net amount of low-grade wood that could be available for use as biomass fuel, referred to here as the net available low-grade growth (NALG).

Table 7: Total Annual New Available Low-Grade Growth

Counties	Bole Wood	Top & Limb Wood	Total
Franklin, MA	161,899	-	156,899
Hampshire, MA	92,360	-	87,360
Hampden, MA	91,685	-	86,685
Berkshire, MA	205,933	-	200,933
Worcester, MA	250,524	-	245,524
Windham, VT	160,741	-	155,741
Cheshire, NH	118,242	-	113,242
Total	1,081,384	-	1,046,384

There is an estimated annual surplus capacity of slightly more than one million green tons of low-grade wood within the total procurement area after the firewood, pulp, and other market demands are combined and compared to the estimated annual growth of low-grade wood on accessible and actively managed timberland. If the Greenfield energy plant consumes between 9,000 and 24,000 green tons annually, there is currently ample supply of low-grade wood to fuel this facility in a sustainable way.

It is important to keep in mind that existing market demands for low-grade wood can grow and new ones can develop.

Conceptual Timberland Area Necessary to Supply the Greenfield Plant

It is common for decision makers to ask the question: “How much actively managed forest land would it take to supply our project?” Wood fuel will likely come from all over the given procurement region depending on where the harvesting happens to be taking place at the time. However, to put things in perspective, it is useful to calculate the theoretic timberland area needed to sustainably supply the on-going fuel needs of the system. Here are a few key assumptions needed for calculating the necessary timberland area to supply a given project.

Typical Massachusetts Forest Stocking	100 green tons/acre
<u>Average Net Annual Growth Rate</u>	<u>2.0%</u>
Sustained -Yield	2.0 green tons/acre/year

Assuming two-thirds of the annual growth is higher quality material suitable for lumber production, there are approximately 0.66 green tons of wood grown per acre per year that are suitable for use as woodchip fuel. The following table reflects the amount of managed timberland needed to supply the annual fuel requirement for the six different energy options being considered for Greenfield.

Table 8: Managed Timberland Necessary to Meet the Annual Fuel Needs in Greenfield, MA

Energy Option	Annual Wood Consumption (green tons)	Annual Acres of Timberland Required (assuming 0.66 green tons per acre)
Option I	9,321	14,123
Option II	20,492	31,048
Option III	23,695	36,311
Option IV	20,616	31,236
Option V	21,993	33,323
Option VI	n/a	n/a

It is crucial to note that the previous calculation is purely conceptual and is not meant to reflect the amount of harvesting actually happening. For comparison, the approach above can be compared to a slightly different basic method of calculating the required timberland area as presented below for Option I:

9,321 green tons of woodchip fuel needed per year

Divided by 100 tons of forest inventory per acre of timberland

Equals 93.21 acres of harvested timberland per year

Multiplied by 125-year harvest rotation

Equals 11,651 acres of timberland required

The following table gives estimates of the amount of timberland required to provide wood fuel to the Greenfield energy plant using this second method described above.

Table 9: Timberland Necessary to Meet the Annual Fuel Needs in Greenfield, MA (Method 2)

Energy Option	Annual Wood Consumption (green tons)	Annual Acres of Timberland Required (using the method described above)
Option I	9,321	11,651
Option II	20,492	25,615
Option III	23,695	29,619
Option IV	20,616	25,770
Option V	21,993	27,491
Option VI	n/a	n/a

Based on the outcome of the two approaches it can be concluded that the Greenfield energy plant would require between about 12,000 and 36,000 acres of timberland to sustainably provide the annual wood fuel requirements. Where within this range the actual number lies depends on the chosen energy option, and therefore the annual wood fuel consumption, and the method used to calculate the required timberland.

Wood Fuel Pricing

Woodchip pricing is highly variable and is somewhat prone to market volatility. For the past few decades woodchips have exclusively been supplied as a byproduct of the timber and lumber industries, which have experienced cyclical periods of strong market conditions followed by weak market conditions. This ebb and flow in the demand (and therefore the supply) of timber has historically driven the supply and pricing of chips. More recently, increased market demand for wood fuels coupled with declining generation of by-products has changed the pricing landscape.

Factors Affecting Wood Prices

The price of wood is affected by numerous factors, but the primary ones are:

- Wood source and production costs. This varies widely depending on whether the wood is a by-product of some more lucrative activity.
- Strength of the sawlog market. Higher prices paid for veneer and sawlogs can help lower prices for pulp and chips. More demand for roundwood timber products also produces more chips from slash.
- Regional balance of supply and demand for low-grade wood. Both supply and demand for low-grade wood wax and wane over time. Shortage of supply during periods of wet weather coupled with higher demand can drive prices upward. Conversely, surplus supply at times of weak demand causes prices to drop.
- Trucking distance from point of generation to end market. The cost of trucking is discussed in greater detail in the section below. In short, the price paid per ton of feedstock is dependent heavily on the cost to transport the material; this cost rises with higher diesel prices and with greater trucking distances. Further examination of the major trucking cost variables of distance and diesel fuel costs is provided in the tables and graphs below.

