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Northeastern Area
State and Private Forestry

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Preliminary Feasibility Report

Biomass Heating Analysis for Canton Central School

Canton, NY
July 2011

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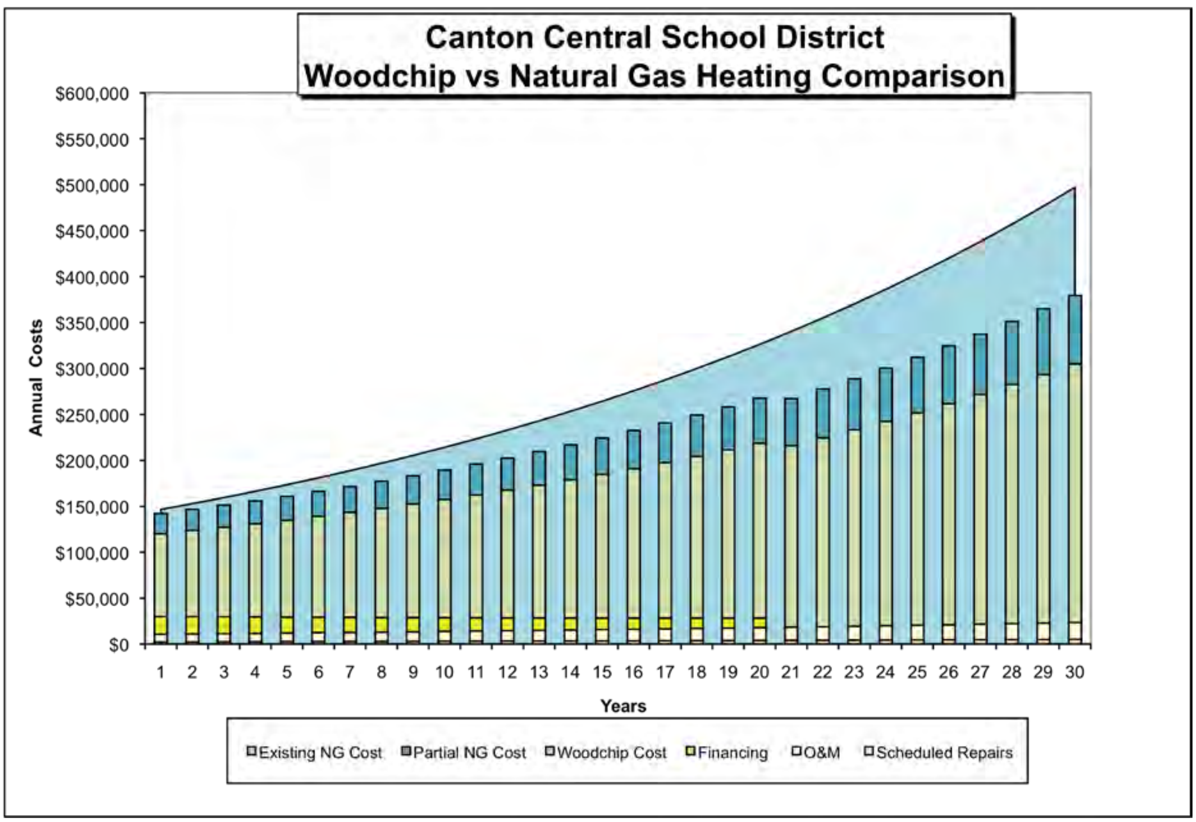
EXECUTIVE SUMMARY

The Canton Central School is a school campus housing an Elementary, Middle School and High School located in Canton, New York. The school has approximately 287,000 square feet of conditioned space in these three buildings. The campus has a central boiler system with four aging steam boilers in need of replacement. The boilers are fully depreciated and the analysis in this report assumes that the School will receive 89% state school construction aid for the project. School officials should consult with the New York State Department of Education before embarking on any construction project to determine eligibility for state school construction Aid. Canton Central School is considering a major capital project that would include the replacement of the existing steam boilers. The School is also considering upgrading portions of the heat distribution system from steam to hot water.

The three buildings on the campus currently use an average of 209,491 therms of natural gas each year. The average price paid by the School over the past two years was $0.70 per therm. At that price Canton Central School will spend approximately $146,644 on natural gas this coming year.



The analysis provided in this report, assuming the School receives 89% state school construction aid, indicates that Canton Central School could save over $615,000 in operating costs over 30 years in today's dollars even when the cost of financing is included. The analysis shows more than $34,400 in fuel savings in the first year alone. However, a biomass heating project does not look favorable at this time if the School is not able to obtain full state school construction aid for the project.

This report analyzes the opportunity to utilize wood energy at Canton Central School. While investing in a woodchip system is not practical at this time due to the current price of natural gas, as natural gas prices increase, installation of a woodchip system may become a better investment for the School. The sensitivity analysis, located in Appendix A, indicates that even without state aid, a woodchip heating project looks favorable when natural gas prices climb to $1.00 per therm.

Regardless of whether or not Canton Central School moves forward with a biomass project we recommend the school consider the following:

1. The School should consider energy efficiency improvements simultaneously with boiler upgrades. The efficiency of the building envelope and ventilation equipment need to be considered when sizing new boiler equipment. The New York State Energy and Research Authority (NYSERDA) and/or the New York Power Authority (NYPA) should be engaged to develop comprehensive energy efficiency recommendations and proposals for incentives for efficiency upgrades before undertaking a major building project. Information on energy efficiency programs and incentives is included in the Resource Binder accompanying this report.
2. In order to effectively measure progress toward energy efficiency goals historical energy consumption data should be collected and updated frequently. There are many tools to help the School accomplish this. One such tool is the EPA Energy Star Portfolio Manager software. It is free public domain software that helps facility managers track energy and water use. This software can be downloaded at: http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager
3. The School should also consider the addition of solar hot water generation at the time of the boiler upgrade. Solar hot water with thermal storage could help to offset the School's heat load.
4. The School may want to consider converting the existing steam distribution system to a hot water system – this would depend on the existing condition of the distribution system. According to the US Department of Energy, steam systems are generally less efficient than hot water heating systems, but the efficiency gain of upgrading to hot water is probably not worth the expense. It is sometimes possible to convert existing steam distribution pipes to hot water heating, which would be less expensive – this is generally only feasible if the existing steam system is a newer two-pipe system. The School should work with an engineer to understand the existing distribution system and opportunities for upgrades.

If the School does decide to move forward with a biomass project we also recommend taking the following steps:

1. Hire an engineering firm to help refine the project concept and to obtain firm local estimates on project costs. The US Forest Service may be able to provide some technical assistance from an engineering team with biomass experience. If the School moves forward with this project, they should contact Lew McCreery, the US Forest Service Biomass Coordinator for the Northeastern Area to see what assistance can be provided. Contact Lew at (304)285-1538 or lmccreery@fs.fed.us

2. The School should identify any heating system improvements it plans to undertake and include those projects with the biomass project. It is more cost effective to implement boiler room upgrades and heating distribution improvements at the same time a new boiler system is installed.

