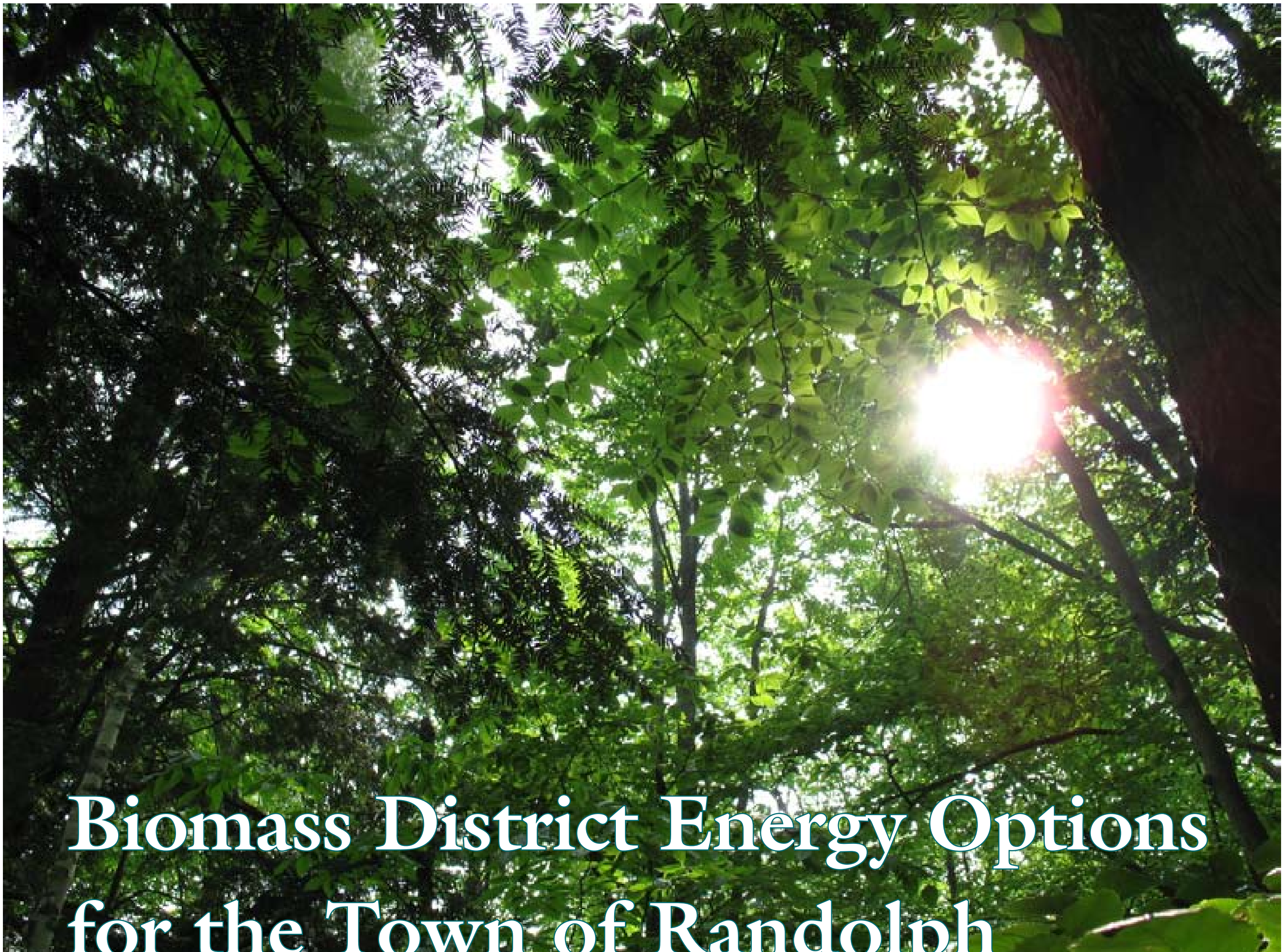


Biomass District Energy Options for the Town of Randolph

Pre-Feasibility Report

August 2009

BERC
Renewable • Reliable • Resourceful
Biomass Energy Resource Center

The Randolph Area Community Development Corporation (RACDC) led a partnership comprising the Biomass Energy Resource Center (BERC) and Vermont Technical College (VTC) in evaluating the potential for a biomass district energy system in the Town of Randolph, Vermont, including the possibility of producing combined heat and power as well as exploring opportunities to integrate a wood pellet (and potentially grass) manufacturing facility at the same site. The study was funded by the Vermont Clean Energy Development Fund (CEDF) and the US Department of Energy.

This report was written by BERC to summarize the preliminary logistical assessment and economic feasibility of such a project, and includes comparisons of various fuels available to Randolph consumers, rough estimates of project costs, potential funding mechanisms and options, a preliminary assessment of the economic feasibility for all energy options identified, and recommendations for next steps in project development.

Biomass Energy Resource Center

The Biomass Energy Resource Center (BERC) is an independent, national nonprofit organization located in Montpelier, Vermont that assists communities, colleges and universities, state and local governments, businesses, utilities, schools, and others in making the most of their local energy resources. 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's particular focus is on the use of woody biomass and other pelletizable biomass fuels. Since 2001, BERC has worked with communities and other partners across the United States to actively explore the potential for substituting locally supplied wood fuel for fossil fuels in heating, combined heat and power, and distributed generation.

Printed on 100% post-consumer recycled paper manufactured using 100% wind-generated electricity.

Biomass District Energy Options for the Town of Randolph, Vermont

Pre-Feasibility Report • August 2009

CONTENTS

I.	Executive Summary	1
II.	Introduction	5
III.	District Energy Overview	11
IV.	Assessment of Heating Demand in Randolph	17
V.	District Energy Technology Options	19
VI.	System Organization and Financing	23
VII.	Policy Framework	27
VIII.	Environmental Impacts	28
IX.	Assessment of Available Wood Fuel Supply	33
X.	District Energy Financial Feasibility	45
XI.	Conclusion and Recommendations	51
	Appendices	

Examples of buildings in Randolph that are under consideration for connection to the proposed district energy system.

I. EXECUTIVE SUMMARY

The cornerstone of the system options studied is district heating—the creation of a woodchip-fired central heating plant that would deliver low-cost space heating (and possibly domestic hot water) to buildings in Randolph village through buried hot-water piping.

In 2008, the Randolph Area Community Development Corporation (RACDC) was awarded a $25,000 grant by the Vermont Clean Energy Development Fund (CEDF) to study district heating and other renewable energy options for the Town of Randolph, Vermont. RACDC partnered with the Biomass Energy Resource Center (BERC) to carry out a large portion of the work in the preliminary study, with a primary focus on wood-fired district heating and combined heat and power (CHP) options for Randolph, and a secondary focus on the potential for co-locating a wood-pellet manufacturing plant at the same site.

RACDC also partnered with Vermont Technical College (VTC) to evaluate grass as fuel for energy. BERC matched the CEDF grant with approximately $18,000 and additional work related to advancing this and other district energy projects, and in-kind contributions were provided by RACDC and VTC.

BERC created a partnership with VisionPower USA, a district energy development and implementation company, to study the technical and financial viability of the system.

This is the final report by BERC on the wood-energy options.

DISTRICT HEATING SYSTEM

The cornerstone of the system options studied is district heating—the creation of a woodchip-fired central heating plant that would deliver low-cost space heating (and possibly domestic hot water) to buildings in Randolph village through buried hot-water piping. Voluntary connection to this system involves running pipes from the new heat mains into a building, where the heat transferred to the building's existing heating system is metered, with monthly billing for heat used.

A preliminary district heating design was developed, and after evaluation of several potential sites, assumes the plant would be located in the Industrial Park on the west side of Beanville Road (Vertek/Applied Research site). From there, heating water distribution lines would be laid to the industrial users in the area, access the "hill" neighborhood near Gifford Memorial Hospital, and then extend to the downtown and other residential neighborhoods on either side of Main Street, to most homes, businesses, and municipal buildings located south of the third branch of the White River.

VisionPower and BERC jointly hired FVB Energy, a district heating engineering firm located in Minneapolis, to provide preliminary design and cost estimation. The goal of the preliminary design and cost estimation was to provide realistic inputs for a business model for the new heat service. The project study team selected a local-control, local-ownership model designed to deliver lowest-cost heating to residential, commercial, institutional, and industrial buildings in the target area of Randolph.

This approach is common in European communities that use district heating. It uses this local control/investment model of ownership making the "customers" of the system also the owners, who contribute equity generally through all or part of their connection fees. There are also options for local investment and return for other businesses and stakeholders in the town, such as banks, forest industry players, and fuel dealers. The Town of Randolph is envisioned as a leading member of the system.

The study model calls for the capital cost of the system to come from three sources:

Member equity (connection charges)	20%
Grants	50% (min.)
Debt (bonds and other borrowing)	30% (max.)

As this is a first of its kind in the United States—and a state-of-the-art application of proven technology of national interest—BERC believes that there are good opportunities to realize 50% or more in grants, which would reduce the amount of borrowing and lower the rates customers would pay for heat.

BERC's preliminary study assumes that the entire district heating system would be built at the same time with all customers who might be served connected at the start (in reality, implementation would probably be staged over a few years). The assumption is that the local ownership model sets the price of heat at 95% of the price of oil at the time of construction. This provides some savings to the users immediately, while providing adequate revenue to pay debt and return on investment. These initial "savings" to the user compared to the equivalent cost of oil would increase over time, assuming oil prices rise, keeping energy costs more stable for the user.

BERC performed a sensitivity analysis that showed how the system economics look under different assumptions on the cost of oil at the time when the project becomes operational (with a range of $2.50 to $3.50 per gallon), and under two assumptions about how much of the total project cost would come from borrowing (30% and 50%). This analysis shows that if oil is $3 per gallon at the time of system implementation, and 50% of the project cost is borrowed (with 20% member equity and 30% grants), the system would be in the black in the first year. If more grant funding is available, such as through the Department of Energy solicitation under consideration (20% member equity and 30% borrowed), the system would see positive first-year cash flow of $720,000. Generally, oil prices have increased at significantly more than the rate of inflation and wood has increased at approximately the rate of inflation. To estimate conservatively, assuming that oil price increases at 1.5% per year above the rate of general inflation, and that wood price increases at 0.5% above the rate of inflation, the financial performance would improve each year. System economics also dramatically improve if oil is greater than $3 per gallon at the time of construction, or if it increases at a faster rate than 1.5% above general inflation.

In the future, once the system has been running in the black for a number of years, the net earnings can be used for system expansion, rate reduction, or payment of dividends.

As this is a first of its kind in the United States—and a state-of-the-art application of proven technology of national interest—BERC believes that there are good opportunities to realize 50% or more in grants,

EXECUTIVE SUMMARY *(cont'd)*

An installation of [Organic Rankine Cycle] technology in Randolph could be the first of its kind in the country, making Randolph a national leader in renewable energy application and carbon footprint reduction.

COMBINED HEAT AND POWER

The study also examined the option of producing electricity at the central district energy plant using CHP technology. In reviewing available wood-fired CHP technology at this scale, BERC and VisionPower identified the Organic Rankine Cycle (ORC) technology as the most beneficial to this project. This technology has been widely and successfully used in district energy systems and other applications in Europe for the last 10 years, but has not been introduced to the United States. VisionPower has hands-on district energy experience with ORC in Europe. An installation of this technology in Randolph could be the first of its kind in the country, making Randolph a national leader in renewable energy application and carbon footprint reduction.

Due to the passage of Vermont's new energy legislation (H.446), the state is now the first in the United States to pay qualifying green power producers full retail price for electricity they sell into the grid. BERC believes that wood-fired ORC technology will qualify for this favorable rate, making CHP a viable system option and strengthening the economics of the district energy system. The legislation also enabled Randolph to take advantage of a pilot project status if it meets certain efficiency targets, which this project will. To take full advantage of this program, the town would need to inform the state of its interest and intent to participate in the pilot program. While the potential implications of H.446 are discussed in this report, the economic analysis model assumes the current price of electricity at 95% of $0.13 per kWh.

CO-LOCATED WOOD PELLET FACILITY

The study team also considered the co-location of a community-scale wood pellet manufacturing facility with the district energy plant. According to the study results, a pellet plant would strengthen the district energy system by providing an additional, large, 12-month per year heating customer that would buy heat for drying its wood feedstock in the summer when other heating loads are very low. Like the CHP option, if a company developed a pellet production facility at the site of a scale compatible with the system and community, it would improve the district energy system economics substantially. The model assumes that the district system would pay the costs of expanding the heating plant facility to support the pellet mill energy requirements so that it would be a "turn-key" hookup, but assumes that the capital costs of the pellet mill itself would come from private capital or other outside sources. BERC and RACDC have discussed the pellet mill component with a local wood pellet manufacturing company to confirm the size, heating load needs, and feasibility of this option, and it appears to be both feasible and of interest to that company.

SUSTAINABLE WOOD SUPPLY

BERC also studied the sustainable wood fuel supply for all three options: 1) heat-only district energy; 2) district energy with CHP at the central plant; and 3) addition of a 10,000 ton-per-year pellet production plant. Annual green wood fuel requirements to run the district energy system in the three options are approximately 12,000 tons, 14,000 tons, and 24,000 tons per year respectively.

Under the third option, the manufacturing of pellet feedstock would add approximately 20,000 green tons to the combustion amount, for a total demand of approximately 44,000 tons. BERC's analysis of the amount of wood that could be provided each year on a sustainable, ongoing basis within 35 miles of Randolph is more than 750,000 tons of net available low-grade growth (NALG) wood, which far exceeds the wood requirements of all three options. This does not include grasses and agricultural residues that might prove available from marginal pasturelands, energy crops, or other agricultural-based biomass for use in district energy system combustion, pellet production, or both.

RECOMMENDATIONS AND NEXT STEPS

In light of the strong economic and local energy system benefits of a year-round load for a district energy system, it is recommended that an integrated system of district energy, thermally matched electricity production, and heat load for a community-scale pellet facility be further evaluated, and, if the findings of this pre-feasibility analysis are confirmed, pursued for the residents, businesses, and overall community of the Town of Randolph. The next steps will require more detailed feasibility and engineering work, community outreach, local ownership model company research and formation, and pellet manufacturing feasibility work. Support from the town and potential users of the system to continue with the evaluation is critical.

District Energy Option Parameters*	Option 1. District Heat**	Option 2. District Heat & CHP***	Option 3. District Heat, CHP & Pellet Mill****
Boiler Size (MMBH)	42	47	57
Wood Requirement (tons/year)	12,400	14,700	24,100
Total Cost ($ million)	27.47	35.8	36.87
Grant (50%)	13.73	17.90	18.44
Borrowing (30%)	8.24	10.74	11.06
Equity (20%)	5.49	7.16	7.37
Year-1 System Revenue – Heat ($ million)	2.67	2.67	3.89
Year-1 System Revenue – Electricity ($ million)	0.00	0.51	1.35
Year-1 System Cash Flow ($ million)	0.72	.84	2.40
Payback on Equity (20%) (years)	7.59	9.75	3.49
Payback on Total Investment (100%) (years)	37.95	48.74	17.46

*Assuming heating oil displaced at $3/gallon at time of construction and 50% grants, 20% member equity and 30% debt.

**Includes wood energy system, building, buried piping, and customer connections.

***Compared to Option 1, additional cost for increased capacity combustion system, thermal oil heater and other components of ORC CHP system, additional building space, and costs of electrical grid interconnect. Additional wood use due to additional energy output (electricity). System efficiency is improved by running the plant at higher capacity during summer months to produce electricity, compared to heat-only operation.

****Additional district energy plant capacity and cost, and additional wood consumption, due to heat requirements for wood drying in pellet manufacturing. Pellet plant to be developed by private firm using own investment capital. Financial analysis is for incremental costs and revenues to the district heating system, not a business plan for the pellet plant. District energy system efficiency and economics improved by having a large new heat customer with a large, year-round heat requirement (particularly in summer months when the district heating demand is low) – increasing utilization of capital plant. Also, electric production and revenue increase due to year-round operation.

II. INTRODUCTION

PROJECT OVERVIEW

The Randolph Area Community Development Corporation requested assistance from the Biomass Energy Resource Center in a preliminary evaluation of the logistic and economic feasibility of a biomass-fired district energy (BDE) system that would provide thermal energy for Randolph's municipal, public, and private buildings and residences. This feasibility study included an assessment of the potential for combined heat and power (CHP) at the plant as well as the integration of wood pellet manufacturing at the same site. The study was funded by Vermont's Clean Energy Development Fund.

This preliminary logistic and economic feasibility study compared various fuels available to consumers in the Town of Randolph; provided rough estimates of project costs, including initial capital and ongoing operation and maintenance; evaluated potential funding mechanisms and options; and gave a preliminary assessment of the economic feasibility for all identified energy options. The results presented here will inform the decision to further evaluate—at the engineering level—a BDE system for the Town of Randolph.

In parallel with this work, the Center for Sustainable Practices at Vermont Technical College is performing an independent analysis of the potential for using locally produced

Below: Aerial image of Randolph, Vermont from the south.

agricultural residues and energy crops such as *Panicum virgatum* (Switchgrass) as a sustainable fuel source for the Town of Randolph under the same Clean Energy Development Fund support.