These primary factors are variables that BEREC tracks and feeds into our economic model to determine wood fuel prices. All model based calculations are cross-referenced with anecdotal price information gathered by interviewing key wood suppliers and buyers.

Production Costs

The table below shows the itemized production cost range and average for both low-grade pulpwood and whole-tree chips using approximate costs (as the costs to harvest, process, and haul pulpwood changes from harvest job to harvest job and depends widely on dozens of variables such as volumes harvested, layout of skidding roads, skid distances, equipment used, topography,

distance to the mill, etc.). It also assumes the pulpwood is harvested as part of an integrated harvest where some sawlogs are removed at the same time.

Table 10: Itemized Production Costs for Harvested Pulpwood and Chips

	Pulpwood		Whole-tree Chips	
	Cost Range (green tons)	Average Cost (green tons)	Cost Range (green tons)	Average Cost (green tons)
Stumpage	\$0.50 - \$5.00	\$4.50	\$0.50 - \$1.50	\$1.00
Cost to fell, skid, and process at landing	\$15.00 - \$25.00	\$17.00	\$8.00 - \$15.00	\$11.00
Cost to haul to mill	\$10.00 - \$20.00	\$15.00	\$10.00 - \$20.00	\$15.00
Total Cost	\$20.00 - \$50.00	\$36.50	\$18.50 - \$36.50	\$27.00

If pulpwood were harvested without any sawlogs, the costs presented in the table above would be higher, since the economic gains from harvesting sawlogs can help to “subsidize” the cost of removing low-grade wood. Harvesting low-grade wood is often a break-even cash flow booster whereas most loggers achieve their profit margin in the sawlog harvest.

Sawlog Market Influence

As mentioned above, sawlogs are the most profitable portion of the timber harvest for both landowners and loggers. If sawlog markets are strong and sawlog prices are high it can stimulate more harvesting and feed more low-grade wood into the pulp and biomass markets. However, when sawlog markets are weak many landowners hold off harvesting and wait for the market to rebound. This can reduce the flow of wood to the other markets.

Regional Supply/Demand Balance

Fundamental macro-economics are at play in the wood markets. When supply exceeds demand, prices drop. When demand exceeds supply, prices rise. Changes in global markets and currency exchange rates can influence wood demand on a day-to-day basis. Similarly weather and other factors can influence supply on a day-to-day basis.

Transportation

In general, the cost of woodchip fuel is affected by the hourly cost to transport the material, the overall distance of transport (and therefore the amount of time and fuel used), and the amount of woodchips being delivered in one load. One obvious factor is the cost of diesel fuel. The table below tallies, across a range of diesel prices, the average cost to transport green wood on a per-ton basis.

Table 11: Transport Cost Sensitivity to Diesel Fuel Price

Price of Diesel Fuel (\$/Gallon)	\$2.50	\$3.00	\$3.50	\$4.00	\$4.50
Labor Cost (per hour)	\$18.00	\$18.00	\$18.00	\$18.00	\$18.00
Trucking overhead (per hour)	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00
Hourly Cost of Transportation	\$100.50	\$113.00	\$125.50	\$138.00	\$150.50
Average Haul Distance (Miles)	35	35	35	35	35
Average Speed (MPH)	47	47	47	47	47
Average Transport Time - One Way (Hours)	0.74	0.74	0.74	0.74	0.74
Average Load and Unload Time (Hours)	1	1	1	1	1
Average Load Size (Green Tons)	30	30	30	30	30
Average Transport Cost per Green Ton	\$8.34	\$9.38	\$10.41	\$11.45	\$12.49

As is seen in both the table above and the following graph, there is a positive correlation between increasing diesel prices and the average cost to transport a green ton.