3. Key decision makers should tour facilities that have biomass energy systems and talk with systems operators to better understand the technology. Vermont has over forty schools that heat with wood and New York also has several biomass energy systems that could be comparable.

4. Concurrent with the design of the project, the School should cultivate potential biomass fuel suppliers. School staff should work with the State of New York Wood Utilization program staff to identify potential New York woodchip suppliers. Sloane Crawford is currently the leader of that program, his contact information is below.

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This preliminary feasibility study was prepared by Yellow Wood Associates in collaboration with Richmond Energy Associates for the Watertown Industrial Center. Both Yellow Wood and Richmond Energy have extensive community economic development experience and Richmond Energy specializes in biomass energy projects. This study was funded by the Wood Education and Resource Center, Northeastern Area State and Private Forestry, U.S. Department of Agriculture.

INTRODUCTION

There is a significant volume of low-grade biomass in the United States that represents a valuable economic and environmental opportunity if it can be constructively used to produce energy. Commercially available biomass heating systems can provide heat cleanly and efficiently in many commercial applications. Biomass heating technologies are being used quite successfully in over 40 public schools in Vermont alone and the concept of heating institutions with wood is catching on in several other areas of the United States and Canada. Good candidate facilities for biomass energy systems include those that have high heating bills, those that have either steam or hot water heating distribution systems and those that have ready access to reasonably priced biomass fuel.

This report is a pre-feasibility assessment specifically tailored to Canton Central School outlining whether or not a woodchip heating system makes sense for this facility from a practical perspective. In March, 2011 staff from Yellow Wood Associates traveled to Canton, NY to tour the Canton Central School. This assessment includes site specific fuel savings projections based on historic fuel consumption, and provides facility decision-makers suggestions and recommendations on next steps.

The study was funded by the U.S. Department of Agriculture Wood Education and Resource Center.

This preliminary feasibility study was prepared by Yellow Wood Associates and Richmond Energy Associates, LLC.

ANALYSIS ASSUMPTIONS

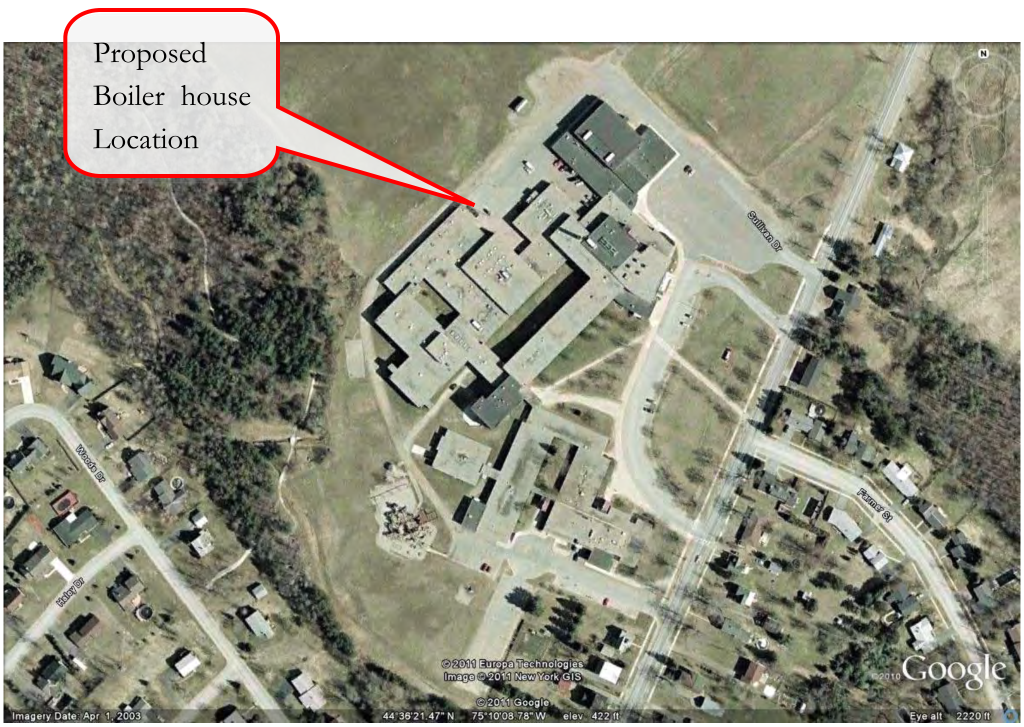
DESCRIPTION OF THE EXISTING HEATING SYSTEMS

The Canton Central School serves grades K-12 with an Elementary, Middle and High School in Canton, NY. The school houses approximately 1,680 students in the 56,149 SF Elementary School, 114,726 SF Middle School and 116,254 High School. All three schools are connected and have a centralized heating system that is run by four 190 BHP Cleaver Brooks FLX-200 Flex Fuel steam boilers. The boilers were installed in 1994, are aging poorly, and are in need of replacement. Based on fuel bills provided by the School, an average of 209,491 therms of natural gas was used to heat this campus over the past two years.

DESCRIPTION OF THE PROPOSED BIOMASS SYSTEM

There appears to be sufficient space behind the school to locate a woodchip boiler house and chip storage building. Figure 1 shows the suggested boiler house location.

Figure 1: Site Plan



The biomass scenario envisions building a 2,500 square foot stand-alone boiler house and chip storage facility, which would house a 6.0 mmBtu woodchip hot water boiler, woodchip fuel storage and fuel handling equipment to feed the boiler automatically. The biomass system would tie into the central boiler plan via insulated, underground piping. It was assumed the woodchip boiler would be able to supply 85% of the facility's heating needs. The scenario also assumes two of the existing steam boilers will be refurbished to provide back-up heat for the shoulder seasons and supplemental heat during the coldest days if necessary. Costs for upgrading the existing heating systems to hot water were not included in the analysis because these are costs the School is planning to incur regardless of whether or not a biomass system is installed.

Hot water from the woodchip boiler house would be tied into the exiting HVAC systems via approximately 150 feet of underground insulated piping. Costs for a tall stack were included to ensure good emissions dispersal. Costs for an underground woodchip storage bin were included, as below grade chip storage bins are less likely to freeze in the coldest winter weather and chip delivery using self unloading trailers into below grade bins is fast and easy.

A thermal storage system is included in the capital cost estimate for this study. In this case the thermal storage system includes a large, insulated hot water tank and ancillary piping and pumps that connect the insulated storage tank to the wood fired boiler and to the buildings' heating system. Heat from the wood boiler is stored in the water in the insulated tank until needed by the building system. This allows the boiler to operate in a high fire state at peak efficiency and then be turned off or to go into a stand-by mode where a minimal amount of fuel is being burned. This improved efficiency means fuel savings and reduced emissions. The thermal storage system also allows peak load shaving and as a result a smaller combustion system can be installed. The stored energy in the tank provides a buffer for peak loads during the day. The boiler loads energy into the tank during periods of low demand. When periods of peak demand occur, the energy stored in the tank responds immediately to the buildings demand while the wood-fired boiler is reaching a "high fire" state. Then the boiler provides the additional energy required to meet the peak demand. In commercial or school settings these peak demand periods are often periods of maximum air exchange with the outdoors.