Clean Energy Development Fund (CEDF). The Vermont CEDF was established in 2005 through ACT 74 with the purpose of promoting the long-term development and deployment of cost-effective and environmentally sustainable alternative power resources, primarily with respect to renewable energy and the use of CHP technologies.

Town of Randolph. The Town of Randolph, Vermont has 4,853 citizens, making it the largest town in Orange County. The town was originally settled as three villages: Randolph Center, East Randolph, and West Randolph. The central village of the current town was formerly known as West Randolph village and is the main area under consideration in this study, illustrated in Appendix A, and is referred to as the Town of Randolph in this report.

Randolph Area Community Development Corporation (RACDC). RACDC promotes and implements community-based economic development projects and initiatives for the Town of Randolph. Some of its primary functions are:

- Developing grant proposals for the Vermont Community Development Program (VCDP) and other state and federal grant programs
- Administering ongoing state- and federally funded projects
- Working with the Town of Randolph to plan long-term economic development policies and infrastructure requirements
- Downtown and village revitalization
- Working to attract new businesses to the Town of Randolph and assist in the expansion of existing businesses
- Developing and maintaining affordable rental and for-sale housing options

Vermont Technical College (VTC). VTC's main campus is located in Randolph Center, Vermont. As part of a campus-wide sustainable-technology field laboratory, VTC is planning to install a biomass pellet-fired boiler in the historic Red School House that houses VTC's Dairy Farm Management and Agribusiness Management programs. This project will help train students for work in the bio-fuels field and will serve as a model for other Vermont institutions.

VTC's Center for Sustainable Practices is contributing to RACDC's Biofiber Project, which is funded by a grant from CEDF. The Biofiber Project is an assessment of the potential for locally sourced agricultural residues to possibly supplement wood fibers in fueling the potential district energy system or pellet mill in Randolph, Vermont.

Biomass Energy Resource Center (BERC). 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 communities, industries, schools, institutions, and others in initiating and constructing biomass projects for their heating and power needs.

The results presented here will inform the decision to further evaluate—at the engineering level—a BDE system for the Town of Randolph.

INTRODUCTION *(cont'd)*

SCOPE OF WORK

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

Data Collection. RACDC and BERC collected information on the characteristics and specifics of the energy demand for the Town of Randolph. Selected industrial, commercial, and residential buildings and building owners were surveyed on their respective energy systems and energy use intensity (EUI). These were used as key inputs in this 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 of the proposed Randolph BDE system.

Heating Fuel Comparison. Several fuels potentially available to the Town of Randolph were compared: heating oil, propane, and woodchips. The average current price for heating fuels was collected and compared on a Btu basis.

Available and appropriate technologies identified. Once the system capacity was calculated, commercially available technologies to meet that energy load were identified. BERC 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 Randolph's energy requirements. Preliminary estimates in terms of initial capital costs and cost of fuel, operation, and maintenance were also collected.

Site assessment. BERC evaluated the space available for a new energy plant. Any potential air-quality permits required for a biomass CHP plant were also identified and basic recommendations on permitting were given in this report.

Fuel supply assessment. This pre-feasibility study included a preliminary quantification of the low-grade wood available for woodchip fuel or wood pellet feedstocks within cost-effective delivery range of downtown Randolph. The study included an estimation of sawmill residues and forest inventory and growth surrounding the Town of Randolph. 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. The Center for Sustainable Practices at VTC will prepare an independent report covering its scope of work and Biofiber Grass Shed assessment.

Pellet plant assessment. At RACDC's request, BERC also evaluated the possibility of a wood pellet mill co-located with the district energy plant. In this scenario, the district energy plant would provide the pellet mill with process heat needed to produce the pellets, and the pellet mill would increase—and potentially optimize—the year-round heat load of the district energy facility. Subsequently, the study partners met with a private wood pellet company with a potential interest in developing such a pellet mill in Randolph. BERC gathered data on pellet manufacturing systems and incorporated the thermal requirements of a pellet mill into the analysis.

Economic analysis. BERC has developed a proprietary tool analyzing the financial feasibility of BDE systems. The tool was used to evaluate the relative costs and revenues of three possible options. The analysis used much of the Randolph data collected to establish inputs and assumptions, including current fuel usage and prices, recommended system capacities and layouts, and estimated project costs.

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 three 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, BERC staff will make a return trip to Randolph for a follow-up meeting to present these findings and recommendations.

METHODOLOGY

RACDC hosted a series of public meetings in the Town of Randolph to gauge public interest and support in pursuing the preliminary assessment and further exploring a BDE plant with CHP as well as the integration of a pellet manufacturing facility. Numerous stakeholders were present at the meetings, including local business owners and residents, RACDC board members, Randolph energy committee members, Randolph forestry committee members, state and local government officials and representatives, Vermont CEDF representatives, and USDA Rural Development board representatives, among others. Future stakeholder meetings are being planned to discuss the results and findings of this pre-feasibility study.

RACDC, BERC, and VTC outlined a preliminary area for the heating district from which BERC would develop its recommendations, including, if necessary, phasing or alteration of the optimal district boundaries. A team of BERC staff made scheduled visits to Randolph and collected available information from the town clerk's office and individual property owners. Special consideration was given to collecting relevant data from the residential, commercial, and industrial sectors. In this effort, RACDC 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 area under consideration for connection to the heating plant grid was acquired using the latest data from the property tax assessor's office.

INTRODUCTION *(cont'd)*

Approximate thermal EUI was calculated by collecting actual data from building owners and applying an appropriate fuel-usage multiplier to the appropriate industrial, commercial, and residential buildings in question. Total thermal energy demand for the buildings in Randolph 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 Randolph BDE plant was calculated and all available technology options for the recommended capacity of the project were identified. Project viability was assessed for three technology options: a woodchip boiler providing heat to a district distribution system as a new heat utility service; the integration of a CHP system sized to meet peak heat demand that would produce electricity as a secondary product; and the addition of a pellet mill that would serve as an anchor heat load and would be located at the Randolph BDE plant site.

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. The assessment of each of the options was based on the performance and preliminary cost data provided by system vendors.

BERC created a partnership with VisionPower USA, a district energy development and implementation company, to utilize their expertise in district heating to inform BERC's feasibility analysis. VisionPower and BERC jointly hired FVB Energy, a district heating engineering firm located in Minneapolis, to assist with the preliminary design and cost estimation and provide realistic inputs for a business model of the new heating service. The project study team selected a local-control, local-ownership model designed to deliver lowest-cost heating to residential, commercial, institutional, and industrial buildings in the target area of Randolph.

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

An assessment was conducted of how each of these technologies could be utilized to meet the Town of Randolph's energy requirements, including site suitability. 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 equity payback periods were calculated.

Using the above methodolgy, BERC considered three potential district energy options for Randolph:

- **Woodchip District Heating.** Meeting the town's thermal needs alone
- **Woodchip Combined Heat and Power (CHP).** A district combined heat and power system that uses excess heating capacity to generate and sell electricity to the grid
- **Woodchip CHP with Pellet Mill as an Anchor Load.** A district combined heat and power system sized to allow for a co-located wood pellet manufacturing plant, or pellet mill

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 Randolph's heating energy demand
- An assessment of current and projected fuel usage and costs in Randolph
- An assessment of current and projected local biomass fuel availability and costs
- An assessment of available biomass technologies, including CHP equipment
- An overview of modern and commercially available emissions reduction technologies
- An overview of the regulatory climate surrounding biomass heat/CHP systems
- An overview of funding opportunities and project ownership structures
- Projected costs of installing and operating a biomass heat/CHP system
- An assessment of the potential for a pellet plant in the Randolph area
- A financial feasibility analysis of each option identified
- Conclusions and recommended next steps

The Randolph House, a 34,000 square foot senior apartment complex, is one of the buildings being considered for connection to the proposed district energy system.

III. DISTRICT ENERGY OVERVIEW

SYSTEMS AND TECHNOLOGY

District energy systems can be an efficient form of municipal infrastructure, similar to public water or sewage systems.

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. Energy is then extracted at the buildings and the water is brought back to the plant, through return pipes, to be heated again. In this way district energy systems can be an efficient form of municipal infrastructure, similar to public water or sewage systems.

The heat distribution piping is typically thin-wall welded steel with integral foam insulation and plastic jacketing, designed to be direct-buried at a depth of about three feet. Pipes are placed in pairs with supply pipes for the hot water from the plant and return pipes for the lower-temperature water being returned 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 heating system of a building. The central plant uses variable speed pump controls to minimize the amount of electricity used in the pumping process.

District energy plants can be designed to produce not only thermal energy, but also electrical power. This is called cogeneration or combined heat and power (CHP). CHP plants are able to get more usable energy out of the input fuel than a plant that produces electricity only. A CHP project that is sized to the heating load but produces electricity as a secondary product is likely to have efficiencies as high as 60-80% compared to an electrical generating facility that does not use the thermal output and can have efficiencies as low as 20%.

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

- **Thermal energy generation.** The boilers where steam or hot water are produced
- **Thermal energy transmission and distribution (T&D).** The pipelines delivering 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)
- **CHP component.** The integration of electrical generation technology

Inside each connected building, there is an ETS. For a building with hot water heat (serving baseboard, radiators, unit heaters, or fan coil units for individual room heat), the ETS includes one water-to-water heat exchanger for space heat and a smaller one for domestic hot water (DHW) supply. Hot-air furnaces need to have water-to-air coils installed in the main heating ducts. Propane space heaters need to be removed and replaced with baseboard hot water for room heating.

For most buildings in Randolph, these heat exchangers will be compact and can be floor or wall mounted. The ETS also includes a heat meter that measures how much heat is taken out of the system water and transferred to the building. These meters are typically read monthly—like water or electric meters—with billing according to consumption.

District energy systems can provide space heating and domestic hot water 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. Some district energy systems supply thermal energy to industrial customers for "process heat," while others capture low-grade waste heat from industry to sell to customers.

ADVANTAGES OF DISTRICT ENERGY

A district energy system can provide, in one centralized system, 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 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, 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 (see "Advantages of Biomass" section on page 14).

Air Quality Improvements. Air quality improves—as does community livability—when emissions from a single, well-managed plant replace uncontrolled stack emissions from boilers and furnaces in many individual buildings. In addition, district heating systems are of a size that make it possible and economically feasible to install best available technology and emissions control equipment that is typically not feasible in individual building heating systems.

A district energy system can provide, in one centralized system, the heat that would otherwise be produced in hundreds or thousands of smaller, individual heating systems.

DISTRICT ENERGY OVERVIEW (*cont'd*)

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.

Revitalized Communities. District energy infrastructure and stable energy rates improve a community's business climate. Local businesses can become more competitive with lower energy costs, which can help to revitalize downtowns and urban core areas helping to alleviate suburban sprawl. Using biomass as the fuel source, district energy can help build and support sustainable infrastructure.

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.

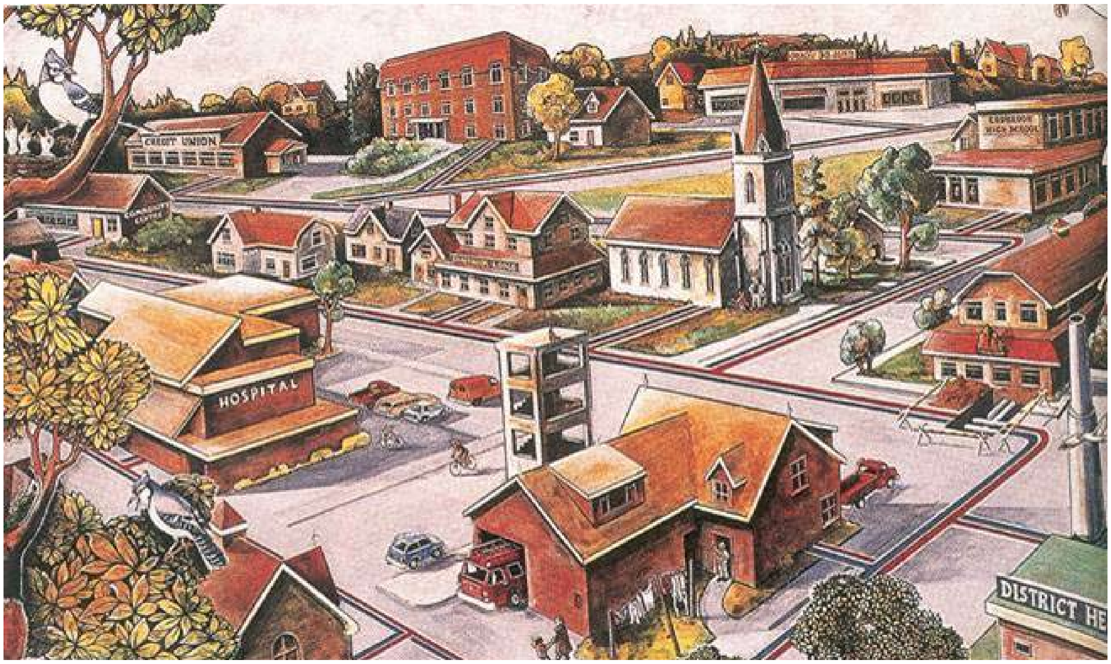
Reduced Environmental Risks. District energy systems can help to mitigate environmental risks by consolidating fuel storage to one or a very few locations compared to numerous onsite storage tanks that serve individual buildings. Conventional onsite fuel storage includes underground and aboveground storage tanks. Failing underground tanks can pose a threat to ground and surface waters. Aboveground tanks can pose fire hazards as well as the risk of dislodging in the event of a flood.

Power Generation Systems. In addition to the need of finding new ways to heat buildings, there is also a need to provide electricity from locally available, renewable resources. New "emerging technologies," such as the Organic Rankine Cycle (ORC) technology and gasification for both small-scale CHP and utility-scale power plants, can become commercially available and deployed for the benefit of regions like rural Vermont.

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 incentives from 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



There are numerous environmental and socio-economic advantages to using sustainably procured biomass fuel to meet energy needs instead of fossil fuels.

- 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

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 SYSTEMS

There are numerous environmental and socio-economic advantages to using sustainably procured biomass fuel to meet energy needs instead of fossil fuels, such as heating oil or propane. Several benefits are listed below, followed by 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

DISTRICT ENERGY OVERVIEW (*cont'd*)

The Vermont Job Gap Study found that Vermonters spend more than $1 billion annually for fuel and energy imported from outside the state.

- Support of local economies will contribute to the overall fiscal health of the community through additional purchases, jobs, and an increased tax base
- Decreased susceptibility to interruptions in fuel supply
- Potential eligibility for "carbon credits" or Renewable Energy Credits due to using a carbon neutral energy source to produce electricity (in the case of biomass CHP)

Dollars Remain in the Local Economy. Unlike fossil fuels that come from outside the northern New England 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, 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 community, but the country. Fuel supply is increasingly an issue of national security, especially for places, like Vermont, that rely heavily on heating fuels during much of the year. A study funded by the Northeast Regional Biomass Program (NRBP) found significant economic benefits from using wood for energy[1].

For each 1,000 tons of wood used, the following is added to the local economy:

- Total net income increases by $73,573[2]
- 1.45 jobs are created in addition to the existing job market
- $3,579 is paid in state and local taxes
- $13,452 is paid in federal taxes[3]

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 also outside the local and regional economies. The Vermont Job Gap Study[4] found that Vermonters spend more than $1 billion annually for fuel and energy imported from outside the state. By contrast, jobs associated with wood fuel extraction, reforestation, and fuel transport are within the local and regional economy. Money spent on biomass keeps energy dollars in the local economy and supports jobs and economic development in the forest products industry and agricultural sector.

FIGURE 1. Cost of Producing Energy

	MMBtu per Unit (Dry)	Moisture Content	Average Seasonal Efficiency	MMBtu per Unit After Combustion	Cost per MMBtu After Combustion
Wood Pellets ($260 per ton)	16,500,000	6%	80%	12.41	$20.95
Woodchips ($50 per green ton)	16,500,000	40%	65%	6.22	$7.77
Propane ($1.80 per gallon)	92,000	0%	80%	0.074	$24.46
Oil ($2.50 per gallon)	138,000	0%	70%	0.104	$24.15

Positive Impact in Moderating Global Climate Change. Burning biomass for energy instead of fossil fuels mitigates the effects of climate change. Carbon dioxide (CO_2) buildup in the atmosphere is a significant contributor to global climate change. Fossil fuel combustion takes carbon that was locked away underground (as crude oil and gas) and transfers it to the atmosphere as CO_2. When biomass is burned, however, it recycles carbon that was already in the natural carbon cycle. Consequently, the net effect of burning biomass fuel is that no *new* CO_2 is added to the atmosphere.

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 Randolph project can be harvested from local forests, which will improve the market for low-grade wood needed to practice 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.

The demonstration value of using an indigenous source of energy in a sustainable manner cannot be overstated. In this particular project, there are potential academic benefits from collaboration with VTC, and other academic institutions. Engineering, economics, forestry, agriculture, environmental science, and other programs and students could benefit by integrating the Randolph BDE and pellet manufacturing facility into their curricula.

Lower cost. While all of these benefits are important from a public policy perspective, probably the most compelling reason for a facility or any consumer to decide on switching to biomass energy is that the cost of biomass fuel is generally much less than the cost of fossil fuels on a Btu basis. These hard-dollar savings often make the investment in biomass heating technology a win-win for facilities and customers looking to reduce operating costs and energy expenditures. At the heart of this new application of wood energy is the attraction of using a renewable, locally produced energy source that can save money. More detailed comparison of heating costs is given in Figure I on page 15.