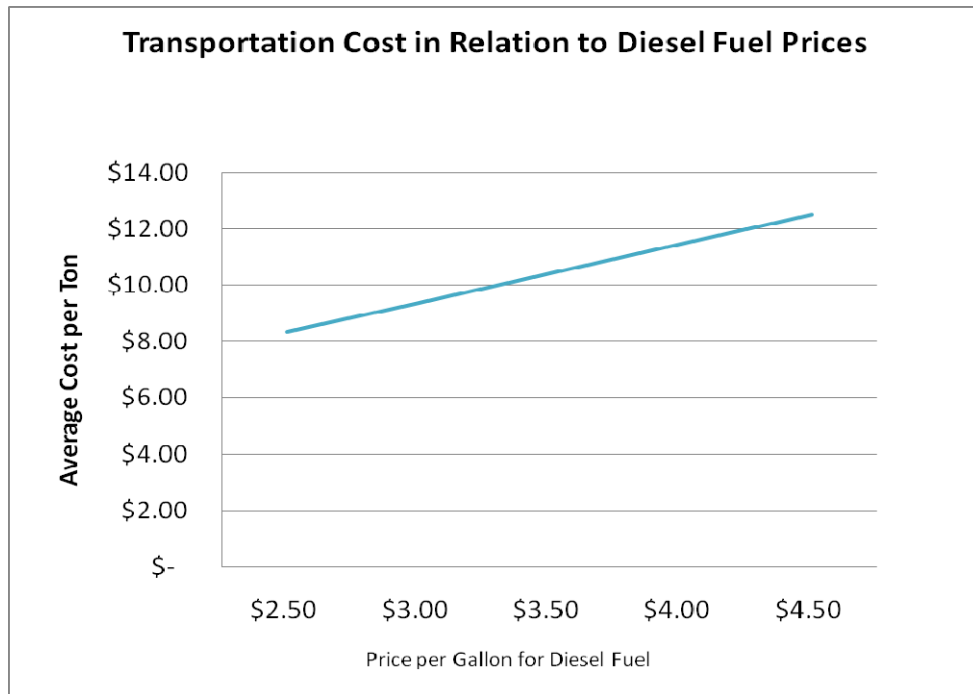


Figure 8: Graph of Transportation Cost in Relation to Diesel Fuel Prices

Another factor affecting the cost of woodchip fuel is trucking distance. While the above table and graph assumed the same 35-mile haul distance across a range of diesel prices, the table below summarizes the impact of increasing haul distances at a consistent diesel price.

Table 12: Transport Cost Sensitivity to Transport Distance

Price of Diesel Fuel (\$/Gallon)	\$2.50	\$2.50	\$2.50	\$2.50	\$2.50
Labor Cost (per hour)	\$18.00	\$18.00	\$18.00	\$18.00	\$18.00
Trucking overhead (per hour)	\$20.00	\$20.00	\$20.00	\$20.00	\$20.00
Hourly Cost of Transportation	\$100.50	\$100.50	\$100.50	\$100.50	\$100.50
Average Haul Distance (Miles)	35	45	55	65	75
Average Speed (MPH)	47	47	47	47	47
Average Transport Time - One Way (Hours)	0.745	0.957	1.170	1.383	1.596
Average Load and Unload Time (Hours)	1	1	1	1	1
Average Load Size (Green Tons)	30	30	30	30	30
Average Transport Cost per Green Ton	\$8.34	\$9.76	\$11.19	\$12.62	\$14.04

Similarly to the impact of diesel prices described above, there is also a positive correlation between increasing haul distances and increasing transport costs as is shown in the graph below.

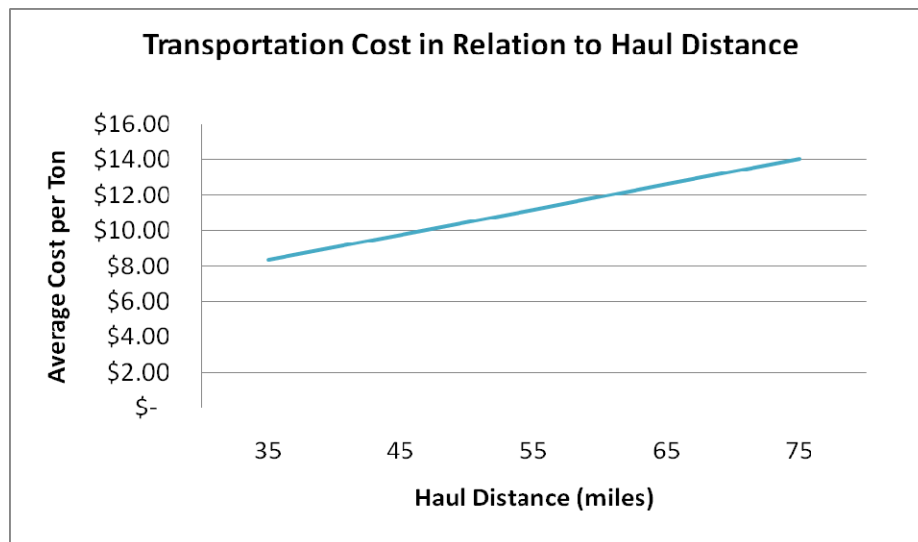


Figure 9: Graph of Transportation Cost in Relation to Haul Distance

Another factor affecting wood fuel transport costs on a dry-weight basis is the moisture content of the material. Weight is the limiting factor for truck transport of woodchips due to the weight of water—a tractor trailer will typically reach its legal load limit before it reaches the volume-holding capacity of the trailer.