Additional benefits of the thermal storage system include the ability to extend the operation of the wood combustion system during warmer spring and fall periods, and in some cases, to address summer domestic hot water needs. Additionally solar thermal energy systems can be connected to the storage tank. In fact such combination systems are often used in Europe to meet summer domestic hot water needs and increase overall system efficiency.

Figure 2: Willisamstown, VT High School Woodchip Boiler Plant

A healthy construction contingency, standard general contractor mark-up and professional design fees were also included. Below are images of insulated piping representative of what is specified in this analysis.

Figure 3: Underground Insulated Piping[1]

[1] Photos excerpted from *Heating Communities with Renewable Fuels* published by Natural Resource Canada.

LIFE CYCLE COST METHODOLOGY

Decision makers need practical methods for evaluating the economic performance of alternative choices for any given purchasing decision. When making a choice between mutually exclusive capital investments, it is prudent to compare all equipment and operating costs spent over the life of the longest lived alternative in order to determine the true least cost choice. The total cost of acquisition, fuel costs, operation and maintenance of an item throughout its useful life is known as its "life cycle cost." Life cycle costs that should be considered in a life cycle cost analysis include:

- Capital costs for purchasing and installing equipment
- Fuel costs
- Inflation for fuels, operational labor and major repairs
- Annual operation and maintenance costs including scheduled major repairs
- Salvage costs of equipment and buildings at the end of the analysis period

It is useful for decision makers to consider the impact of debt service if the project is to be financed in order to get a clearer picture of how a project might affect annual budgets. When viewed in this light, equipment with significant capital costs may still be the least-cost alternative. In some cases, a significant capital investment may actually lower annual expenses, if there are sufficient fuel savings to offset debt service and any incremental increases in operation and maintenance costs.

The analysis performed for this facility compares different scenarios over a 30-year horizon and takes into consideration life cycle cost factors. A 30-year time frame is used because it is the expected life of a new boiler.

The alternative biomass scenario envisions installing a new woodchip heating system that would serve the Canton Central School. The scenario includes all ancillary equipment and interconnection costs. Under the biomass scenario, some of the existing heating equipment would still be used to provide supplemental heat during the coldest days of the year if necessary and potentially for the warmer shoulder season months when buildings only require minimal heating during chilly weather.

The analysis projects current and future annual heating bills and compares that cost against the cost of operating a biomass system. Savings are presented in today's dollars using a net present value calculation. Net present value (NPV) is defined as the present dollar value of net cash flows over time. This is a standard method for using the time value of money to compare the cost effectiveness of long-term projects.

It is not the intent of this project, nor was it in the scope of work, to develop detailed cost estimates for a biomass woodchip system. It is recommended that for a project of this scale, the Canton Central School hire a qualified design team to refine the project concept and to develop firm local cost estimates.

Therefore the capital costs used for the biomass scenario are generic estimates based on our experience with similar scale projects.

NATURAL GAS COST ASSUMPTIONS

During the past two school years the Canton Central School used an estimated 209,491 therms (equivalent to 20,949 mmBtu) of natural gas to heat the Elementary, Middle and High Schools The total of 209,941 therms of natural gas was the assumed annual fuel consumption used for the base case in the analysis. According to bills provided by the School, the average price paid for natural gas over the past two years was $0.70 per therm. At that price, Canton Central School will spend approximately $146,644 to heat the campus next year.

WOODCHIP FUEL COST ASSUMPTIONS

Frequently, operators of institutional woodchip systems don't fire up their biomass boilers until there is constant demand for building heat. During the fall and spring, fossil fuel boilers are often used as they are easier to start up and turn down. Woodchip boilers are then typically used in place of fossil fuel boilers for the bulk of the winter heating season. In Vermont where there are well over 40 schools that heat with wood, the average annual wood utilization is about 85%. This analysis assumes that 85% of Canton Central School heating needs will be covered by the woodchip boiler, using approximately 1,899 tons of woodchips each year.

After consulting with other woodchip users in the region, we are projecting a first year cost of $47.50 per ton for woodchips (this is an average price based on our research) which is equivalent to about $0.44 per therm of natural gas.

The remaining 15% of the heating needs were then assumed to be provided by the retrofitted natural gas steam boilers consuming about 31,424 therms of natural gas. In the analysis the costs for woodchips and supplemental natural gas are adjusted for inflation each year over the 30-year horizon.

INFLATION ASSUMPTIONS

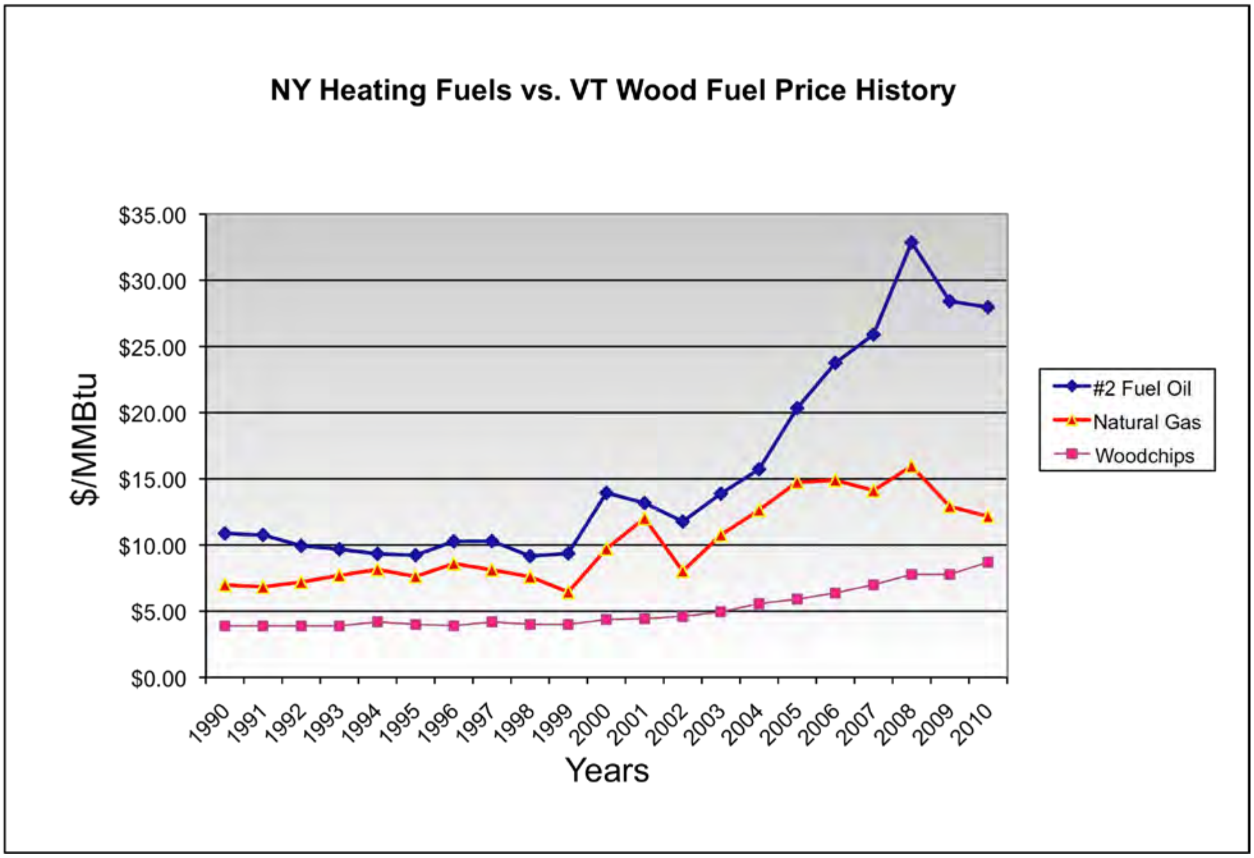
Estimating future fuel costs over time is difficult at best. Over the past few years it has become even more difficult as fuel prices have fluctuated dramatically. Nevertheless, in order to more accurately reflect future costs in a thirty-year analysis, some rate of inflation needs to be applied to future fuel costs.