Probably the most compelling reason for a facility or any consumer to decide on switching to biomass energy is that the cost of biomass fuel is generally much less than the cost of fossil fuels on a Btu basis.

Perhaps the most relevant example of the fuel cost savings achievable in Randolph can be realized by examining Randolph Union High School's (RUHS) biomass system performance. Functioning since its construction in 1995, the 6.5 MMBH (million Btu per hour) system is an excellent example of biomass energy benefits. During the 2007-2008 heating season, the RUHS system has achieved an estimated fuel cost savings of $51,168, when the cost of biomass fuel is compared to what it would have paid if using fossil fuels for space heating[5].

IV. ASSESSMENT OF HEATING DEMAND IN RANDOLPH

TOTAL AREA

As is shown in Appendix A, the study area includes industrial users along Beanville Road and South Main Street, access the "hill" neighborhood near Gifford Memorial Hospital (including the hospital), and then extends to the downtown and other residential neighborhoods on either side of Main Street, including Randolph Avenue and School Street.

Most homes, businesses, and municipal buildings located south of the third branch of the White River and north of Shaw's supermarket and Vertek industrial complex are included in the assessment of heating demand in Randolph. In this preliminary analysis, 431 buildings are under consideration for the Randolph BDE system. Of these buildings, 69 are industrial/commercial, 282 are small residences with an assumed average size of 1,700 square feet, and 80 are larger residences with an assumed average size of 3,100 square feet. Total heated space to be connected to the Randolph BDE system was estimated to be 1,602,028 square feet.

431 buildings are under consideration for the Randolph BDE system. Below: Examples of residential, commercial, and industrial buildings in the study area.

HEATING LOAD

The heat load is the total heating demand of the buildings in the proposed district area. The majority of buildings in Randolph use fuel oil for heating, though some use propane or cordwood. For the purposes of this study, all heating fuel consumption is reported in gallons of oil for ease of comparison; any propane or cordwood use was converted to oil equivalents. The area under consideration for the Randolph BDE plant currently uses the equivalent of approximately 870,000 gallons of oil per year for space heating.

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%. Based on this assumption, the size recommended for the Randolph BDE system is 42 MMBH in heat output.

The majority of buildings in Randolph use fuel oil for heating, though some use propane or cordwood.

V. DISTRICT ENERGY TECHNOLOGY OPTIONS

The study analyzed three options for district energy systems:

1. **Woodchip district heating**
2. **Woodchip CHP**
3. **Woodchip CHP with pellet mill as an anchor load**

The study analyzed three options for district energy systems, described below.

OPTION 1. WOODCHIP DISTRICT HEATING

The first option is to construct a new BDE plant producing thermal energy for heating only. This central energy plant would be connected via buried hot-water distribution piping to the district energy grid system in order to deliver heat to the 431 industrial, commercial, and residential buildings in the study area. Heat exchangers and meters would be installed at each building to connect each user to the grid.

In this option, the BDE plant would require 12,433 tons per year of green woodchips (with an assumed value of 40% moisture content) in order to generate enough thermal energy to meet these buildings' heating demand. During standard operation, the BDE plant would require 844,208 kWh of electricity annually, which would be purchased from the existing electrical grid.

Technology Description. Technology for thermal energy includes a biomass combustion chamber (furnace) and boiler, a biomass gas turbine and biomass gasification. Based on BERC's review, a fully automated woodchip combustion system was considered for this option. 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.

Plant Siting. An ideal site for the Randolph BDE plant is on Beanville Road adjacent to an industrial park, as illustrated in Appendix A. This land is located within a reasonable distance to install piping to major industrial users, is within an economically feasible distance of the downtown area, and is zoned for industrial use. The owner of the parcel has expressed willingness to sell this parcel of land for development as a district energy plant.

Conceptual System Design.

- **Energy Plant Building.** A new building to house system equipment and a biomass fuel storage area will need to be constructed at the proposed plant site. The biomass boiler plant will have direct access from the main road for easier woodchip deliveries. During BERC's site visit, it was determined that a new 7,500 square foot building would be sufficient to house the necessary equipment considered in the preliminary design stage for this study. 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 central 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 Randolph BDE 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 emission control technologies at each site. BERC recommends that the Randolph BDE 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 emission 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 energy plant should include space for the recommended emissions control equipment and the appropriately sized stack.

OPTION 2. WOODCHIP COMBINED HEAT AND POWER (CHP)

The second biomass energy option is to produce thermal energy and electricity onsite using a woodchip-fired CHP system. This option builds on the woodchip heating system, with biomass being used for thermal energy production; however, in this CHP option, the heat generated by combusting woodchips will be also be used to produce electricity. As indicated earlier, the electric generation system would be sized to the heat load so that heat would be the primary product and, when excess heat is available, electricity would be produced as the secondary product. This configuration is significantly more efficient than sizing CHP systems to the electrical load and producing heat as a by-product.

Even when electrical generation is determined by heat production rather than vice versa, the process of electrical generation does require a slightly higher fuel input than heating alone. Boiler sizing recommendations for Option 1 (woodchip district heating) apply also to Option 2 (woodchip CHP), though an additional 5 MMBH would be required in capacity to handle the increase in the wood fuel required for electrical generation, bringing the total boiler size to 47 MMBH. Option 2 with CHP would require an additional 2,233 tons per year of green woodchips (40% moisture content) for a total consumption of 14,666 green tons per year (40% moisture content) to produce heat for the town and 5,053,400 kWh of renewable electrical energy annually. BERC estimated that the plant would operate for 2,297 hours annually and that during standard operation the CHP plant itself would require 949,229 kWh, leaving a surplus of 4,104,171 kWh annually for sale to the grid.

Due to the passage of Vermont's new energy legislation (H.446), Vermont is now the first state in the US to pay qualifying green power producers full retail price for electricity they sell into the grid. BERC believes that wood-fired ORC technology will qualify for this favorable rate, making CHP a viable system option and strengthening the economics of the district energy system. The economic analysis assumes sale of the excess electrical generation at 95% of the current electrical rate of $0.13 per kWh.

BERC recommends that the Randolph BDE plant install a baghouse (in addition to the standard cyclone) to control particulate emissions.

DISTRICT ENERGY TECHNOLOGY OPTIONS *(cont'd)*

BERC has entered into a memorandum of understanding with VisionPower-USA to explore the potential for importing an ORC system and utilizing this technology for the Randolph district energy project.

Other options in which the surplus renewable electricity produced by the Randolph BDE plant could be distributed, using community net-metering models, renewable energy credits (RECs), and other methods, should be explored further in the future phases of the project development process.

Technology Description. 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 provide steam for space heating and cooling.

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 is a low pressure application that will not require 24/7 operator attention. These technologies are described in greater detail in Appendix C.

Plant Siting. The plant would be sited at the same location described for Option 1 (see page 19).

Conceptual System Design.

- **Wood Boiler and ORC System.** A 2.2 MW ORC system would be installed adjacent to the 47 MMBH woodchip boiler system. BERC staff recently visited several successfully operating ORC systems in Europe and interviewed European vendors of this equipment. At this time, all ORC system equipment must be imported from Europe (it is not yet commercially available in the United States). BERC has entered into a memorandum of understanding with VisionPower-USA to explore the potential for importing an ORC system and utilizing this technology for the Randolph district energy project.
- **Central Energy Plant Building.** This option will also require the construction of a new energy plant to house the woodchip boiler, emissions control equipment, and wood fuel storage as described in Option 1, plus additional space for the ORC system. A 13,000 square feet building would be required.
- **Stack and Emissions Controls.** As in Option 1, a stack will need to be installed to disperse any emissions as sited and sized by a dispersion modeling study. A baghouse and cyclone would be the recommended control technologies.

OPTION 3 – WOODCHIP CHP WITH PELLET MILL AS AN ANCHOR LOAD

The third option for system configuration includes the addition of a pellet production mill, located at the same site as the BDE plant, to serve as a year round anchor load, or a large industrial heat user.

Pellet production would extend the benefits of renewable energy, and support the sustainable fuel market development, beyond the consumers served directly by the district energy system. An added benefit of a local pellet mill is that it would offer affordable, renewable thermal energy in the form of wood pellets to the more rural portions of the community that are outside the area of the district heating system.

The mill would use process heat for pellet production. The addition of a pellet mill would increase the capacity of the system to 57 MMBH and total hours of plant operation would increase to 6,457 hours (compared to 2,297 hours per year for Options 1 and 2).

This option would build on the CHP option, as described previously, and require an additional expansion of the woodchip system. A higher woodchip fuel use would be required for the process heat required by the plant at peak load. The BDE plant capacity would increase to 57 MMBH, and require an additional 9,431 green tons of woodchips per year, for a total consumption of 24,097 tons per year for thermal, electrical and process heat production. The pellet plant would also consume 20,000 tons of wood fiber annually as a raw material for pellet fuel production.

Conceptually, the pellet production mill would be located adjacent to the energy plant at the same location as was described for the previous options. The building size and emissions controls required for the BDE plant would remain the same as in Option 2.

While a private pellet manufacturer has expressed interest in developing a pellet plant co-located with a BDE plant in Randolph, it is important to note that this third scenario and the addition of a possible pellet mill is, at this time, completely hypothetical.

Technology Description. While pellet mills can range in capacity widely, for the purpose of this study we choose to examine a "community-scale" pellet mill. The pellet mill would be sized to produce 10,000 tons of pellets per year and would consume 20,000 tons of wood fiber annually as a raw material. The wood pellet production process uses established technologies that are well-known in the wood products and feed manufacturing industries. Pellet manufacturing is described in greater detail in Appendix D.

The technology used in the BDE plant would be the same as was described for Option 2.

Pellet production would extend the benefits of renewable energy, and support the sustainable fuel market development, beyond the consumers served directly by the district energy system.

VI. SYSTEM ORGANIZATION AND FINANCING

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 United States.

PUBLIC-PRIVATE PARTNERSHIPS

There is a growing interest among Vermont communities in developing BDE systems. 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 United States. In regions of Europe, especially, biomass district heating 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, BERC 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 include:

- 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)

CO-OP AND LOCAL INVESTMENT MODELS

In the long term, there is little doubt that a BDE system can deliver heat at lower and less volatile costs if oil prices stay at current rates, or, as we expect, if they increase significantly over the coming years. In fact, as thermal energy accounts for a full 30% of oil usage nationally, implementing biomass district energy systems where wood is plentiful and relatively inexpensive can reduce the cost of oil by reserving oil usage for those systems in which it is truly the best or only fuel option. However, the biggest barriers to entry are the high capital costs of developing the systems and unfamiliarity with them in most of the United Sates. If up-front capital can be reasonably obtained, there is evidence from decades of success in similar European communities that long-term benefits will more than compensate for the up-front costs.

The European model which appears to deliver the lowest-possible cost of district heating over time is a cooperative ownership model in which the users of the system are also the owners of the system. While such co-op models of district heating system ownership are currently non-existent in the US, co-ops are successfully used here in many other applications, including wind farms and ethanol plants, and they are very commonly used to organize district heating systems in Europe. In a co-op BDE model, each building owner invests a certain amount in the system at the start, which buys them a share in its ownership and one vote as a co-op member. The board of the co-op, including member representatives, decides on the issues of finance and management, including: establishing the BDE system, setting rates for metered purchase of heat from the system; disposition of revenue in excess of expenses; establishing reserve funds; use of surplus funds; payment of member dividends; hiring contractors and purchasing equipment for establishing the system; hiring staff; undertaking expansion projects; marketing to potential new customers; and more.

If potential member-owners are unable or unwilling to commit enough funds to establish a reasonable equity share of the project cost, it may be advisable to attract investment from other stakeholders in the community. Such stakeholders may include local banks, businesses in the forest products industry, local forestland owners, large customers seeking a higher investment and ownership of the system, and possibly fuel dealers. In return for this investment, these stakeholders would likely expect dividends or some other form of repayment over time. It is important for district energy co-ops that attempt to attract some non-customer investment to assure that the customer-owners' control over key decisions is not eroded by non-customer equity shares.

In the European co-op model for community district energy systems, member equity targets are often about 20 percent of total project cost, while the balance is achieved from securing grants and financing through public or private institutions.

GRANT OPPORTUNITIES

Until recently grant opportunities specific to district energy have been practically non-existent. There have been some grant opportunities and incentives for green power projects, but not for renewable energy heating. At its inception, the Vermont CEDF would grant funding only for projects that produced electricity or "green power," but not specifically for district heating systems (unless CHP was part of the project structure). That is now changing and it is expected that there will be more CEDF grants for district heating, whether power production is a component.

On the federal side, the 2007 Farm Bill included a community energy section that supported grants for district energy systems. While the Farm Bill authorized this program, no funds were appropriated at the time of passage nor have any been appropriated since.

The European model that appears to deliver the lowest-possible cost of district heating over time is a cooperative ownership model in which the users of the system are also the owners of the system.

SYSTEM ORGANIZATION AND FINANCING *(cont'd)*

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.

In June 2009, the US Department of Energy issued a Funding Opportunity Announcement (FOA) that provides significant grant funds in four project categories, including district energy. While the district energy grants are expected to be large ($10 million minimum), there are only expected to be one to four grants made in this category nationwide. To be competitive in applying and winning the few grants that will be awarded, projects that apply must show they are well-developed ("shovel ready") and produce jobs. The selection process does not give special weight to renewable energy projects; however, funds come from the ARRA, was enacted to "…create jobs, restore economic growth, and strengthen America's middle class through measures that modernize the nation's infrastructure, [and] enhance America's energy independence." The objectives of the FOA include supporting the deployment of "sustainable energy infrastructure projects." Community-scale biomass energy projects clearly meet many of the criteria outlined in ARRA. Other ARRA programs are anticipated to be announced in the coming months.

District energy projects may also be eligible for federal and state grant programs that have non-energy related objectives. For example, Community Development Block Grant funds are available for projects that stimulate economic development or benefit low-moderate income people. Power-producing projects that generate fewer than 4 million MWH annually and owned by small businesses could qualify for USDA Rural Energy for America Program (REAP) funds. Other programs may assist certain users (e.g., housing facilities, hospitals) with hook-up and conversion fees.

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 heating 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.

Recently enacted Vermont legislation, Energy Bill H.446, includes a provision (Section 15e) that allows for the establishment of Clean Energy Assessment Districts (CEADs), a tool that has been used in California, New York, and Colorado, to help property owners invest in energy efficiency and renewable energy projects in their homes or businesses.

The new legislation allows towns to borrow funds for this purpose. Participating property owners then pay back the cost as a regular municipal assessment on their property tax or other municipal bill. Participation in the district is entirely voluntary. CEADs could be used as a mechanism for municipal loan funds to be used for efficiency improvements and connection costs for buildings connected to a district energy system in a municipality that has created a CEAD.

The Emergency Economic Stabilization Act passed in the fall of 2008 includes a new category of tax credit bonds called "Qualified Energy Conservation Bonds" (QECBs). QECBs are expected to perform as no-interest bonds for the end user. The bondholder will receive federal tax credits in lieu of traditional interest. QECBs can support a variety of energy conservation and possibly renewable energy purposes including capital expenditures for publicly-owned buildings and certain demonstration projects. QECBs could possibly be used as a finance source for district energy projects. As a new federal program, the applicability of QECBs 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.

The Kimball Library, the Chandler Music Hall, and the Train Depot are buildings in downtown Randolph that could be included in the district energy system.

VII. POLICY FRAMEWORK

The recently passed Vermont Energy Act of 2009 includes several provisions relevant to renewable biomass energy for district energy systems in the state

VERMONT ENERGY ACT OF 2009

The recently passed Vermont Energy Act of 2009 includes several provisions relevant to renewable biomass energy for district energy systems in the state:

- **Standard Offer.** The act creates a "Standard Offer" for qualifying renewable energy resources with a plant capacity of 2.2 MW or less. These standard offers will be available until a cumulative statewide plant capacity of 50 MW has been provided. The price will be determined by the Public Service Board, and the terms will be 10-20 years, except for solar power plants with terms of 10-25 years.
- **Biomass Efficiency Threshold.** Wood biomass resources may receive the standard offer only if they have a design system efficiency of at least 50%.
- **Clean Energy Development Fund.** The act expanded the focus of the CEDF to include thermal energy and geothermal resources (previously only electric power supply was eligible), opening up this important state program to district heat and CHP systems. The act also allocated the ARRA state energy funds to the CEDF, significantly expanding its capacity.
- **Vermont Village Green Renewable Pilot Program.** The Act created the Vermont Village Green Renewable Pilot Program to develop district heating or CHP systems to serve downtown development districts or growth centers as defined in the legislation. Two pilot communities were established to launch this program: Randolph and Montpelier. These two towns are eligible to meet requirements and submit an application to the Public Service Board for a minimum of $100,000 in connection incentives to help customers connect to new district energy systems. Qualifying biomass CHP systems must achieve at least a 50% net annual efficiency during the heating season and a minimum conversion efficiency of 70% considering all energy inputs and outputs at a normal load. Eligible projects using woody biomass as fuel must use procurement standards, management practices, and a supply chain that is third-party certified using a performance-based audit. Vermont Village Green renewable energy projects must also comply with all applicable national air-quality standards and air-pollution control regulations of the Vermont Agency of Natural Resources, including the anticipated new EPA emission standards for wood-fueled boilers, due out in July 2009.