In Massachusetts, chip trucks are limited to a gross weight (the weight of the truck plus the weight of the load it is carrying) of 80,000 pounds on both designated highways and all other roads. This means that the maximum net load a truck can legally carry is 40,000 pounds or 20 tons (assuming the weight of the truck itself is 40,000 pounds or 20 tons).

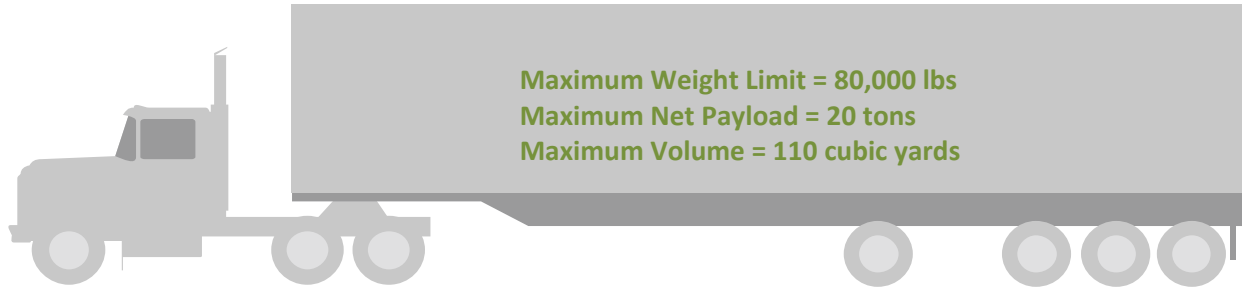
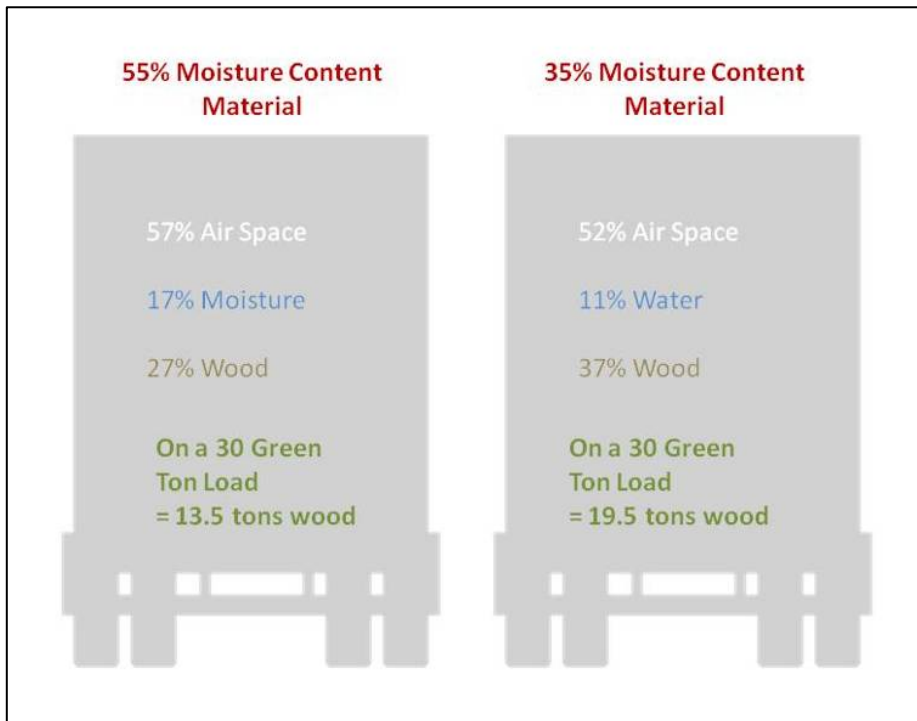


Figure 10: Maximum Amounts of Wood Fuel that a Standard Chip Truck Can Haul

If chips were drier, more volume could be carried before reaching either the legal weight limit or the volume capacity of the trailers, improving transport economics.

It is important to note that while moisture content has a dramatic impact on wood fuel value and



the economics of transporting the fuel there are few effective strategies for reliably drying wood prior to transport. Given the wet and humid climate in the Northeastern US wood drying from when it is cut green to when it is loaded onto trucks is minimal. Many efforts have been explored over the years to dry woodchips but none have proven cost effective.

Figure 9: Illustrating the Difference Moisture Content has on Load Capacities