We looked retrospectively over the last 20 years (1990 – 2010) using US Energy Information Agency data and found that the average annual increase for natural gas in New York was 4.3% per year. The analysis projects this average inflation rate for natural gas forward over the thirty-year analysis period.

Canton Central School's fuel rate of $0.70 per therm (or $7.00 per mmBtu) was used for the first year of the analysis and then inflated each year at 4.3%.

The cost of woodchips used for heating fuel tends to increase more slowly and has historically been much more stable in price over the past two decades than fossil fuels. In Vermont for example, the statewide average woodchip fuel price for institutional biomass heating systems rose from $25/ton to $56/ton in the period between 1990 and 2010. The average annual increase during this period was about 4.0% annually[2] with the greatest increases happening recently. Because woodchip fuel is locally produced from what is generally considered a waste product from some other forest product business, it does not have the same geopolitical pressures that fossil fuels have. Over the past twenty years, woodchip fuel costs have been far less volatile than fossil fuels.

Figure 4: Woodchip and Fossil Fuel Inflation



[2] Extrapolated from Vermont Superintendent Association School Energy Management Program data

The overall Consumer Price Index for the period between 1990 and 2010, the last year for which full data is available, increased an average of 2.7% annually. This is the annual inflation rate that was used in projecting all future labor costs, operations and maintenance costs and scheduled major repair costs for the biomass scenario.

OPERATION AND MAINTENANCE ASSUMPTIONS

It is typical for operators of fully automated woodchip heating systems of this size to spend 15-30 minutes per day to clean ashes[3] and to check on pumps, motors and controls. For the woodchip scenario, it was assumed that existing on-site staff would spend approximately one half hour per day, on average, in addition to their current boiler maintenance for 150 days per year and 20 hours during the summer months for routine maintenance. At a loaded labor rate of $25/hr, this equals $2,375 annually. An additional $6,000 in annual operational costs is assumed for electricity to run pumps, motors and pollution control equipment.

Another operations and maintenance cost that is included in the analysis is periodic repair or replacement of major items on the boiler such as the furnace refractory. It is reasonable to anticipate these types of costs on a 10-15 year cycle. For this analysis, $25,000 of scheduled maintenance was anticipated in years 10, 20 and 30 and then annualized at $2,500 per year to simulate a sinking fund for major repairs. This $2,500 was then inflated at the general annual inflation rate. It was assumed that all costs for the operation and maintenance of a biomass boiler are incremental additional costs.

STATE SCHOOL CONSTRUCTION AID

Biomass boilers are eligible for New York State school construction aid. The New York Facilities Planning Division for the State Department of Education (SED) does not like to fund new boilers until the existing boilers are fully depreciated. SED generally considers boilers fully depreciated after fifteen years although they do recognize that boilers can last a good deal longer. Since most of Canton Central School's boilers are 17 years old, the School should consult state officials about any planned construction project and get their determination on state aid directly from SED. For the analysis in this report, it was assumed that this project would receive 89% state school construction aid.

[3] Wood ash is generally not considered a hazardous material in most states and can be landfilled or land applied as a soil amendment by farmers or on-site maintenance staff.

FINANCING ASSUMPTIONS

Financing costs were included in the analysis to give facility decision makers a sense of how this project may impact their annual budget. It was assumed that the Canton Central School would be able to obtain a 20 year bond for their portion of capital costs for a biomass project at a bond interest rate of 4.5%. The bond payment schedule that was used has fixed principal payments and variable declining interest payments over the term of the bond. Other financing schedules could also create favorable cash flows depending on how much of the project costs are financed and how the remaining financing is structured. See the section in this report on Project Funding Opportunities to learn about alternative funding and financing options.

A sensitivity analysis is included in the appendices to this report that show the relative life cycle cost savings under various financing scenarios. If the School would like to see other cash flows using different financing schemes, Yellow Wood can provide additional analysis.