BIOMASS ENERGY DEVELOPMENT WORKING GROUP

The Vermont Legislature recently passed into law H.152, creating the "Biomass Energy Development Working Group." This working group was established to enhance the growth and development of Vermont's biomass industry while also maintaining forest health. In order to meet these goals, the working group will analyze current issues and develop a coherent body of recommendations that include incentives, harvesting guidelines, and procurement standards for biomass energy in the state. It will include 15 members representing the state, legislature, forest products interests, environmental interests, consulting foresters, biomass interests, utilities that produce electricity or heat from biomass, university representatives, and others. The working group is authorized to operate for a maximum of three years, with interim reports due to the legislature on November 15 in 2009 and 2010.

VIII. ENVIRONMENTAL IMPACTS

AIR EMISSIONS FROM WOODCHIP BOILERS

As the number of biomass energy systems increases across the United States and throughout the world, there is growing concern about the potential emissions from biomass systems and their impact on air quality.

Emissions from wood-fired boilers are different than emissions from 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 MMBtu (1 MMBtu is the amount of heat energy roughly equivalent to that produced by burning 8 gallons of gasoline, or 121 lbs of dry woodchips).

All heating fuels— including wood—produce particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur dioxide (SO_2) in varying amounts. Burning wood in a modern and well-maintained woodchip boiler, for example, produces more particulate matter than burning oil, but less SO_2 than oil. Emissions rates are given in Figure II below (in lbs per MMBtu) for woodchip and oil boilers.

Modern wood systems produce less than 2% the SO_2 emissions of fuel oil. Wood and fuel oil combustion have similar levels of NOx emissions. All fuel combustion processes produce 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 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.

All heating fuels—including wood—produce particulate matter, carbon monoxide, nitrogen oxides, and sulfur dioxide in varying amounts.

Figure II. Emissions Rates for Woodchip and Oil Boilers (in lbs/MMBtu)*

	PM10	CO	NO_x	SO_2
Woodchip Boiler**	0.1	0.73	0.165	0.0082
Oil Boiler	0.014	0.035	0.143	0.5

*Without emission control equipment with the exception of PM10. Emissions given on a heat input basis.

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

ENVIRONMENTAL IMPACTS (*cont'd*)

Particulates are pieces of solid matter or very fine droplets, ranging in size from visible to invisible.

In terms of health impacts from wood combustion, 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. PM exacerbates asthma, lung diseases and increases mortality among sensitive populations.

Fine particulates (PM2.5) are a growing concern as they are known to increase health-related problems as compared to the larger particulates. Work investigating woodchip and pellet boiler emissions of very fine particulates is ongoing.

Figure III. Reductions Rates Achievable with Emissions Control Devices

	PM10	PM2.5
Cyclone	50%	0-50%
Multi-Cyclone	73%	0-10%
Core Separator	90%	40-60%
Fabric Filter or Baghouse w/ Cyclone	99%	90-99%
Electrostatic Precipitators (ESP)	98-99%	90-99%

USDA Forest Service; U.S. Environmental Protection Agency (OAQPS, Regions 1 and 8); Montana Department of Natural Resources; Washington Department of Ecology; North East States for Coordinated Air Use Management (NESCAUM).Information on Air Pollution Control Technology For Woody Biomass Boilers, March 2009.

CONTROL DEVICES FOR PM

As described above, fine PM is the pollutant of greatest concern with regard to wood systems. Even with the greater climate change benefits of wood energy, the PM2.5 issue needs to be considered as the regulatory framework is changing. The National Ambient Air Quality Standard for PM2.5 has recently been changed, with the standard becoming tighter. The region of Randolph, Vermont 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/MMBtu.

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%. Core separators and water scrubbers of the size suitable for boilers such as those being considered for the Randolph BDE system are not commercially available in the United States.

Multicyclones. Multicyclones, or multiple tube cyclones, are mechanical separators that use the velocity differential across the cyclone to separate particles. Multicyclones are more efficient collectors than cyclones because a multicyclone uses several smaller diameter cyclones to improve efficiency. Overall efficiency ranges from 65% to 95% 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% 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/MMBtu the overall control efficiency will be lower. Some combustion units could meet an emission level of 0.1 lb/ MMBtu 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% with control efficiencies almost as high for particle sizes of 1 micrometer or less. Overall ESPs are almost as good as the best fabric filters. Two designs were considered for smaller boilers: a dry ESP and a wet ESP. The systems are basically similar except that wet ESPs 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.

Fabric Filters or Baghouses. With the correct design and choice of fabric, particulate control efficiencies of over 99% can be achieved even for very small particles (1 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"). A cyclone-baghouse combination reduces the fire risk.

BERC recommends the installation of a cyclone and baghouse combination at the Randolph District CHP 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.

Currently, the most common air pollution control devices used to reduce PM emissions from wood-fired boilers are:

- **mechanical collectors**
- **wet scrubbers**
- **electrostatic precipitators**
- **fabric filters**

ENVIRONMENTAL IMPACTS (*cont'd*)

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.

Stack Height. Wood systems 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 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. Randolph district will need to submit a construction permit application for an Air Pollution Control permit for the BDE 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 Randolph BDE 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 H provides details on the air quality operating permit and the requirements of an Act 250 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 (CO_2) 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 CO_2. 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 CO_2 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 870,000 gallons of oil at 22 pounds of atmospheric CO_2 emitted per gallon of heating oil, the buildings in the study area contribute approximately 9,750 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 BDE plant, net CO_2 emissions for heating would be reduced by 75-90% (depending on how much the plant has to rely on back-up fossil fuel boilers).

When wood replaces fossil fuel, no new CO_2 is added to the atmosphere. 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.

IX. ASSESSMENT OF AVAILABLE WOOD FUEL SUPPLY

The wood fuel procurement region for woodchip fuel and wood pellet feedstock supply includes the Vermont counties of Orange, Rutland, Addison, Washington, and Windsor.

Biomass comes in all shapes and sizes. This section focuses on woodchips as the primary fuel for the Randolph BDE 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 concept of expanded wood procurement for a pellet fuel manufacturing facility is explored further in Appendix D. A separate assessment of grass fiber for pellet production was conducted by VTC.

DETERMINING THE WOOD FUEL PROCUREMENT REGION

Woodchip fuel for the Randolph BDE system is likely to be sourced directly from periodic forest harvesting happening within a cost-effective delivery radius from the facility. A 35-mile delivery radius was chosen as the target area for this project based on the volume of woodchip fuel required and transportation costs. The wood fuel procurement region for woodchip fuel and wood pellet feedstock supply includes Orange, Rutland, Addison, Washington, and Windsor Counties of Vermont.

REGIONAL WOOD FUEL AVAILABILITY

Vermont has a relatively mature wood energy market with more than 20 years of using woodchips for heat and power production. Historically, there has been sufficient supply of wood by-products such as sawdust, chips, and bark generated by the forest products industry to meet the 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.

Woodchip and sawdust supply from sawmills is extremely tight in Vermont today and sawmills are unlikely to respond to increased demand by producing more by-product. Despite the downturn 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 feedstock for woodchip and pellet production. While some wood fuel sourced for the Randolph BDE system may be by-product material, a majority of the supply will likely come directly from harvesting low-grade wood from regional forestland.

Wood is renewable but its supply is not infinite – our forests have a finite capacity for supplying wood fuel sustainably. If close attention is not paid to the question of how much, we run the risk of growing our wood fuel demand beyond the capacity of our forests 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 one being considered in Randolph, several steps must be taken:

1. Identify and examine 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 further low-grade wood market demand

A 35-mile delivery radius was chosen as the target area for this project based on the volume of woodchip fuel required and transportation costs.

ASSESSMENT OF AVAILABLE WOOD FUEL SUPPLY (*cont'd*)

Figures IV shows the above-ground wood inventory in the five-county procurement region.

ESTIMATING ACCESSIBLE, MANAGED FORESTLAND AREA

There are more than 2.1 million acres of total forestland area within the five county procurement region surrounding downtown Randolph.

Measuring the amount of forestland within the identified procurement region is an important first step; however, it does not give an accurate picture of the land from which biomass fuels can be harvested. Forestland is too broad a category because it encompasses all forested land including forest preserves and unproductive or sensitive forest areas like forested wetlands. For the purpose of this project, a more specific subset of forestland area, called timberland, was examined. 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."

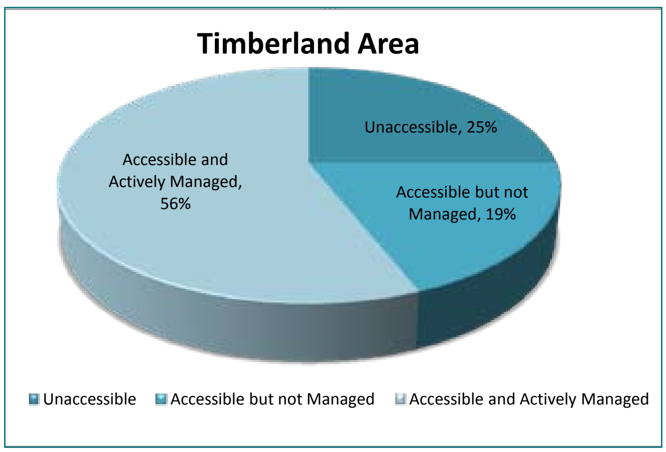
Figure IV below quantifies the total timberland area within the five-county area surrounding Randolph, Vermont. A significant amount of this land area is not accessible for harvesting, due to physical attributes such as slope, elevation, wilderness designation, stream and wetland buffer areas, and key wildlife habitat. In addition, forestland ownership and landowner's objectives further limit access to periodic harvesting. The right hand column of the table below estimates the accessible, managed timberland area factoring both physical limitations and land ownership.

Central Vermont is a heavily forested area. At over 1.9 million acres of total timberland in the procurement region, the total timberland area is significant. It is important to note that, while 1.9 million acres is a vast amount of timberland, not all timberland is actively managed and periodically harvested as was stated above. Therefore, remaining timberland area that is estimated to be actively managed and periodically harvested is slightly more than 50% of the original timberland area—1,074,841 acres within the five-county procurement region.

Figure IV and IV.i (right). Total Timberland Area in the 5-County Area (Acres)

County	Total Timberland Area	Estimated Accessible Managed Timberland
Addison	247,097	138,992
Orange	367,454	206,693
Rutland	464,095	261,053
Washington	336,515	189,290
Windsor	495,667	278,813
Total	1,910,828	1,074,841

Source: Forest Inventory and Analysis (FIA) Program of the US Department of Agriculture (USDA) Forest Service



FOREST INVENTORY AND COMPOSITION

The next step is examining the current amount or inventory of live trees on the timberland footprint. Since it is impossible to count every tree, the USDA Forest Service Forest Inventory and Analysis (FIA) Program uses a statistically designed sampling method. First, aerial photographs of the forest are interpreted. Next, a grid of thousands of points is overlaid on the aerial photos. If forested, each point is classified according to land use and tree size. Using this information, a sample of hundreds of plots is selected for measurement by FIA field crews.

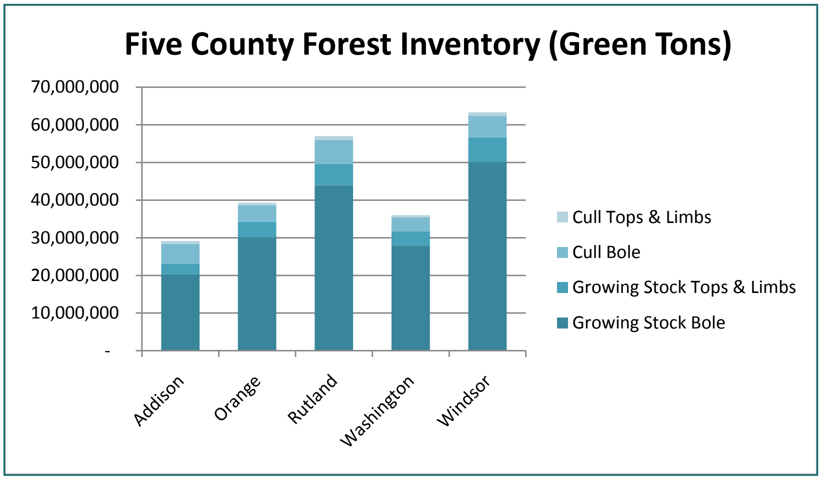
For the five-county woodchip fuel procurement region surrounding downtown Randolph, there were 295 FIA plots. The sample includes plots that were established during previous forest inventories. The re-measurements yield valuable information on how individual trees grow. Field crews also collect data on the number, size, and species of trees, and the related forest attributes. All this information is used to generate reliable estimates of the condition and health of the forest resource, and how it is changing over time.

With more than 224 million green tons of combined above-ground biomass inventory, the region has ample forest inventory. Central Vermont's forests are generally in good health and the age structure is slowly maturing over time. On average, there are nearly 118 green tons of above-ground wood (combining growing stock and cull bole and top and limb wood) on each timberland acre in the procurement region[6].

Figure V shows the above-ground inventory in the five-county procurement region.

Figure V and V.i (below). All Above-Ground Wood Inventory on Timberland Within the Five-County Wood Procurement Region (Green Tons)

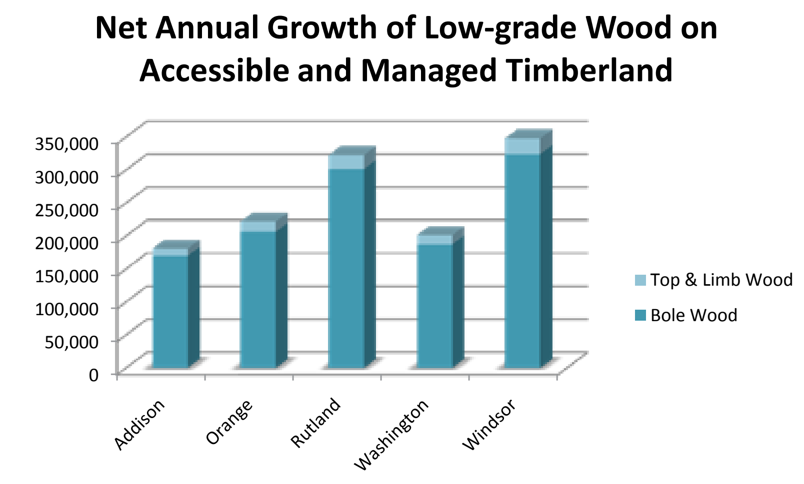
County	Bole Wood	Tops & Limbs	Total
Addison	25,672,000	3,478,000	29,150,000
Orange	34,472,000	4,856,000	39,328,000
Rutland	50,314,000	6,710,000	57,024,000
Washington	31,580,000	4,424,000	36,004,000
Windsor	55,774,000	7,568,000	63,342,000
Total	197,812,000	27,036,000	224,848,000



ASSESSMENT OF AVAILABLE WOOD FUEL SUPPLY (*cont'd*)

Figure VI and VI.i (below). Estimated Net Annual Growth of Low-grade Wood on Accessible, Managed Timberland within the Five-County Wood Procurement Region (Green Tons)

County	Bole Wood	Top & Limb Wood	Total
Addison	169,878	10,956	180,834
Orange	206,580	15,296	221,876
Rutland	301,664	21,137	322,801
Washington	187,392	13,936	201,328
Windsor	324,284	23,839	348,123
Total	1,189,798	85,163	1,274,961



FOREST GROWTH AND SUSTAINED YIELD CAPACITY

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 woodchip energy or wood pellet production.

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. Forest management is similar: sound forest management policy within a state or region allows harvesting only up to the amount of annual growth.

For the purpose of this project, the net annual growth[7] 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. 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 analysis to target a more appropriate amount of wood that could be available for various low-grade wood markets. Using these assumptions, the amount of low-grade wood grown each year on available timberland in the procurement region was estimated and these values are given in Figure VI at left.

A large majority of low-grade wood grown each year is bole wood and the amount of wood contained in the trees' tops and limbs is relatively small. While more than 1.2 million green tons sounds like an extremely large amount that can be harvested on a sustained-yield basis, it should be noted that there is significant existing demand for low-grade wood within this region.

CURRENT MARKET DEMANDS FOR HARVESTED LOW-GRADE WOOD

Historically there have been three main markets for low-grade wood: firewood, pulp, and biomass. Both firewood and pulp markets consume mostly low-grade bole wood, whereas biomass markets often consume just top and limb wood but in some cases utilize entire chipped trees. More recently, two more markets have emerged in addition to firewood, pulp, and biomass. The seasonal chip heating market has grown dramatically over the past few years and pellet manufacturing will soon be a significant market for low-grade wood.

Firewood. Residential firewood accounts for a large majority of low-grade wood demand in the region. Given the current high cost of heating oil, Vermont has seen a dramatic increase in demand for cordwood for home heating over the past five years. Current estimates of firewood use and harvesting in Vermont are 300,000 cords or 700,000 green tons annually[8]. While the most recent data on firewood use are over 12 years old, a new study is underway and the results should be released by the Vermont Department of Forests, Parks and Recreation in the very near future.