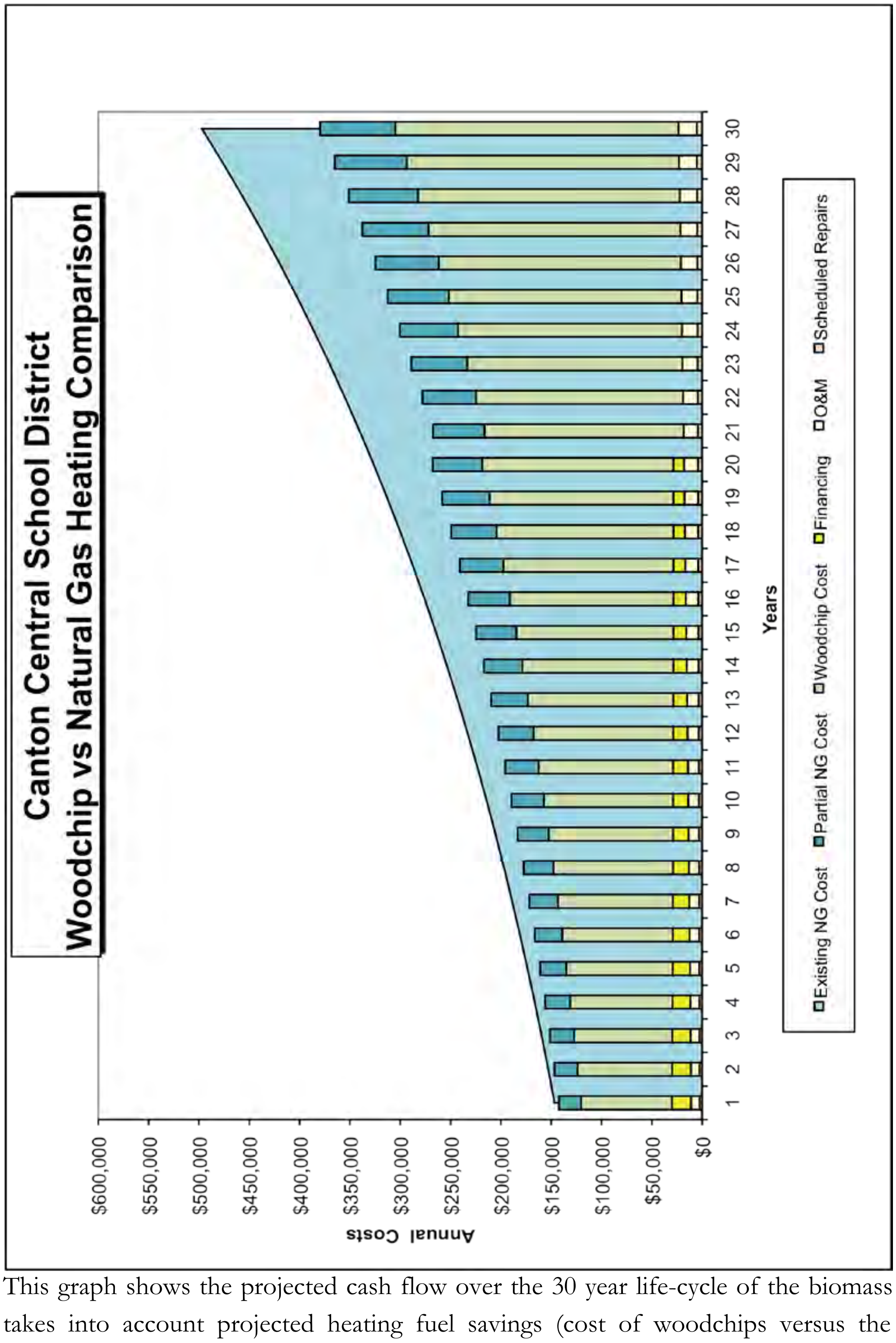
BIOMASS SCENARIO ANALYSIS

With 89% state school construction aid, a biomass project is marginally beneficial from the District's perspective. The analysis shows that the School could save nearly $616,000 in today's dollars in operating costs over the next 30 years by installing a woodchip heating system, even including debt service on the cost of the system. Annual fuel savings alone are projected to be more than $34,400 in the first year and the project should show a positive cash flow from the first year. However, the analysis does not include the cost to convert from steam to hot water as an engineering study for that project is still underway. And state school construction aid is not guaranteed for coming years. The District may want to reconsider biomass more seriously if natural gas prices increase significantly.

Table 1: Biomass Scenario Analysis Assumptions

Canton Central School					
Capital Cost Assumptions					
6.0 mmBtu woodchip hot water boiler system including installation					$600,000
70 ft stack					$35,000
Underground insulated hot water lines	$150	/LF	150	LF	$22,500
Pollution control equipment					$125,000
Biomass boilerhouse and chip storage building	$150	/SF	2,500	SF	$375,000
Thermal storage 6,000 gallon					$60,000
Interconnect to existing boiler systems					$75,000
GC markup at 10%					$129,250
Construction contingency at 15%					$213,263
Design at 12%					$196,202
Total estimated project costs					$1,831,214
State Aid at		**89%**			$1,629,780
Total Local Share					$201,434
Financing Costs					
Financing, annual interest rate					4.5%
Finance term (years)					20
1st full year debt service					$19,136
Fuel Cost Assumptions					
Current annual natural gas consumption in therms					209,491
Assumed natural gas price per therm					$0.70
Projected annual natural gas bill					$146,644
Assumed woodchip price in 1st year (per ton)					$47.50
Projected 1st year woodchip fuel bill					$90,221
Projected 1st year supplemental natural gas bill					$21,997
Inflation Assumptions					
General inflation rate (twenty year average CPI)					2.7%
Natural gas inflation rate (1990 - 2010 average for NY, US EIA)					4.3%
Woodchip inflation rate (average increase in VT from 1990 - 2010 for woodchips is 4.0%)					4.0%
O&M Assumptions					
Annual woodchip O&M cost, including electricity for additional pumps and motors and staff time for daily and yearly maintenance					$8,375
Major repairs (annualized)					$2,500
Savings					
Return on Investment					**17.1%**
Net 1st year fuel savings					**$34,426**
Total 30 year NPV cumulative savings					**$615,826**

Figure 5: Annual Cash Flow Graph for Biomass Scenario



This graph shows the projected cash flow over the 30 year life-cycle of the biomass boiler. The graph takes into account projected heating fuel savings (cost of woodchips versus the cost of propane), projected revenue and projected debt service.

Table 2: 30-Year Life Cycle Analysis Spreadsheet for Biomass Scenario

Canton Central School — **Preliminary Life Cycle Cost Estimate** — ***Woodchip - Heat Only***

Total estimated construction costs	**$1,831,214**		*Estimated state aid **$1,629,780***
Local Share:	**$201,434**		
Financing:	**4.5%**	*Assumed 20 year bond interest rate*	
Equivalent Natural Gas consumption	**209,491**	therms	15% NG= 31,424 therms
Projected first year price of Natural Gas	**$0.70**	/therm in year 1	2,235 tons if 100% woodchips for NG
Projected first year cost of Natural Gas	**$146,644**		94 therms/ton of woodchips
Estimated woodchip utilization	**85%**		
Projected woodchip consumption	**1,899**	tons	
Estimated 1st year woodchip price	**$47.50**	/ ton Year 1	
Projected 1st year woodchip cost	**$90,221**		
Projected 1st year partial NG cost	**$21,997**		
General Inflation:	**2.7%**	**annually**	*Twenty year average annual US Labor Dept. Consumer Price Index increases*
Natural Gas Inflation	**4.3%**		*Average Increase for New York Commercial NG users from 1990 - 2010 (US EIA)*
Woodchip Inflation:	**4.0%**	**annually**	*Average increase in VT from 1990 - 2010 for woodchips is 4.0%*
O & M.:	**$8,375**	**in Year 1 $**	*Estimate of additional electricity for feed system motors and additional maintenance staff time*
Major Repairs:	**$2,500**		*Contingency for major repair (e.g. refractory replacement) at Years 10, 20 and 30 annualized*

Yr.	Existing NG Cost	Financing	Woodchip Cost	Partial NG Cost	O&M	Scheduled Repairs	Total	Annual Cashflow	Cumulative Cashflow
1	$146,644	$19,136	$90,221	$21,997	$8,375	$2,500	$142,229	$4,415	$4,415
2	$152,949	$18,683	$93,830	$22,942	$8,601	$2,568	$146,624	$6,326	$10,741
3	$159,526	$18,230	$97,583	$23,929	$8,833	$2,637	$151,212	$8,315	$19,055
4	$166,386	$17,777	$101,486	$24,958	$9,072	$2,708	$156,000	$10,385	$29,441
5	$173,540	$17,323	$105,546	$26,031	$9,317	$2,781	$160,998	$12,543	$41,984
6	$181,003	$16,870	$109,767	$27,150	$9,568	$2,856	$166,212	$14,790	$56,774
7	$188,786	$16,417	$114,158	$28,318	$9,827	$2,933	$171,653	$17,133	$73,907
8	$196,904	$15,964	$118,724	$29,536	$10,092	$3,013	$177,328	$19,575	$93,482
9	$205,370	$15,510	$123,473	$30,806	$10,365	$3,094	$183,248	$22,123	$115,605
10	$214,201	$15,057	$128,412	$32,130	$10,644	$3,177	$189,421	$24,780	$140,385
11	$223,412	$14,604	$133,549	$33,512	$10,932	$3,263	$195,859	$27,553	$167,937
12	$233,019	$14,151	$138,891	$34,953	$11,227	$3,351	$202,572	$30,446	$198,384
13	$243,039	$13,697	$144,446	$36,456	$11,530	$3,442	$209,571	$33,467	$231,851
14	$253,489	$13,244	$150,224	$38,023	$11,841	$3,535	$216,868	$36,621	$268,472
15	$264,389	$12,791	$156,233	$39,658	$12,161	$3,630	$224,474	$39,915	$308,387
16	$275,758	$12,338	$162,483	$41,364	$12,489	$3,728	$232,402	$43,356	$351,744
17	$287,616	$11,885	$168,982	$43,142	$12,827	$3,829	$240,664	$46,951	$398,695
18	$299,983	$11,431	$175,741	$44,997	$13,173	$3,932	$249,275	$50,708	$449,403
19	$312,882	$10,978	$182,771	$46,932	$13,529	$4,038	$258,248	$54,634	$504,037
20	$326,336	$10,525	$190,082	$48,950	$13,894	$4,147	$267,598	$58,738	$562,775
21	$340,369		$197,685	$51,055	$14,269	$4,259	$267,269	$73,100	$635,875
22	$355,005		$205,592	$53,251	$14,654	$4,374	$277,872	$77,133	$713,008
23	$370,270		$213,816	$55,540	$15,050	$4,493	$288,899	$81,371	$794,379
24	$386,191		$222,369	$57,929	$15,456	$4,614	$300,367	$85,824	$880,203
25	$402,798		$231,263	$60,420	$15,874	$4,738	$312,295	$90,503	$970,705
26	$420,118		$240,514	$63,018	$16,302	$4,866	$324,700	$95,418	$1,066,123
27	$438,183		$250,134	$65,727	$16,742	$4,998	$337,602	$100,581	$1,166,704
28	$457,025		$260,140	$68,554	$17,194	$5,133	$351,021	$106,004	$1,272,708
29	$476,677		$270,545	$71,502	$17,659	$5,271	$364,977	$111,700	$1,384,408
30	$497,174		$281,367	$74,576	$18,135	$5,414	$379,492	$117,682	$1,502,090
Totals	$8,649,040	$296,611	$5,060,027	$1,297,356	$379,633	$113,323	$7,146,950	$1,502,090	
30 Yr. NPV at	$4,095,098	$201,434 4.5%	$2,418,148 Discount Rate	$614,265	$189,006	$56,420	$3,479,272	$615,826	

Total Annual Heating Costs	Woodchip Fuel /Year	Partial Natural Gas First Year	Woodchip System O&M /yr	Contingency Allowance / Year	Woodchip + NG + O&M + Contingency	Annual Fuel Cost Savings	Local Share Cost	Simple Payback (yrs)	30 Yr. NPV Savings	Return on Investment
$146,644	$90,221	$21,997	$8,375	$2,500	$123,092	$34,426	$201,434	5.9	$615,826	17.1%

ADDITIONAL ISSUES TO CONSIDER

ENERGY MANAGEMENT

In order to effectively manage energy use and to identify efficiency opportunities in buildings it is very important to track energy usage. Unless energy consumption is measured over time, it is difficult or impossible to know the impact of efficiency improvements or renewable energy investments. The Environmental Protection Agency has developed a public domain software program called Portfolio Manager that can track and assess energy and water consumption across an entire portfolio of buildings. Portfolio Manager can help set efficiency priorities, identify under-performing buildings, verify efficiency improvements, and receive EPA recognition for superior energy performance. Yellow Wood recommends that the School input several years' worth of energy and water use data into *Portfolio Manager* as soon as it can. The EPA *Portfolio Manager* software can be downloaded at the following address:
http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager

ENERGY EFFICIENCY

Whether Canton Central School converts to biomass or stays with natural gas, the School should use its heating fuel efficiently. The New York State Energy Research and Development Authority (NYSERDA) and/or the New York Power Authority (NYPA) can help identify and prioritize appropriate energy efficiency projects that will improve the School's infrastructure and save money. Both of these agencies can help with the evaluation of energy efficiency opportunities and provide financial incentives to upgrade and improve equipment efficiencies. If the School decides to move forward with a biomass energy project, it should work with one of these agencies to identify other efficiency projects that could be completed at the same time.

General information on efficiency programs in New York are included in the *Biomass and Green Building Resources Binder* accompanying this report.

COMMISSIONING

Building, or systems, commissioning is a process that verifies that a facility and/or system is functioning properly. The commissioning process takes place at all phases of construction, from planning to operation, to confirm that facilities and systems are performing as specified. Commissioning of a new system provides quality assurance, identifies potential equipment problems early on and provides financial savings on utility and maintenance costs during system operations. A recent study of 224 buildings found that the energy savings from commissioning new buildings had a payback period of less than five years. Additional benefits of commissioning include: improved indoor air quality, fewer deficiencies and increased system reliability. We strongly recommend that Canton Central School work with an independent, third-party, commissioning agent during the design and construction of a biomass heating system. See the *Biomass and Green Building Resources Binder* for more information on commissioning.

HOT WATER VS. STEAM HEATING DISTRIBUTION

It is our understanding that the School is considering replacing the existing boilers and upgrading the entire heating distribution system to hot water instead of steam. The costs for converting the existing heat distribution system were not included in the analysis for this report because estimating those costs was beyond the scope of this project. In addition, these are costs that could be incurred regardless of the choice of boiler fuels.