Pulpwood. Pulpwood demand and harvesting in Vermont has gradually declined over the past decade, although there are still several large pulpmills in eastern New York, southern Quebec, and northwestern Maine that draw upon Vermont for their wood supply. Although pulp volumes have declined, current prices paid by the pulpmills have increased dramatically in the past 12 months. In 2004, over 650,000 green tons of pulpwood were harvested and exported to the regional pulpmills. Just two years later, only 250,000 greens tons of pulpwood were harvested—a 62 percent reduction[9]. In 2006, there were only 85,321 green tons of pulpwood reported as harvested in the five-county wood procurement zone.

Biomass Power Plants. Whole trees and tops and limbs cut from logs are chipped into fuel. Both of Vermont's wood-fired power plants, McNeil Station in Burlington and Ryegate Power Station in Ryegate, consume large amounts of harvested wood in the form of whole-tree chips. International Paper and Finch Paper also consume whole-tree chips as boiler fuel in addition to the pulpwood and pulp chips they consume for making paper. Over the past several years nearly 200,000 green tons of low-grade wood from whole-tree harvesting in Vermont has been chipped for power plant fuel each year. Due to their locations, both Ryegate and McNeil Station source significant portions of their wood fuel from adjoining New York State and New Hampshire. In 2006 there were just over 100,000 tons of chipwood harvested from the five counties.

Institutional Chip Heating Market. Woodchip heating for schools and institutions has grown steadily over the past two decades in Vermont and in the past two years this growth has increased dramatically with several more schools and two college campus installations.

The seasonal chip heating market has grown dramatically over the past few years and pellet manufacturing will soon be a significant market for low-grade wood.

ASSESSMENT OF AVAILABLE WOOD FUEL SUPPLY (*cont'd*)

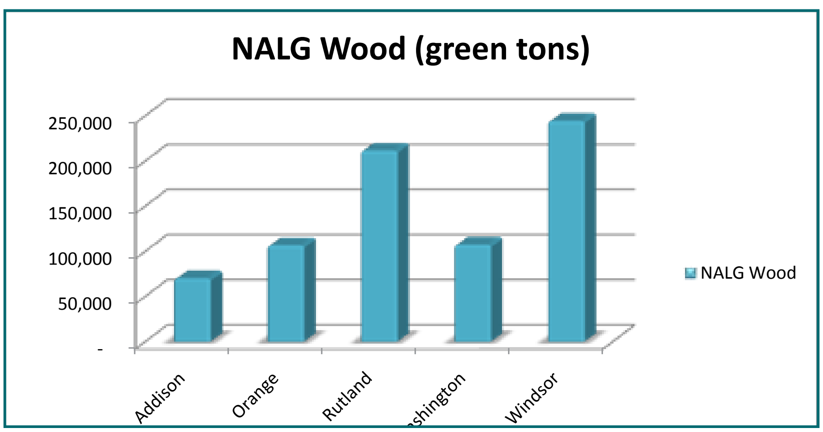
In the past two years, the combined chip heating market has grown from consuming approximately 25,000 tons annually to more than 50,000 tons.

Initially, nearly all woodchip heating systems sourced their chip fuel directly from sawmills as a by-product material; however as sawmill activity has slowly declined and demand for chip fuel has increased, a larger percentage of chip systems now source their fuel from chipped pulpwood as a commodity. In the past two years the combined chip heating market has grown from consuming approximately 25,000 tons annually to more than 50,000 tons. The recently installed woodchip system at Middlebury College accounts for a large portion of this recent growth. There are currently several large heating projects proposed in Vermont.

Pellet Manufacturing. While there currently are no operational pellet mills in Vermont and few in the surrounding states, there are numerous proposals for pellet mills to be built in Vermont, New York, and New Hampshire in the near future[10]. If only a small portion of the proposed mills are built, they will constitute a significant market for low-grade wood. Similar to the institutional chip heat market, pellet mills have transitioned from sourcing their fiber from exclusively sawmill by-product to increasingly sourcing pulpwood that is then debarked, chipped, and re-ground to their specifications onsite.

Figure VII and VII.i (below). Estimated Low-Grade Wood Grown & Harvested Annually on Accessible Managed Timberland within the Five-County Area (Green Tons)

County	Estimated Low-Grade Growth	Estimated Current Low-Grade Wood Harvest	Net Available
Addison	180,834	112,500	68,334
Orange	221,876	112,500	109,376
Rutland	322,801	102,500	220,301
Washington	201,328	92,500	108,828
Windsor	348,123	92,500	255,623
Total	1,274,961	512,500	762,461



NET AVAILABLE LOW-GRADE GROWTH (NALG) WOOD

Once the current demand for low-grade wood has been examined, the forest's capacity to supply low-grade wood beyond current demand can be determined. Figure VII on the previous page shows the estimated growth of low-grade wood on accessible and managed timberland within the procurement region as well as the region's estimated low-grade wood harvest and the difference between the two, or the NALG wood that could become woodchip fuel (or feedstock for wood pellet production).

When the pulp, firewood, and biomass chip market demands are added up and compared to the estimated annual growth of low-grade wood on available timberland, there is an estimated annual surplus capacity of more than ¾ million green tons within the five-county area surrounding downtown Randolph.

The three BDE configuration options for downtown Randolph presented in this report would consume significantly less wood than the local forests can sustainably supply on a sustained yield basis. Figure VIII below shows the annual woodchip fuel requirements for each of the three options.

When compared to the more than ¾ million tons available annually in the five-county area, these are relatively small amounts that would not over-burden the region's forests. Given Randolph's location away from the larger consumers of low-grade wood, competition for the resource is not as great were the project located closer to large wood consumers like pulpmills and biomass power plants.

CONCEPTUAL FORESTLAND AREA NECESSARY TO SUPPLY THE RANDOLPH DISTRICT ENERGY SYSTEM

It is common for decision makers to ask: "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. For perspective, one can calculate the theoretic forestland area needed to sustainably supply the ongoing fuel needs of the system. Following are a few key assumptions needed to calculate the necessary forestland area to supply a given project.

Typical Vermont Forest Stocking	100 green tons/acre
Average Net Annual Growth Rate	2.25%
Annual Sustained Yield	2.25 green tons/acre

The three BDE configuration options for downtown Randolph presented in this report would consume significantly less wood than the local forests can sustainably supply on a sustained yield basis.

Figure VIII. ANNUAL WOODCHIP REQUIREMENTS FOR THE THREE BDE OPTIONS

District Energy Option	Annual Woodchip Fuel Requirements
Woodchip District Heating	12,433 green tons
Woodchip CHP	14,666 green tons
Woodchip CHP with Pellet Mill as a Thermal Host	24,097 green tons

ASSESSMENT OF AVAILABLE WOOD FUEL SUPPLY (*cont'd*)

Figure IX. MANAGED TIMBERLAND NEEDED TO SUPPLY BDE OPTIONS

Option 1. Woodchip District Heating	Option 2. Woodchip CHP	Option 3. Woodchip CHP with Pellet Mill as Anchor Load
12,433 green tons	14,666 green tons	24,097 green tons
0.75 tons per acre	0.75 tons per acre	0.75 tons per acre
16,577 acres	19,554 acres	32,105 acres

The district energy system for downtown Randolph, would require 15,000 to 33,000 acres of forestland to sustainably fuel the system with woodchips for the life span of the energy system.

Assuming two-thirds of the annual growth is higher quality material suitable for lumber production, there is approximately 0.75 green tons of wood grown per acre per year suitable for use as woodchip fuel. Figure IX above reflects the amount of managed timberland needed to supply the BDE configuration options for Randolph.

It is important to note that the calculation above 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 forestland area as presented below for the woodchip district heating option:

12,433 green tons of woodchip fuel needed per year;

Divided by 100 tons of forest inventory/acre of forestland;

Equals 124.33 acres of harvested forestland/year;
Multiplied by 125-year harvest rotation;

Equals 15,541 acres of forestland required

Based on the outcome of the two approaches it can be concluded that the BDE system for Randolph would require 15,000 to 33,000 acres of forestland to sustainably fuel the system with woodchips for the life span of the energy system.

WOOD SOURCES

Woodchips and wood pellet feedstocks have historically been 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. 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 are dragged (skidded) from the stump to the central log landing instead of just the log—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 forest 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.

Sawmills. The business of sawing round logs into dimensional lumber produces a significant amount of by-product wood. 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 highest quality, thus best suited for use as fuel in biomass 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 empty trailers are set in their places.

Chipped Pulpwood. Bole chips are produced from low-grade 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.

"Mill" or "paper" chips are the highest quality, thus best suited for use as fuel in biomass heating systems.

WOODCHIP PRICING

The price of woodchips is affected by numerous factors, but the primary factors which influence chip pricing are:

- Wood source and production costs (varies widely depending on whether the wood is a by-product of some more lucrative activity)
- Regional balance of supply and demand for low-grade wood
- Trucking distance from point of generation to end market

ASSESSMENT OF AVAILABLE WOOD FUEL SUPPLY (*cont'd*)

The benefit of bole chips is that more chips can be produced as energy market demand increases as opposed to by-product chips from sawmills.

Whole-tree chips are an excellent and cost-effective fuel for larger systems which are designed to handle oversized chips. Whole-tree chips in Vermont range widely in price but are most commonly available within the range of $30 to $40 per green ton for large power plants. At 2009 pricing, whole-tree chips delivered to downtown Randolph in live-bottom trailers could be expected to cost $41 per green ton (due to the smaller quantities needed). While whole-tree chips could be a feasible low-cost woodchip fuel for the Randolph district energy system, there are some logistical difficulties in supplying hardwood only whole-tree chips consistently throughout the heating season. Harvesting wood in Vermont is very seasonal and susceptible to wet conditions. Similarly, the heating season in Vermont is seasonal and unfortunately the timing of heat demand does not always coincide with ideal harvesting conditions. Therefore it is recommended that whole-tree chips make up approximately 40 percent of the total annual fuel requirement.

Bole chips are typically available to the seasonal heating market in Vermont for $50 to $65 per green ton. Given the preference of hardwood species due to slightly lower moisture content and the seasonal demand for fuel, bole chips are the most available and logistically feasible woodchip fuel. Unlike whole-tree chips, round wood readily can be harvested, sorted, and trucked to an aggregation/storage yard. With recent losses of pulpwood markets throughout Vermont, "bole" fuel chips could prove to be a helpful local market for low-grade wood that would otherwise need to be trucked out of state. The benefit of bole chips is that more chips can be produced as energy market demand increases as opposed to by-product chips from sawmills. At 2009 pricing, it is expected that bole chips could be secured for $55 per green ton. It is recommended that delivered bole chips account for 40% of the annual fuel needs of the Randolph district energy plant.

Figure X. FUEL REQUIREMENTS AND AVERAGE PRICING FOR THE BDE CONFIGURATIONS

	Option 1. Woodchip District Heating	Option 2. Woodchip CHP	Option 3. Woodchip CHP with Pellet Mill as Anchor Load
Green Tons Annually	12,433	14,666	24,097
Whole-Tree Chips (40%)	$41 per ton	$41 per ton	$41 per ton
Bole Chips (40%)	$55 per ton	$55 per ton	$55 per ton
Roundwood & Onsite Chipping (20%)	$58 per ton	$58 per ton	$58 per ton
Total Annual Cost	$621,650	$733,300	$1,204,836
Average Cost	$50 per ton	$50 per ton	$50 per ton

For added security and longer term on-site storage it is recommend that 20 percent of the annual fuel requirements be met with purchased roundwood to be chipped on-site as needed by hired chipping contractors. It is expected that pulp-grade roundwood can be purchased for $36 per ton. When handling, storage, and chipping costs are factored this material will cost $58 per ton. If for some reason on-site chipping is not an option (due to local permitting) the amount of whole-tree chips and bole chips can be increased to 50 %.

Figure X on page 43 presents the three district heating options, their fuel requirements and averaged pricing.

Over the past 20 years, woodchip prices have increased at approximately 1% annually—well under the general rate of inflation. This is due to the fact that woodchips have historically been a by-product of other primary activities like timber harvesting and lumber production. Looking forward, woodchip prices are expected to increase, on average at 3.75% annually, slightly above the general rate of inflation.

CONCLUSIONS

Randolph is surrounded by over one million acres of managed timberland within the five-county wood procurement region.

The forests of central Vermont have ample stocking and annual growth of low-grade wood suitable for wood fuel production. On average, the current demand and harvesting for wood in Vermont is half of the amount actually grown annually. While the forest products industry in Vermont has experienced a gradual decline in harvesting and processing, much of the necessary infrastructure (foresters, loggers, chippers, sawmills, truckers, etc.) are in place and have the capacity to supply the required volume of woodchip fuel. Demand for wood fuels for biomass electric generation, home firewood heating, commercial and institutional heating, and pellet fuel production will likely continue to grow in the future. Forest sustainability safeguards such as harvesting standards, logger certification and third-party "green" certification of the wood fuel should be explored in an effort to make sure forest resources are responsibly managed in the face of increased demand for energy from wood.

Given the volumes of wood fuel required, the fuel storage capacity at the energy plant, and the fuel handling systems likely to be employed at the wood energy plant, whole-tree chips will be the most cost effective and feasible source of wood fuel. However, a mixture of both bole chips produced at a remote location and pulp-grade roundwood could be sourced in effort to even out the seasonality of whole-tree chip supply. Roundwood delivered to the energy plant could be stored and chipped on-site as needed to supplement the sporadic supply of chips delivered directly from the woods. This mixture of whole-tree chips, bole chips and roundwood for periodic chipping will provide an optimum balance of price, reliability and sustainability.

Randolph is surrounded by over one million acres of managed timberland within the five-county wood procurement region.

X. DISTRICT ENERGY FINANCIAL FEASIBILITY

The analysis assumes a local-control, user-owner model designed to deliver lowest-cost heating to residential, commercial, institutional, and industrial buildings in the target area of Randolph.

ANALYSIS METHODOLOGY

BERC used a proprietary economic analysis tool to examine the costs and cash flow for three independent configurations for a BDE system in Randolph on a "whole-project" basis. The preliminary analysis model uses financial assumptions and estimates based on actual data and utility operations to examine the overall economic feasibility of each option. The analysis is applied in year one of the analysis period and includes the ongoing costs of fueling, operating, and maintaining the system in each configuration as well as the sale of heat and/or power. Annual inflated costs and revenues were calculated over a 20 year period. The result is annual costs and revenues, net 20-year cash flow presented in 2009 dollars, and a timeframe for simple equity payback for each configuration option. These results can be compared across the three configuration options to identify the best option for the project from an economic perspective. Full economic analyses are included as Appendix E, F, and G.

The analysis assumes a local-control, user-owner model designed to deliver lowest-cost heating to residential, commercial, institutional, and industrial buildings in the target area of Randolph. This approach is common in European communities using district heating. It uses this local control/investment model of ownership making the "customers" of the system also the owners, who contribute equity generally through all or part of their connection fees. There are also options for local investment and return for other businesses and stakeholders in the town, such as banks, forest industry stakeholders, and fuel dealers. The Town of Randolph is envisioned as a leading member of the system. Different approaches that involve for-profit ownership may require less up-front investment from local users, but are very likely to cost significantly more over time.

Members in a user-owner model would be expected to enter into long-term contracts to pay for heat on a metered, per MMBtu basis. This analysis assumes that the cost of heat to members in the first year would be indexed at a 5% savings from the current cost of fuel oil. A fuel oil price of $2.50 per gallon is the equivalent of paying $25.88 per MMBtu; a member beginning a contract when fuel oil prices are at $2.50 a gallon would pay $24.59 per MMBtu for heat from the district energy plant. The purchase heat contracts would increase the price of heat each year at the rate of general inflation (3.25%). Fuel oil prices generally rise faster than the rate of general inflation. If fuel oil rates rise at a conservative estimate of 4.75%, and the price of heat from the district heating plant rises at the current rate of general inflation, by year 20, the price of oil heat will have risen to $65.47 per MMBtu while the price of heat from the district energy plant will have risen to $46.61 per MMBtu. Under this conservative assumption, the savings to the consumer in year 10 would be 17% off the cost of heating with oil, and by year 20 would be 29% off the cost of heating with oil.

Funds for the project were assumed here to be sourced from 50% federal and state grants, 20% by owner equity, and 30% commercial financing at 4.0% over a 20-year term.

It is important to note that the analyses were conducted for a full-system buildout, assuming that the entire district heating system would be built at the same time with all customers who might be served connected at the start. In reality, implementation would probably be staged over a few years.

ASSUMPTIONS USED IN THE ECONOMIC ANALYSES

The following assumptions were made in estimating the capital cost for each configuration option:

- System costs are based on estimates from several vendors, with a contingency of 5%
- All costs are estimates based on BERC's experience with similar projects; these cost estimates are intended as the basis for preliminary feasibility analysis and are expected to be within +/- 20% and subject to change
- A fully redundant oil backup system will be installed alongside the biomass system
- Building costs were estimated at $200 per square foot
- A total of 38,220 trench feet of piping will be required to connect the district system
- The analysis does not include the cost of any changes to the existing heating distribution system within the consumer facilities to interface with energy transfer stations
- Peak heating season is four months out of the year. Three months of the year are fringe months where some heating is required, though not all the time or to a lesser degree
- Total fuel consumption for the area was converted into Btu(s) and then into a gallons-of-oil equivalent of 870,000 gallons per year
- A load coincidence factor of 85% was assumed
- Regional woody biomass fuels average 16.5 million Btu(s) per dry ton
- The average moisture content of woodchips is 40 percent, meaning each ton delivered to the boiler contains 9.9 MMBtu(s)
- The price of woodchips was estimated at $50 per ton
- The average seasonal efficiency of woodchip boiler combustion equipment is 78%; the average seasonal efficiency for individual heating systems is 70%
- The rate of general inflation was assumed to be 3.25% annually, with fossil fuel prices inflating at 4.75% and wood fuel prices inflating at 3.75%
- Heat will be sold on a metered, per Btu basis to each consumer facility. The sale price of heat from the plant to the consumer will be 5% below the price of heating oil
- The initial price of heating oil is $2.50 per gallon, or $25.88 per MMBtu
- First year sale of heat price is $24.59 per MMBtu

Some additional assumptions were made specifically for each of the individual configurations options. Because these additional assumptions do not apply to each of the options (or they vary between options), they are explained below within the context of each separate option.

The Town of Randolph is envisioned as a leading member of the system. Different approaches that involve for-profit ownership may require less up-front investment from local users, but are very likely to cost significantly more over time.

DISTRICT ENERGY FINANCIAL FEASIBILITY (*cont'd*)

OPTION 1. WOODCHIP DISTRICT HEATING

Capital Cost. Total capital cost for Option 1 was estimated to be $27,470,000 and is itemized below.

CAPITAL COST (US $ million)

Wood energy system	42	MMBH	$3.74
Building			$1.50
Backup System			$2.84
Land			$0.25
Handling equipment			$0.15
Network			$4.93
Building connections			$5.17
Energy transfer stations			$4.31
Design, engineering & permitting	15%		$3.43
Contingencies	5%		$1.14
Total Capital			$27.47

Additional Assumptions. The following additional assumptions were made in the economic analysis of Option 1:

- A total of 2,297 hours of plant operation was assumed
- Total annual operation and maintenance (O&M) costs are estimated at $1,199,537 based on the following assumptions:
  - Purchase of 12,433 tons of woodchips annually at $50 per ton
  - Two plant employees for a total of 4,160 hours of staff time annually at a cost of $30 per hour
  - The plant will consume 844,208 kWh annually at an electric rate of $0.13/kWh
  - $343,350 will be spent annually on equipment maintenance

Cash Flow and Payback Period. The model predicts that the first year expenses of operating the project would be $1,941,173, including $741,636 in capital and financing costs, and $1,199,537 in operating and maintenance costs. The first year revenues would be $2,220,871 for the sale of 90,331 MMBtu of heat at $24.59 per MMBtu.

With these assumptions, the project shows positive cash flow from year one. The first year cash flow would be $279,698, and annual cash flow would increase in each following year. The project would have a 20 year cumulative cash flow of $15,547,610 ($9,074,726 in 2009 dollars).

The simple payback period on the member equity for the project would be 19.64 years.

Sensitivity Analysis. Many of the assumptions used above are subject to refinement. BERC performed a sensitivity analysis that showed how the system economics look under different assumptions on the cost of oil at the time when the project becomes operational (with a range of $2.50 to $3.50 per gallon), and under two assumptions about how much of the total project cost would come from borrowing (50% and 30%). The following table displays the results of the first year cash flow and the simple payback period on owner equity with 30% and 50% of the project funds acquired through commercial financing (both at 4.00% for a 20-year term), for fuel prices of $2.50, $3.00 and $3.50.

Financed Amount: 30% - $8,240,400

Oil Price	First-Year Cash Flow	Payback Period
$2.50/gal	$279,698	19.64 years
$3.00/gal	$723,873	7.59 years
$3.50/gal	$1,168,047	4.70 years

Financed Amount: 50% - $13,734,000

Oil Price	First-Year Cash Flow	Payback Period
$2.50/gal	-$214,726	N/A
$3.00/gal	$229,449	23.94 years
$3.50/gal	$673,623	8.16 years

DISTRICT ENERGY FINANCIAL FEASIBILITY (*cont'd*)

OPTION 2. WOODCHIP CHP

Capital Cost. The capital cost for Option 2 was estimated to be $35,800,000 and is itemized below.

CAPITAL COST (US $ million)

Wood energy system	47	MMBH	$4.30
ORC system (2,200 kW * $ 2,400 /kW)			$5.28
Building			$2.60
Backup system			$2.84
Land			$0.25
Handling equipment			$0.15
Network			$4.93
Building connections			$5.17
Energy transfer stations			$4.31
Design, engineering & permitting	15%		$4.47
Contingencies	5%		$1.49
Total Capital			$35.80

Additional Assumptions. The following additional assumptions were made in the economic analysis of Option 2:

- A total of 2,297 hours of plant operation was assumed
- Total annual operation and maintenance (O&M) costs are estimated at $1,367,933 based on the following assumptions:
  - Purchase of 14,666 tons of woodchips annually at $50 per ton
  - Three plant employees for a total of 6,240 man hours annually at a cost of $30 per hour
  - $447,450 will be spent annually on equipment maintenance
- The plant will generate 4,104,171 kWh annually in excess of its energy needs
- Excess electrical production will be sold to the grid at a rate of 95% of the current rate of $0.13 per kWh

Cash Flow and Simple Payback Period. The model predicts that the first year expenses of operating the project would be $2,334,425; including $966,492 in capital and financing costs, and $1,367,933 in operating and maintenance costs. The first year revenues would be $2,727,736, including $2,220,871 for the sale of 90,331 MMBtu of heat at $24.59 per MMBtu and $506,865 for the sale of 4,104,171 kWh of electricity.

With these assumptions, the project shows positive cash flow from year one. The first year cash flow would be $393,311, and annual cash flow would increase in each following year. The project would have a 20 year cumulative cash flow of $21,167,284 ($12,378,735 in 2009 dollars).

The simple payback period on the member equity for the project would be 20.76 years.

Sensitivity Analysis. The table below displays the results of a sensitivity analysis of the first year cash flow and the simple payback period on owner equity considering both 30% and 50% commercial financing and for year one oil prices of $2.50, $3.00 and $3.50.

Financed Amount: 30% - $10,738,800

Oil Price	First Year Cash Flow	Payback Period
$2.50/gal	$393,311	20.76 years
$3.00/gal	$837,485	9.75 years
$3.50/gal	$1,281,659	6.35 years

Financed Amount: 50% - $17,898,000

Oil Price	First Year Cash Flow	Payback Period
$2.50/gal	-$251,017	N/A
$3.00/gal	$193,157	42.26 years
$3.50/gal	$637,331	12.81 years

DISTRICT ENERGY FINANCIAL FEASIBILITY (*cont'd*)

OPTION 3. WOODCHIP CHP WITH PELLET MILL AS A THERMAL HOST

Capital Cost. The total capital cost for Option 3 was estimated to be $36,870,000 and is itemized below.

CAPITAL COST (US $ million)

Wood energy system	57	MMBH	$5.20
ORC system (2200 kW * $ 2400 /kW)			$5.28
Building			$2.60
Backup system			$2.84
Land			$0.25
Handling equipment			$0.15
Network			$4.93
Building connections			$5.17
Energy transfer stations			$4.31
Design, engineering & permitting	15%		$4.47
Contingencies	5%		$1.49
Total Capital			$36.87

Additional Assumptions. The following additional assumptions were made in the economic analysis of Option 3:

- A combined total 6,457 hours of woodchip boiler operation was assumed for community heating, CHP, and pellet production
- Total annual operation and maintenance (O&M) costs are estimated at $1,852,918 based on the following assumptions:
  - Purchase of 24,097 tons of woodchips annually at $50 per ton
  - Three plant employees for a total of 6,240 man hours annually at a cost of $30 per hour.
  - $460,882 will be spent annually on equipment maintenance
- The plant will generate 10,969,360 kWh annually in excess of its energy needs
- Excess electrical production will be sold to the grid at a rate of 95% of the current rate of $0.13 per kWh

Cash Flow and Simple Payback Period. The model predicts that the first year expenses of operating the project would be $2,848,424, including $995,506 in capital and financing costs, and $1,852,918 in operating and maintenance costs. The first year revenues would be $4,598,357, including $3,243,645 for the sale of 131,931 MMBtu of heat at $24.59 per MMBtu and $1,354,712 for the sale of 10,969,360 kWh of electricity.

With these assumptions, the project shows positive cash flow from year one. The first year cash flow would be $1,749,934, and annual cash flow would increase in each following year. The project would have a 20 year cumulative cash flow of $58,218,296 ($35,414,443 in 2009 dollars).

The simple equity payback period for the project would be 4.79 years.

Sensitivity Analysis. As with Options 1 and 2, sensitivity analysis was performed for two factors: the initial price of heating oil ($2.50, $3.00 and $3.50) and the percentage of the project cost to be acquired by commercial financing (30% and 50%). The table below displays the results of this sensitivity analysis.

Financed Amount: 30% - $11,061,175

Oil Price	First Year Cash Flow	Payback Period
$2.50/gal	$1,749,934	4.79 years
$3.00/gal	$2,398,663	3.49 years
$3.50/gal	$3,047,392	2.75 years

Financed Amount: 50% - $18,435,292

Oil Price	First Year Cash Flow	Payback Period
$2.50/gal	$1,086,263	7.71 years
$3.00/gal	$1,734,992	4.38 years
$3.50/gal	$2,383,721	3.51 years

FINANCIAL ANALYSIS CONCLUSIONS

The economic analysis concludes that all three options considered will produce positive cash flow for the project from year one, while saving customers of the system money on their annual heating bill since heat will be sold at a 5% discount off the current price of oil.

While the district heating option of supplying thermal energy to the Town of Randolph produces positive results, better cash flow and payback will be achieved by the inclusion of an ORC system to produce electricity for internal use and sale to the grid. The combinations of savings on electrical costs and revenues produced by selling electricity to the grid will produce revenues far in excess of the increased capital and operating costs of the ORC system.

If a pellet plant is located on the same site as the BDE plant, the project could benefit from both the sale of process heat and the increased electrical generation from the additional hours of system operation required by the pellet mill.

The most cost-effective BDE option for Randolph would be to include CHP using an ORC, and strong effort should be made to locate a pellet mill at the site to maximize cash flow.

XI. CONCLUSIONS AND RECOMMENDATIONS

The economics of the three configuration options studied here for the Randolph BDE system are good. Though not studied in detail here, the costs (dollar, social, and environmental) of continuing to use and purchase energy within existing systems is high. With a calculated load of 870,000 gallons of oil per year, the buildings in the study area could be spending $2,175,000 at an oil price of $2.50 per gallon. With installation of a BDE system for the community, over $100,000 could be saved by heating customers in the first year. The remaining $2 million would primarily stay within the local and regional economy rather than being exported to foreign economies of oil-producing nations.

While the price of oil is difficult to project, a conservative inflation rate of 4.75% puts the price of oil at $6.32 per gallon in 20 years. The average business owner, using 2,178 gallons of oil per year, would be paying $13,775 (2009 dollars escalated at the rates assumed in the economic analyses) in 20 years to heat their business; a resident may pay $4,950 to over $9,000 (2009 dollars escalated at the rates used here and considering a home size of 1,700 or 3,100 square feet, respectively). With a BDE system, these costs would be up to 30% lower, since the operating model will be designed to give customers a discount off oil. The Town of Randolph will see the additional economic benefit of retaining its energy dollars within the community.

Among the three BDE system configuration options studied here, the most favorable cash flow would be achieved by installing a biomass CHP system (an ORC system) with a pellet mill co-located at the site to serve as a large energy user. An added benefit of a co-located pellet mill is that it would offer affordable, renewable thermal energy in the form of wood pellets to the more rural portions of the community that are outside the area of the district heating system.

In the absence of a pellet mill, CHP (Option 2) is still more economically favorable than heating alone. Ultimately, the option chosen should be further evaluated, at the engineering level. If the findings of this pre-feasibility analysis are confirmed, the concept should be pursued on the implementation and development level.

BERC concludes that the findings of the pre-feasibility study for the Randolph BDE system are favorable and recommends that the project should be pursued further. Recommended next steps and a summary of implementation steps are outlined below:

NEXT STEPS

- Form exploratory committee of Randolph stakeholders
- Develop preliminary plan on connection fees and member/owner equity payments
- Continue providing community education
- Meet with building owners to collect detailed building and fuel use data
- Refine system load and financial analysis
- Conduct more detailed engineering and cost analysis
- Obtain signed commitments (“If you build the system, I will connect”)
- Make a Go/No Go decision on forming a new District Energy co-operative to build the project

SUMMARY OF IMPLEMENTATION STEPS

- New District Energy co-op board is formed
- Co-op board assembles implementation team including hiring staff
- Equipment specifications produced
- Engineering and design completed
- Financing secured (grants and loans)
- Construction starts
- System construction completed and system begins producing energy
- Facility is commissioned

ENDNOTES

[1] Resource Systems Group, Economic Impact of Wood Energy in the Northeastern States, Vol. I., prepared for the Northeast Regional Biomass Program, CONEG Policy Research Center, Washington, D.C., 1994.

[2] Net income accounts for the difference between direct payments associated with biomass energy and payments associated with conventional fuels, as well as indirect income from the multiplier effect as primary dollars circulate throughout the local and regional economies.

[3] Figures represented in constant 1994 dollars.

[4] Hoffer, Doug and Ellen Kahler, The Leaky Bucket: An Analysis of Vermont's Dependence on Imports, Vermont Job Gap Study, Phase 6, Peace and Justice Center, July, 2000.

[5] Statistics from a study presented by The Vermont Department of Forests and Parks, Vermont Superintendents Association's School Energy Management Program, and the Biomass Energy Resource Center

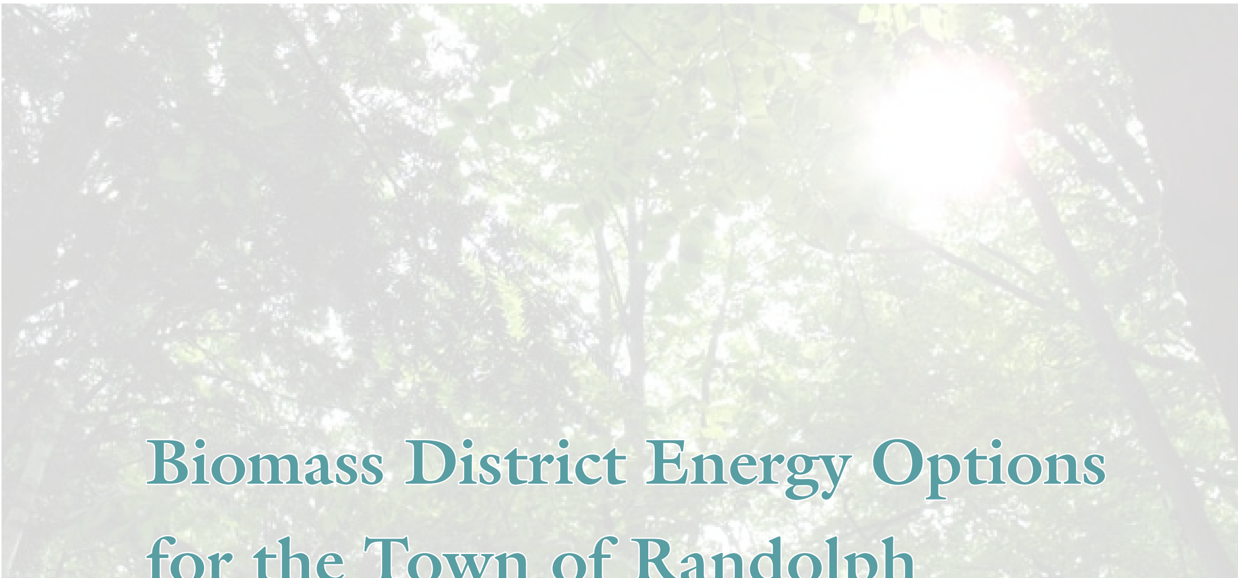
[6] Growing stock are the traditionally merchantable trees and cull trees are traditionally un-merchantable trees due to being rough or rotten.