According to the US Department of Energy, steam systems are generally less efficient than hot water heating systems. In addition, hot water heat distribution is generally easier to maintain, is easier to control and is a more comfortable heat source than steam. The distribution water temperature can be adjusted more easily than steam. When it is very cold outside, the water temperature can be high which provides more heat. When the outdoor temperature is cool the distribution temperature can be set back to provide some heat, but not more than is required to make the space comfortable.

It is sometimes possible to convert existing steam distribution pipes to hot water, if the existing steam system is a two-pipe system. If the existing system is not a two-pipe system, then conversion costs can be considerably more expensive. The School should work with an engineer to understand the existing distribution system and opportunities for upgrades.

PROJECT FUNDING POSSIBILITIES

USDA FUNDING OPPORTUNITIES

2008 Farm Bill

The 2008 Farm Bill has a number of provisions that may help rural communities consider and implement renewable energy and energy efficiency projects.

- **Section 9009** provides grants for the purpose of enabling rural communities to increase their energy self-sufficiency.
- **Section 9013** provides grants to state and local governments to acquire wood energy systems.

These grants and loan guarantee programs are competitive. The School should check with the local USDA office to express interest and to get program updates.

Rural Community Facilities Grant and Loan Program

The USDA provides grants and loans to assist the development of essential community facilities. Grants can be used to construct, enlarge or improve community facilities for health care, public safety and other community and public services. The amount of grant assistance depends on the median household income and the population of the community where the project is located.

These grants and loans are also competitive. Highest priority projects are those that serve small communities, those that serve low-income communities and those that are highly leveraged with other loan and grant awards.

For more information about USDA programs and services, contact your local USDA office. Information on programs and contact information is provided in the *Biomass and Green Building Resources* binder.

MUNICIPAL LEASE PURCHASE

As a municipal entity, Canton Central School may be eligible for a municipal lease/purchase arrangement to finance the anticipated project costs for a biomass heating system. A municipal lease is a contract that has many of the characteristics of a standard commercial lease, with at least two primary differences:

- In a municipal lease, the intent of the lessee is to purchase and take title to the equipment. The financing is a full payout contract with no significant residual or balloon payments at the end of the lease term.

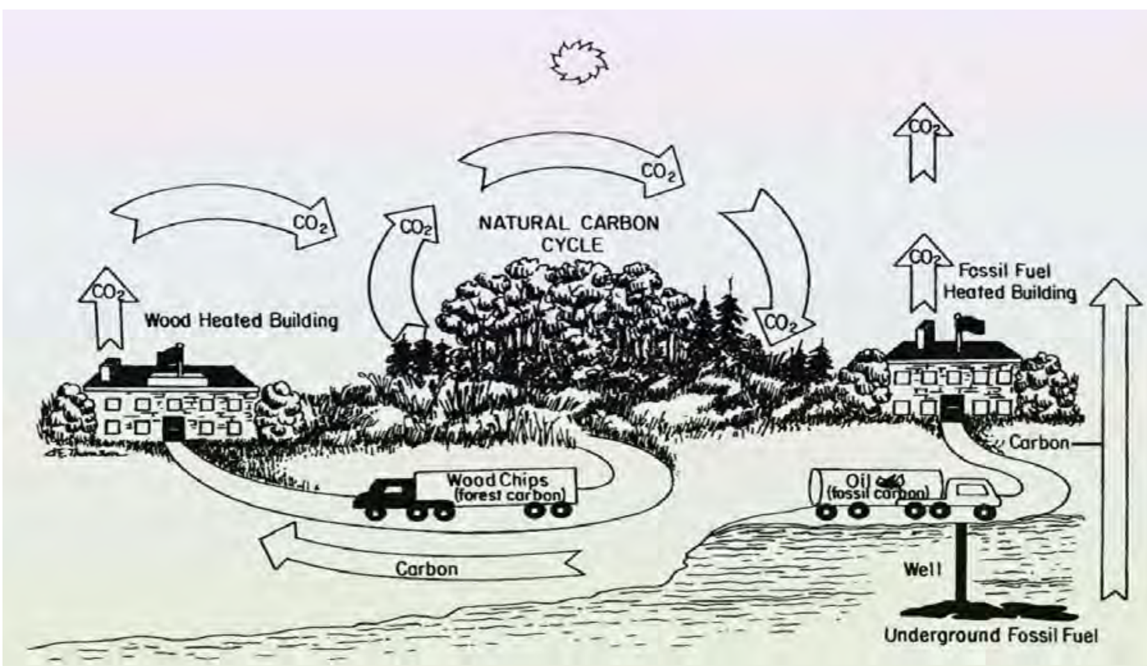
- The lease payments include the return of principal and interest, with the interest being exempt from Federal income taxation to the recipient. Because the interest is exempt from federal tax, a tax-exempt lease offers the lessee a significant cost savings when compared to conventional leasing.

There are a number of companies that provide municipal leases. Information about municipal leases is included in the *Biomass and Green Building Resources Binder* accompanying this report.

CARBON OFFSETS

While fossil fuels introduce carbon that has been sequestered for millions of years into the atmosphere, the carbon dioxide emitted from burning biomass comes from carbon that is already above the ground and in the carbon cycle. Biomass fuels typically come from the waste of some other industrial activity such as a logging operation or from sawmill production. The carbon from this waste would soon wind up in the atmosphere whether it was left to decompose or it was burned as slash. There are few measures Canton Central School could undertake that would reduce its carbon footprint more than switching their heating fuel use from natural gas to a biomass fuel.

Figure 6: Carbon Cycle Illustration[4]



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[4] Illustration taken from a handout produced by the Biomass Energy Resource Center

Carbon offsets help fund projects that reduce greenhouse gases emissions. Carbon offset providers sell the greenhouse gas reductions associated with projects like wind farms or biomass projects to customers who want to offset the emissions they caused by flying, driving, or using electricity. Selling offsets is a way for some renewable energy projects to become more financially viable. Buying offsets is a way for companies and individuals to compensate for the CO_2 pollution they create.

For a biomass heat-only project, a Btu-for-Btu displacement of heating fuel (based on historic purchase records) by biomass is assumed over the project's predicted operating life. CO_2 avoidance is based on the emissions profile (Lbs. CO_2 /Btu) of the displaced fuel. The US EPA calculates that 11.7 lbs. of CO_2 is produced from each therm of natural gas consumed. It is projected that the Canton Central School can offset approximately 178,067 therms of natural gas per year by replacing that heat using biomass. This is equivalent to about 1,042 tons of CO_2 annually. The market value of this type of offset is between $3/ton and $5/ton. These offsets can be negotiated as either a lump sum offset for up to 10 years or can be paid out as an annual payment. This could mean annual payments of $3,100 - $5,200 or a lump sum up front payment of as much as $52,000.

There are a number of companies that are interested in contributing to the construction of new sources of clean and renewable energy through carbon offsets. Information about carbon offsets is included in the *Biomass and Green Building Resources* binder accompanying this report.