[7] 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-growth + Accretion – Mortality = Net growth

[8] Vermont Department of Public Service 1997 Firewood Consumption Survey

[9] Harvest numbers from Vermont Forest Parks and Recreation Department's Annual Harvest Reports

[10] There is one pellet mill in Clarendon, Vermont that expects to be producing 10,000 tons annually by Fall 2009



Biomass District Energy Options for the Town of Randolph

APPENDICES

A. Randolph District Energy System Area Map

B. Woodchip Technology Description

C. Woodchip Combined Heat and Power Description

D. Pellet Mill Description

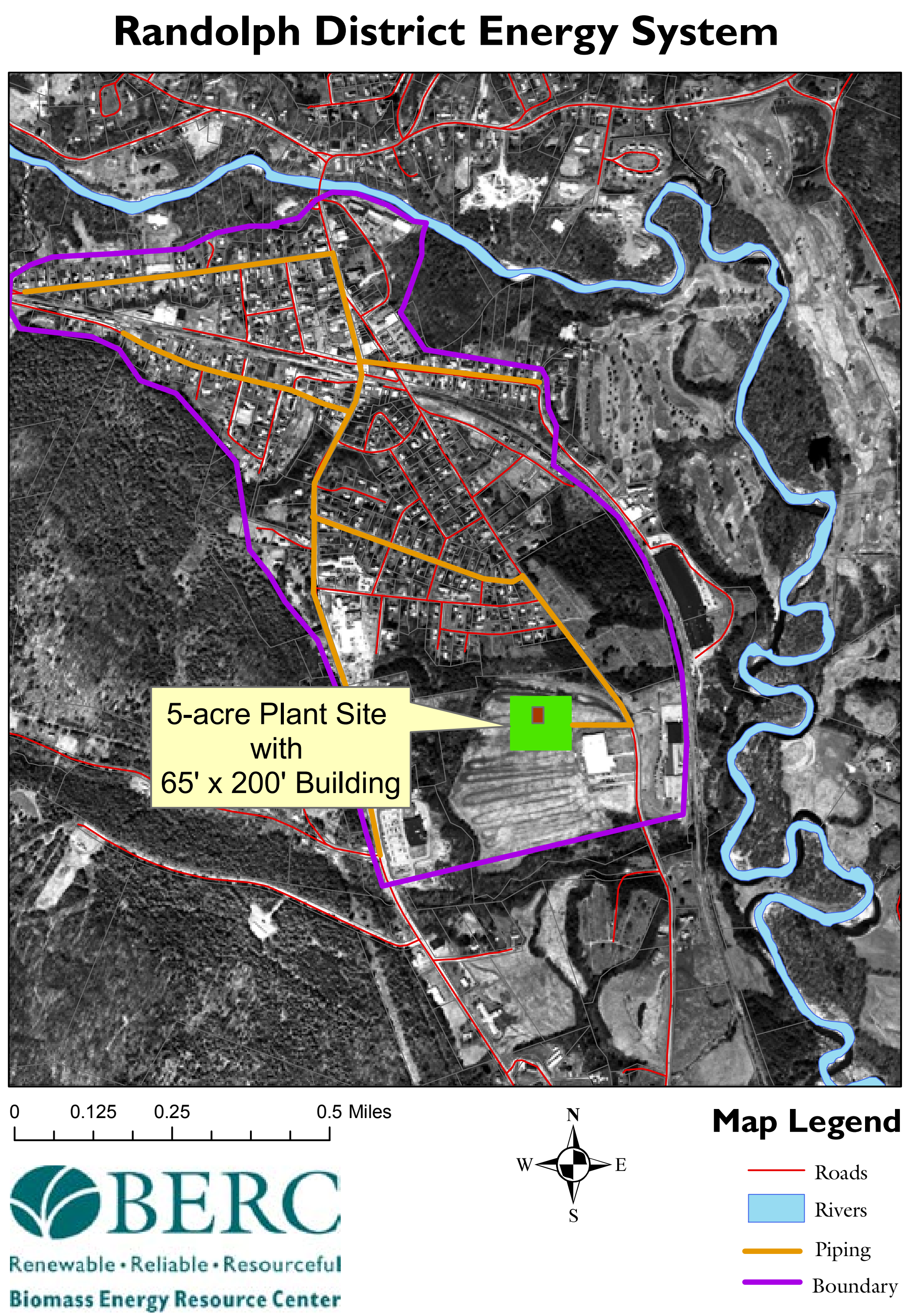
E. Financial Analysis of Woodchip District Heating

F. Financial Analysis of Woodchip District CHP

G. Financial Analysis of Woodchip CHP with Pellet Mill as Anchor Load

H. Regulations and Permitting

APPENDIX A. RANDOLPH DISTRICT ENERGY SYSTEM AREA MAP



BERC
Renewable • Reliable • Resourceful
Biomass Energy Resource Center

This map was produced by Biomass Energy Resource Center using data provided by the Two Rivers Ottauquechee Regional Commission.

APPENDIX B. WOODCHIP TECHNOLOGY DESCRIPTION

A biomass boiler has a modular design based on direct combustion technology. Different biomass boilers have different combustion zones and different fuel and ash handling requirements.

In boilers, the energy released by biomass combustion is transferred via water to a heat distribution medium – either hot water or steam. Steam produced from the biomass boiler can be used for all of the same purposes as steam from a fossil fuel boiler including heat, domestic hot water, sterilization, heat for absorption chilling, and power production through a steam turbine and generator. Two basic types of boilers are stoker and fluidized bed boilers. Stoker boilers burn biomass in a pile on the grate (or on sloped grates) whereas in fluidized bed boilers the biomass is in large-scale, specialized suspension burners. Stoker boilers were generally found to be less expensive to build than fluidized bed systems in the capacity range of interest to the Randolph project.

The boiler can be designed either with water in the tubes and combustion gases in the shell of the heat exchanger (called a water tube boiler) or with combustion gases in the tubes and water in the shell (a fire tube boiler). At pressure requirements below 300-400 psig, either fire tube or water tube boiler designs can be used.

In a typical grate and stoker boiler, the wood boiler type best suited for this scale of application, biomass is burned on a grate with a continuous supply of fuel fed by a stoker auger, with continuous or manual ash removal. The most common fuel type used in grate boilers is wood chips, but mixtures of wood chips and peat, wood chips and shavings from saw-mills, briquettes and crop residues from arable land are also frequently used. Fuels with a moisture content of 25% to 45 % are commonly burned in the grate and stoker boilers.

An automated auger or conveyor system carries the wood fuel from the wood fuel storage facility to the stoker system in the boiler. A stoker system uses one or more screw augers or a piston to feed incoming fuel onto the grate. By contrast, in a spreader stoker arrangement, a high-speed rotor throws the fuel over the grate, to promote fuel distribution.

There are various types of grates. The most common are the fixed sloping grate, the moving horizontal grate, the moving sloping grate and the multi-stage grate. With moving sloping grates the fuel bed is mixed mechanically allowing more fuel flexibility than with fixed grates. Fuels with significantly varying particle sizes and variable moisture contents also tend to work better with a moving grate system. The moving horizontal grate is generally intended to move ash along the grate's surface rather than to mix the fuel. Moving grates are unusual in boilers smaller than 5 MMBH and are seen more in systems larger than 10 MMBH.

The firing of biomass involves three processes. In the first, gasification, preheated air dries the wet fuel and provides air for fuel gasification and burning of fixed carbon. The first heat directed to a particle of green wood is used to drive off the water. After the water has been evaporated, additional heat raises the temperature of the wood and drives off the volatile gases, which then can be ignited. The weak chemical bonds in the wood fuel are broken and hydrocarbon gases are formed. The fixed carbon reacts with limited oxygen and forms carbon monoxide gas.

In the second stage, ignition, the heated volatile gases rise up into the ignition region. The high temperature volatile gas easily ignites as it contacts the oxygen provided by the air supply fans. The ignition zone temperatures can range from 1,800° to 2,000° F, depending on water vapor content and excess air levels.

The third process is the final combustion. The burning gases enter a large combustion chamber or furnace to complete the combustion process at temperatures of 1,400° to 2,000°F. This zone, consisting of a refractory lined furnace and boiler water wall, absorbs the radiant energy from the burning gases and allows any carry-over of unburned material to fall into a high temperature dropout zone to complete combustion. The response time of a boiler to changing demand is almost instantaneous since the rate of wood gasification and burning of gases is directly controlled by the amount of air admitted.

The primary components of the wood boiler are the air preheater, fuel metering bin, fuel supply conveyor/ metering conveyor, grate, stoker, combustion system, air fan with motor drives, combustion air system, soot blower, ash removal system, ash handling/storage system, air control dampers, rotary air lock valve, dust (particulate) collector or other emissions control device, combustion control and computer-based automation system to match heat load and maintain efficient combustion. The balance of the other associated equipment will include a de-aerator, feed pumps, transfer pumps, water treatment, chemical feed, stack, switchgear, and protective relaying.

In addition to the boiler, other biomass system components are woodchip storage, wood fuel handling equipment, boiler controls, a properly sized stack and emission control equipment. Both the boiler itself and the additional equipment require more mechanical room space than fossil fuel combustion equipment because the fuel is a bulkier, solid fuel requiring more space for storage and fuel handling equipment. Also, since the wood chips are delivered by self-unloading live bottom tractor trailer trucks, the chip storage site must be carefully located for truck access. Newer boilers will include computer diagnostics and controls, including remote connection to the boiler for both an operator and the boiler manufacturer with alarms that can alert the operator to various conditions and to eliminate the need for continuous supervision. With biomass fuels in particular, ash handling in the boiler can become a significant use of time, and so automatic ash removal is a commonly utilized optional feature.

Seasonal or year-round average boiler efficiency is the difference between the total energy flow rate in from the fuel and the heat that goes out into the boiler water. This efficiency is typically between 70-80% in the boiler size range for this project. The efficiency depends on the moisture content of the biomass fuel. With each additional increase of 10% moisture content in the biomass fuel, the boiler efficiency is lowered by about 2%.

In most cases, equipment provided and installed by the biomass boiler vendor includes the automated equipment to unload the woodchip storage bin, the fuel handling equipment that carries woodchip fuel to the boiler (conveyors and augers), the combustion chamber and boiler, combustion air supply fans, boiler connection to the stack, controls, safety devices and possibly emissions control equipment.

APPENDIX C. WOODCHIP COMBINED HEAT AND POWER DESCRIPTION

Introduction

Combined heat and power (CHP), or cogeneration, is the onsite generation of electricity and the recovery of useable heat produced during electric generation. The recovered heat can be used for space heating or other demands for thermal energy. Cogeneration allows the facility to make thermal energy and provide some or all of its electric requirements on-site. By design, CHP is intended to improve overall energy efficiency of fuel use, reduce total emissions, and save the facility money.

CHP is not a single technology but an integrated energy system that can be modified depending on the energy needs of the end user. CHP is a good option if the facility has large thermal loads and considerable electrical demand, room for the additional equipment, and competent staff able to manage and maintain the additional equipment. CHP systems are considered more efficient (and thus a better use of the heating fuel), but can be considerably more expensive and complex to permit and install.

Biomass CHP

Biomass CHP uses the same downstream equipment, but employs biomass as fuel for the power generation. Other additional requirements for biomass CHP are solid fuel storage and fuel handling equipment, which can take up more space than liquid fossil fuel storage and handling systems. Generating energy with biomass can recoup the energy value in the material and avoid the environmental and monetary costs of disposal or open burning of low-value biomass wastes. In addition to the need for added space and equipment, biomass CHP will require added operation and maintenance time, and more staff time to manage the system, make sure the boiler is cleaned, to monitor outputs, and to operate the system efficiently. These tasks also require staff that is technically competent and able to manage the system for efficiency and maximum output.

Organic Rankine Cycle (ORC) System

The Organic Rankine Cycle (ORC) is a thermodynamic process in which, instead of water, a low boiling organic fluid circulates as a working fluid. ORC uses non-flammable silicon oil as the working fluid. Biomass is burned in the combustion chamber and hot exhaust is streamed through the thermal oil boiler. The boiler heats this thermal oil to about 300° C (572° F). The hot thermal oil evaporates the working fluid from the ORC system in the evaporator, turning it into vapor. Under pressure this vapor is forced through the expander, turning it to spin an electric generator. The expander could be a twin screw expander or turbo expander. The vapor is cooled and condensed back into liquid in the condenser; this condensation is obtained by heating hot water. The hot water can then be used for space heating or any other thermal energy requirements. The working fluid liquid is then pumped and returned to the evaporator to repeat the process.

There are several advantages of the ORC system. It is a low pressure system, and so requires minimal operator attention and maintenance. ORC plants do not require stringent supervision by highly trained personnel, which means that the operation of the ORC is less expensive than for some other CHP systems. The system has a few moving parts and so long-term maintenance is also minor. The ORC system also does not require a water treatment system. It has better efficiency and more reliable operation. The expander has lower operating speed, and so is compatible with synchronous generators. ORC system capacities range from 50 kW to 2.2 MW, and can be stacked to provide much larger power outputs. There are a large number of CHP plants using ORC technology successfully running in Europe with continuous and unattended operation.

APPENDIX D. PELLET MILL DESCRIPTION

Introduction

Over the past several years Vermont, as well as the rest of the Northeast, has seen a large increase in use of pellets as fuel for home and small commercial heating. With increased pellet heating appliances such as pellet stoves, boilers, and furnaces the demand for pellet fuels has increased dramatically. Yet availability has been tight in the past few years as the increased demand in the Northeastern US has outstripped regional production. As a result much of the pellets sold in Vermont today are imported from Canada, the Western States, or Southeastern US. There is currently no commercial production of pellets in Vermont. Although, there is one company, Vermont Wood Pellet, with a small pellet mill under start-up located in Clarendon, Vermont. This facility, capable of producing up to 20,000 tons per year, is scheduled to begin producing pellets in summer or fall of this year. In addition to this soon to be operational facility in Clarendon, there are numerous other proposed pellet mills currently under development in Vermont.

The concept of a pellet fuel manufacturing facility located next to the district energy plant is appealing for a number of reasons. First, a pellet mill will help create new manufacturing jobs to the town of Randolph and help further stimulate the local economy. Secondly, a pellet mill will help anchor and further strengthen a local market for low-grade wood. Over the past few decades traditional markets for low-grade wood like pulp have been declining, making it more difficult to effectively thin low-quality wood from the local forests. Thirdly, the year-round heat requirements of a pellet mill will provide significant advantages to the district energy plant as a large and year-round heat utility customer.

Facility Size

Many pellet mills under development and construction today are designed to produce approximately 20-22 tons per hour or 80,000 to 100,000 tons of finished pellet fuel annually. At this scale these facilities require between 160,000 and 200,000 green tons of wood fiber input and need much larger wood procurement areas to supply such large volumes. For this reason and many other reasons, a smaller-scale pellet mill producing 4 tons per hour or 10,000 tons annually is explored in this section.

A pellet mill with a targeted output of 10,000 tons annually will require approximately 20,000 green tons of wood fiber per year. Historically, pellet mills have received sawdust and wood shavings as by-products of sawmills and have little to no drying or grinding requirements. Today, due to the shortage of shavings and sawdust, pellet mills are frequently designed to purchase wood fiber in pulp-grade roundwood form and to debark, chip, regrind, and dry this material before the material is passed through the pellet mill.

Many proposed pellet mills under development in Vermont today are targeting existing sites such as closed sawmills or furniture manufacturing facilities in an effort to utilize existing and idle infrastructure and to lower the capital costs of their project. A pellet mill of this size built from scratch would cost approximately $3-5 million for everything (land, building, all equipment, design, and permitting).

Upon initial review, the site identified as the potential district energy site (Dimmick property next to Vertek) has enough room to accommodate both the energy plant and a pellet mill. If a pellet mill developer were to pursue this concept of locating at this site, further site assessment and analysis of the space requirements would be essential.

Pellet Making Process

The wood pellet production process uses well-established technologies that are well-known in either the wood products or feed manufacturing industries. The process involves the following steps:

1. **Converting to woodchips.** Raw material can be delivered as either clean chips (without bark) or whole logs, which then need to be cleaned, debarked and chipped
2. **Comminuting.** Chips are then feed to a hammer mill to be ground into smaller a more uniform size
3. **Drying.** Moisture content is reduced to approximately 10 to 15 percent, typically through the use of a rotary drum
4. **Mixing and conditioning.** The appropriate recipe of raw materials and binding or conditioning agents (if needed) is blended in order to make the mix malleable for the pelletizing process, helping to produce higher quality pellets with a minimum of blockages

5. **Pelletizing.** The mix is then fed into the mill which uses a combination of heat and pressure to melt the lignins within the biomass and then extrude the hot mix through a perforated die, condensing the mix into a pellet form; mills are available with either flat or ring dies; the resulting pellet quality can be altered by the mill's gearing, the size of the dye's perforations and its thickness, the temperature and speed of the mill, the pressure and the composition of the rollers extruding the pellets; different feedstocks and pellet blends can require different recipes, dyes and pelletizing procedures to achieve the optimum pellet
6. **Cooling.** To harden the pellet; air cooling is often the most effective means once the pellet is cooled it typically has a hard exterior that is often moisture resistant
7. **Screening.** To separate residual fines (dust) from the pellets. Fines can typically be re-used in the process.
8. **Bagging and packaging lines.** Pellets must be dry when packaged. They are typically packed into 40-pound plastic bags which are then stored and transported on pallets. Pellets can also be loaded into 1-ton or 2-ton totes or transported via truck or rail car in bulk.

Energy Requirements

Making pellets requires a significant amount of energy both electrical (to drive the numerous motors for material handling, grinding, mixing, conveyance, bagging, etc.) and thermal energy (for drying green wood from 40-50% moisture content down to 10-12%). Most pellet mills of this size will require three-phase electricity to run all the electric motors. It is estimated that a small-scale pellet mill producing 10,000 tons of product per year would require an estimated 800kW/hour of electricity. As part of the analysis of the third option (District CHP with the Pellet Mill as a Thermal Host) the thermal requirements were calculated to be 10 million Btu per hour.

Raw Wood Fiber Procurement

As explored in the fuel supply section of the main report there are an estimated 1 million acres of managed forestland within the five county wood fuel procurement area identified for this project. On these acres there are well-stocked forests growing additional volumes of wood annually. Periodic, selective and sustainable harvesting of these forests can yield over ¾ million green tons of low-grade more than is currently harvested. While the energy plant would require between 12,000 and 24,000 tons of chips and some roundwood, the additional fiber demand for a pellet mill would be an additional 20,000 green tons of primarily roundwood. When the possible combined new demand for the district energy plant and the pellet mill are examined they account for only 6 percent of the estimated supply of low-grade wood in the five-county area. If a real proposal is put forward by a pellet mill developer further analysis of the wood fiber supply and the possible synergy of combined procurement with the energy plant will be needed. If a pellet mill project materializes in the near future, efforts to develop specific wood procurement strategies to promote buying local wood from well-managed forests should be pursued.

It should be noted that while nearly all commercial production of pellets comes from wood fibers that there is some opportunity to produce pelletized fuel from agricultural fibers such as grasses. In conjunction with this study Vermont Technical College has undertaken an assessment of the local potential to supply grass fiber to a pellet mill. While the potential for grass pellets is exciting and has many benefits, technical challenges remain. Grasses contain much higher concentrations of mineral material than wood fibers. When combusted the minerals materials produce ash and often melt to form clinkers. As a possible solution to this problem grass fiber may be blended in small proportions with wood fibers and made into pellets. The full details of VTC's findings can be found in a separate report.

Local Pellet Fuel Market

The pellet fuel market place has historically been exclusively bagged fuel sold to the residential home heating market. Today the target market of many new pellet manufacturing businesses is still by-in-large the bagged residential market, but more pellet mills are expanding into both the local bulk delivery market as well as the option to export to Europe. Without ready access to rail and nearby seaport, export to European markets is difficult in the northeast. There is little published data for the current market demand for pellets in Vermont, but if each home requires approximately 3 tons per heating season, it would only require 3,333 homes within the local area to heat with pellets to form a sufficient market for a 10,000 ton per year facility. In the five counties (Orange, Washington, Windsor, Addison, and Rutland) examined for fuel supply, there are 243,440 inhabitants and approximately 100,908 households. So, if only 3.3 percent of these households heated with pellets and purchased locally, there would be a sufficient local market.

Pellet Grades and Pricing

Pellet fuel quality is essential to provide the market with efficient and reliable fuel that is no more difficult to use than liquid fossil heating fuels. To help govern pellet fuel quality the Pellet Fuels institute (PFI) has developed pellet fuel quality specifications for four grades of pellets—super premium, premium, standard, and utility. A majority of the residential market require super premium or premium grade pellets. Commercial-scale systems can generally handle the low-quality of standard grade pellet fuel and only large industrial facilities are equipment to burn utility grade pellets. For a pellet mill in Randolph, producing 10,000 tons per year, super premium and premium grade pellets are the recommended grades to be produced.

This past heating season, Super Premium and Premium grade pellets in 40 pound bags retailed for $275 to $325 per ton. Most pellet manufacturers do not sell direct to the retail market and rely upon a network of retailers (hardware stores, feed and seed stores, box stores, etc.) as their wholesale marketplace. Expected wholesale pricing for super premium and premium grade pellets in 40 pound bags is $190 to $220 per ton.

Conclusions

A pellet manufacturing facility co-located at the district energy plant site could prove advantageous for the Randolph district energy project (a big year round heat customer), the community of Randolph (jobs and tax revenue), local forest landowners (local market for low-grade wood), and the larger pellet home heating market in Vermont (options to buy Vermont made pellets).

APPENDIX E. FINANCIAL ANALYSIS OF WOODCHIP DISTRICT HEATING

Capital Cost Table		
Components		**$ in millions**
Wood energy system	12MMBtu	$3.74
Building		$1.50
Backup System		$2.84
Land		$0.25
Handling equipment		$0.15
Network		$4.93
Building connections		$5.17
Energy transfer stations		$4.31
Engineering,project managment & permits @ 15%		$3.43
Contingencies @ 5%		$1.14
Total Capital Cost		$27.47

Economic Assessment Inputs		
Inputs	**Amount**	**Units**
Oil price	$2.50	gallon
Woodchip price	$50	ton
Heat sales	90,331	MMBtu
Electricity sales	-	kWh
General annual inflation rate	3.25	%
Fossil Fuel inflation *	4.75	%
Wood inflation *	3.75	%
Reduction on cost of heating oil **	5	%

* Includes general annual inflation rate
** First year price reduction of heating costs

Operation and Maintenance Cost Table		
Annual Expenditures		**Cost in $**
Purchased wood		$621,639
Plant Electrical Consumption **(kWh)**		844,208
Electric price/KWh		$0.13
Cost of electricity		$109,747
Hourly wage, labor		$30
Labor	2.0 FTE	$124,800
Other O&M		$343,350
Total O&M Cost		$1,199,537

Financing Table		
Financing	**Percentage**	**$ in millions**
Amount grants	50%	$13.73
Amount equity	20%	$5.49
- Member equity	60%	$3.30
- Other local equity	40%	$2.20
Amount debt	30%	$8.24
Interest rate	4%	
First annual payment		$0.742
Finance Term		20 year
Simple Payback for equity		19.64 year

Year	Total Expense *	Heat Revenue**	Annual Cash Flow	Cumulative Cash Flow
1	$1,941,173	$2,220,871	$279,698	$279,698
2	$1,966,785	$2,293,049	$326,264	$605,963
3	$1,993,882	$2,367,573	$373,691	$979,654
4	$2,022,516	$2,444,519	$422,003	$1,401,658
5	$2,052,742	$2,523,966	$471,225	$1,872,882
6	$2,084,616	$2,605,995	$521,380	$2,394,262
7	$2,118,196	$2,690,690	$572,494	$2,966,755
8	$2,153,544	$2,778,137	$624,594	$3,591,349
9	$2,190,721	$2,868,427	$677,706	$4,269,055
10	$2,229,793	$2,961,651	$731,857	$5,000,912
11	$2,270,828	$3,057,904	$787,077	$5,787,989
12	$2,313,893	$3,157,286	$843,393	$6,631,382
13	$2,359,063	$3,259,898	$900,836	$7,532,218
14	$2,406,410	$3,365,845	$959,435	$8,491,652
15	$2,456,014	$3,475,235	$1,019,221	$9,510,873
16	$2,507,953	$3,588,180	$1,080,227	$10,591,100
17	$2,562,311	$3,704,796	$1,142,485	$11,733,585
18	$2,619,174	$3,825,202	$1,206,028	$12,939,613
19	$2,678,631	$3,949,521	$1,270,890	$14,210,503
20	$2,740,773	$4,077,880	$1,337,107	$15,547,610

* Total Expense figure includes Financing Costs and O & M costs
** Revenue generated by the sale of Heat accounting for wood inflation at 3.75%

APPENDIX F. FINANCIAL ANALYSIS OF WOODCHIP DISTRICT CHP

Capital Cost Table		
Components		**$ in millions**
Wood energy system	47 MMBtu	$4.30
ORC system	2.2 MW	$5.28
Building		$2.60
Backup System		$2.84
Land		$0.25
Handling equipment		$0.15
Network		$4.93
Building connections		$5.17
Energy transfer stations		$4.31
Engineering project managment & permits @ 15%		$4.47
Contingencies @ 5%		$1.49
Total Capital Cost		$35.80

Economic Assessment Inputs		
Inputs	**Amount**	**Units**
Oil price	$2.50	gallon
Woodchip price	$50	ton
Heat sales	90,331	MMBtu
Electricity sales	4,104,171	kWh
General annual inflation rate	3.25	%
Fossil Fuel inflation *	4.75	%
Wood inflation *	3.75	%
Reduction on cost of heating oil **	5	%

* Includes general annual inflation rate
** First year price reduction of heating costs

Operation and Maintenance Cost Table		
Annual Expenditures		**Cost in $**
Purchased wood		$733,283
Plant Electrical Consumption **(kWh)**		949,229
Hourly wage, labor		$30
Labor	3.0 FTE	$187,200
Other O&M		$447,450
Total O&M Cost		$1,367,933

Financing Table		
Financing	**Percentage**	**$ in millions**
Amount grants	50%	$17.90
Amount equity	20%	$7.16
- Member equity	60%	$4.30
- Other local equity	40%	$2.86
Amount debt	30%	$10.74
Interest rate	4%	
First annual payment		$0.966
Finance Term		20 years
Simple Payback for equity		20.76 years

Year	Total Expense *	Heat Revenue**	Electricity Revenue***	Annual Cash Flow	Cumulative Cash Flow
1	$2,334,425	$2,220,871	$506,865	$393,311	$393,311
2	$2,361,071	$2,293,049	$523,338	$455,316	$848,627
3	$2,389,420	$2,367,573	$540,347	$518,500	$1,367,127
4	$2,419,530	$2,444,519	$557,908	$582,898	$1,950,025
5	$2,451,465	$2,523,966	$576,040	$648,542	$2,598,567
6	$2,485,289	$2,605,995	$594,761	$715,468	$3,314,034
7	$2,521,069	$2,690,690	$614,091	$783,712	$4,097,746
8	$2,558,876	$2,778,137	$634,049	$853,310	$4,951,056
9	$2,598,782	$2,868,427	$654,656	$924,301	$5,875,357
10	$2,640,860	$2,961,651	$675,932	$996,723	$6,872,080
11	$2,685,188	$3,057,904	$697,900	$1,070,616	$7,942,696
12	$2,731,846	$3,157,286	$720,581	$1,146,021	$9,088,717
13	$2,780,918	$3,259,898	$744,000	$1,222,981	$10,311,698
14	$2,832,488	$3,365,845	$768,180	$1,301,537	$11,613,235
15	$2,886,647	$3,475,235	$793,146	$1,381,734	$12,994,970
16	$2,943,485	$3,588,180	$818,923	$1,463,618	$14,458,588
17	$3,003,099	$3,704,796	$845,538	$1,547,235	$16,005,823
18	$3,065,587	$3,825,202	$873,018	$1,632,633	$17,638,456
19	$3,131,052	$3,949,521	$901,392	$1,719,860	$19,358,317
20	$3,199,599	$4,077,880	$930,687	$1,808,967	$21,167,284

* Total Expense figure includes Financing Costs and O & M costs
** Revenue generated by the sale of Heat accounting for wood inflation at 3.75%
*** Revenue generated by the sale of Electricity accounting for general inflation at 3.25%

APPENDIX G. FINANCIAL ANALYSIS OF WOODCHIP CHP WITH PELLET MILL AS ANCHOR LOAD

Capital Cost Table		
Components		**$ in millions**
Wood energy system	57 MMBtu	$5.20
ORC system	2.2 MW	$5.28
Building		$2.60
Backup System		$2.84
Land		$0.25
Handling equipment		$0.15
Network		$4.93
Building connections		$5.17
Energy transfer stations		$4.31
Engineering project managment & permits @ 15%		$4.61
Contingencies @ 5%		$1.54
Total Capital Cost		$36.87

Economic Assessment Inputs		
Inputs	**Amount**	**Units**
Oil price	$2.50	gallon
Woodchip price	$50	ton
Heat sales	131,931	MMBtu
Electricity sales	10,969,330	kWh
General annual inflation rate	3.25	%
Fossil Fuel inflation *	4.75	%
Wood inflation *	3.75	%
Reduction on cost of heating oil **	5	%

* Includes general annual inflation rate
** First year price reduction of heating costs

Operation and Maintenance Cost Table		
Annual Expenditures		**Cost in $**
Purchased wood		$1,204,836
Plant Electrical Consumption **(kWh)**		3,236,070
Hourly wage, labor		$30
Labor	3.0 FTE	$187,200
Other O&M		$460,882
Total O&M Cost		$1,852,918

Financing Table		
Financing	**Percentage**	**$ in millions**
Amount grants	50%	$18.44
Amount equity	20%	$7.37
- Member equity	60%	$4.42
- Other local equity	40%	$2.95
Amount debt	30%	$11.06
Interest rate	4%	
First annual payment		$0.966
Finance Term		20 years
Simple Payback for equity		4.79 years

Year	Total Expense *	Heat Revenue**	Electricity Revenue***	Annual Cash Flow	Cumulative Cash Flow
1	$2,848,424	$3,243,645	$1,354,712	$1,749,934	$1,749,934
2	$2,892,545	$3,349,064	$1,398,740	$1,855,259	$3,605,192
3	$2,939,046	$3,457,908	$1,444,199	$1,963,062	$5,568,254
4	$2,988,011	$3,570,290	$1,491,136	$2,073,415	$7,641,669
5	$3,039,530	$3,686,325	$1,539,598	$2,186,393	$9,828,062
6	$3,093,694	$3,806,130	$1,589,635	$2,302,071	$12,130,133
7	$3,150,599	$3,929,829	$1,641,298	$2,420,528	$14,550,662
8	$3,210,345	$4,057,549	$1,694,640	$2,541,845	$17,092,506
9	$3,273,032	$4,189,419	$1,749,716	$2,666,103	$19,758,609
10	$3,338,769	$4,325,575	$1,806,582	$2,793,389	$22,551,998
11	$3,407,664	$4,466,157	$1,865,296	$2,923,789	$25,475,786
12	$3,479,831	$4,611,307	$1,925,918	$3,057,393	$28,533,179
13	$3,555,390	$4,761,174	$1,988,510	$3,194,294	$31,727,474
14	$3,634,462	$4,915,912	$2,053,137	$3,334,587	$35,062,061
15	$3,717,174	$5,075,679	$2,119,864	$3,478,369	$38,540,430
16	$3,803,658	$5,240,639	$2,188,759	$3,625,740	$42,166,170
17	$3,894,050	$5,410,960	$2,259,894	$3,776,804	$45,942,974
18	$3,988,491	$5,586,816	$2,333,340	$3,931,666	$49,874,640
19	$4,087,127	$5,768,388	$2,409,174	$4,090,435	$53,965,074
20	$4,190,110	$5,955,860	$2,487,472	$4,253,222	$58,218,296

* Total Expense figure includes Financing Costs and O & M costs
** Revenue generated by the sale of Heat accounting for wood inflation at 3.75%
*** Revenue generated by the sale of Electricity accounting for general inflation at 3.25%

APPENDIX H. REGULATIONS AND PERMITTING

Notes on the Act 250 Permit

Under Act 250, known as the Land Use and Development Act, the State of Vermont created nine District Environmental Commissions to review large-scale development projects using 10 criteria that are designed to safeguard the environment, community life, and aesthetic character of the state. They have the power to issue or deny a permit to real estate developers for any project that encompasses more than 10 acres (40,000 m^2), or more than 1 acre (4,000 m^2) for towns that do not have permanent zoning and subdivision bylaws.

One recently approved Land Use Permit for authorization of construction of a woodchip boiler building at the school in Newport, Vermont has been approved with the following specific conditions.

1. On the request of the commission, the Permittee shall complete a visible emissions test at various loads to identify if there are significant visible emission problems with the installed boiler. On request of the Commission, the Permittee shall submit a written report which summarizes (a) boiler performance vis a vis particulate emissions, (b) currently available particulate treatment technologies, (c) State of Vermont air quality requirements/regulations pertaining to particulate emission from this type/size wood chip boiler, and (d) status of project compliance with the Vermont requirements/regulations. Equipment shall include a single cyclone equipped with an exhaust recirculation duct; the Commission reserves its right to require that the Permittee install additional/replacement particulate treatment system(s) in the future.
2. Within 6 months of permit issuance, Permittee shall complete a refined air dispersion modeling analysis to identify the proper stack height for good dispersion of air pollutants. The analysis shall be submitted to the ANR Air Pollution Control Division for review and approval. The stack height shall be based on the approved analysis, but shall not be less than 48 feet. Permittee shall submit a copy of the analysis to the District Commission prior to construction of the stack. In the event that the analysis yields a stack height in excess of 70 feet, the Permittee shall submit the revised design to the District Commission for additional review and approval.
3. The exterior finish surface of the chimney stack shall be brick masonary, including typical exposed ± 3” x ± 8” traditional type “red clay” bricks, unless otherwise approved by the District Commission.
4. The Permittee shall utilize only “clean chips” (i.e. barkless wood chips) fuel, unless ANR guidance (e.g. test results) provides that the use of “clean chips” does not yield a decrease in PM emissions, for comparable-sized boilers.

Notes on an Air Quality Operating Permit

Under the guidelines of the Vermont Air Pollution Control Regulations Randolph’s Biomass District Energy plant will need to submit a construction permit to accommodate the new biomass energy system, and submit an Air Pollution Control Permit application. The attached link is to the Air Pollution Control Division’s (APCD) web page with information for construction and air regulation permits.

http://www.anr.state.vt.us/air/Permitting/htm/ConstructPermits.htm

Generally the amount of criteria pollutants that may be emitted by a proposed source will be determined by the proposal. The Agency then determines which regulatory requirements the project will trigger.

A new 42-57 MMBH wood fired boiler that includes a cyclone in series with a baghouse will be considered acceptable for PM control.

The contact for the Air Pollution Control Division of the Vermont Department of Environmental Conservation is given below.

Steven Snook, Environmental Engineer
Air Pollution Control Division - Engineering Services
steven.snook@state.vt.us
Phone: 802-241-3856
Fax: 802-241-2590

Renewable • Reliable • Resourceful

Biomass Energy Resource Center

PO Box 1611, Montpelier, VT 05601-1611

ph 802-223-7770 x121 • fax 802-223-7772

info@biomasscenter.org • www.biomasscenter.org