PERMITTING

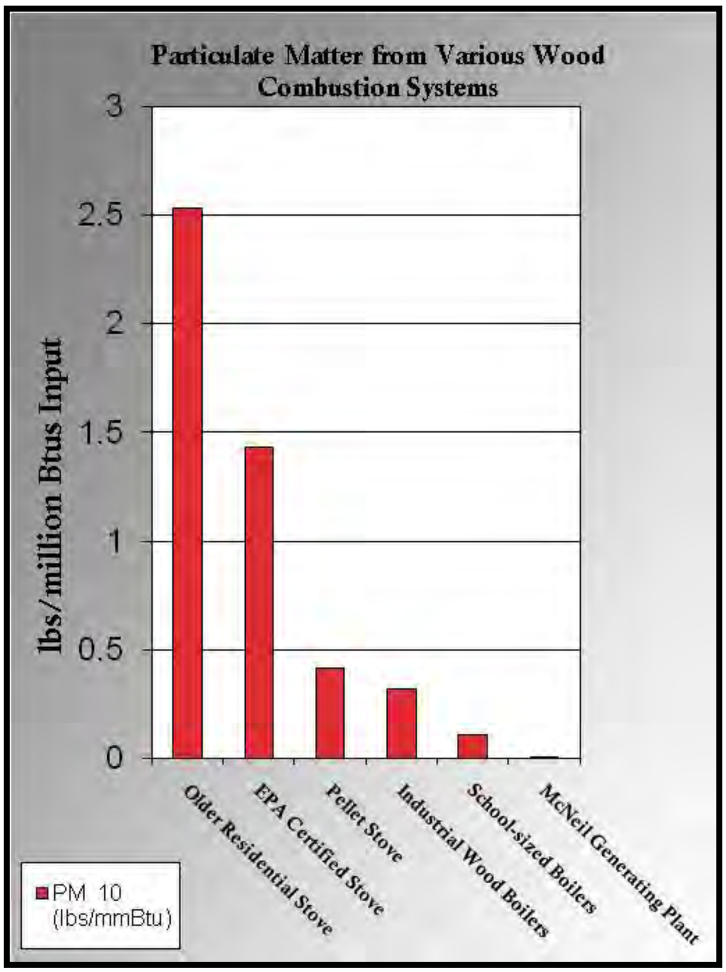
Modern biomass boiler technology is both clean and efficient. Controls moderate both the biomass fuel and air to create either a small hot fire or a large hot fire depending on heat demand from the building. Under full load, modern woodchip boilers routinely operate at steady state efficiencies of 70% – 75%. Operating temperatures in commercial scale biomass boilers can reach up to 2,000 degrees and more, completely eliminating creosote and the need to clean stacks. The amount of ash produced from a 25 ton tractor trailer load of green hardwood chips can fit in a 25 gallon trash can, is not considered a hazardous waste and can be used as a soil amendment on lawns, gardens and playing fields.

However, as with any combustion process, there are emissions from biomass boilers. There is no question that natural gas is the cleanest fuel used for heating. However, biomass compares favorably with fuel oil and modern commercial scale biomass boilers with the appropriate pollution control devices can burn very cleanly and efficiently.

The pollutant of greatest concern with biomass is particulates (PM_{10}). Biomass boilers clearly generate more particulates than fuel oil or gas boilers. That is why it is important to install appropriate pollution control equipment. Many modern types of emission control equipment, capable of reducing particulate matter emissions from 50-99 percent, are commercially available in the US. The most common emission control equipment technologies are baghouses, cyclones, multi-cyclones, electrostatic precipitators, and wet scrubbers. Appropriate emission control equipment technologies should be identified in consultation with local air quality regulators. The emissions from a modern woodchip boiler are much less than most people think.

One of the most common misconceptions about institutional/commercial biomass energy systems comes from the experience people have with residential wood stoves and outdoor wood boilers. In general, an institutional/commercial-scale wood energy system emits only one fifteenth (seven percent) the PM_{10} of the average wood stove on a Btu basis. Over the course of a year, a large, woodchip heated school in a climate like Vermont may have the same particulate emissions as four or five houses heated with wood stoves.

Figure 7: Particulate Emissions[5]



New EPA Regulations

On February 21, 2011, the Environmental Protection Agency (EPA) issued a final rule that will reduce emissions of toxic air pollutants (including mercury, metals and organic air toxics, including dioxins) from existing and new industrial, commercial and institutional boilers. For area source boilers (those that emit less than 10 tons per year (tpy) of any single air toxic or less than 25 tpy of any combination of air toxics) the EPA is issuing regulations based on boiler design. Biomass boilers with heat input equal to or greater than 10 million Btu per hour must meet emission limits for particulate matter (PM) only. Biomass boilers with heat input less than 10 million Btu must perform a boiler tune-up every two years.

[5] Excerpted from a handout produced by the Biomass Energy Resource Center

The EPA has also issued regulations based on boiler size for major source facilities (those that emit or have the potential to emit 10 or more tpy of any single air toxic or 25 tpy or more of any combination of air toxics). For large boilers, those with a heat input capacity equal to or greater than 10 mmBtu/hr, the EPA establishes numeric emission limits for mercury, dioxin, particulate matter, hydrogen chloride and carbon monoxide. In addition, the EPA will require monitoring to assure the boiler and pollution controls are operating properly and compliant with emission requirements. For all new biomass boilers at major source facilities with a heat capacity of less than 10 mmBtu/hr, the EPA has established a "work practice rule" instead of numeric emission limits.

Up-to-date information on EPA emission requirements is available at:
www.epa.gov/airquality/combustion/

In order to install a new woodchip boiler, it is often necessary to obtain an air quality permit or an amendment to an existing permit. For a woodchip boiler, the permit would likely include requirements for pollution control equipment along with a requirement for a tall stack to help with dispersion. Costs for pollution control equipment are included in the cost estimates for the woodchip scenario analyses in this report. Other permit conditions might include testing for emissions and efficiency, keeping records of fuel consumption and test results and making periodic submittals to regulatory agencies.

CONCLUSIONS AND RECOMMENDATIONS

The analysis provided in this report, assuming the School receives 89% state school construction aid, indicates that Canton Central School could save over $615,000 in operating costs over 30 years in today's dollars even when the cost of financing is included. The analysis shows more than $34,400 in fuel savings in the first year alone. However, a biomass heating project does not look favorable at this time if the School is not able to obtain full state school construction aid for the project.

This report analyzes the opportunity to utilize wood energy at Canton Central School. While investing in a woodchip system is not practical at this time due to the current price of natural gas, as natural gas prices increase, installation of a woodchip system may become a better investment for the School. The sensitivity analysis, located in Appendix A, indicates that even without state aid, a woodchip heating project looks favorable when natural gas prices climb to $1.00 per therm.

Regardless of whether or not Canton Central School moves forward with a biomass project we recommend the school consider the following:

5. The School should consider energy efficiency improvements simultaneously with boiler upgrades. The efficiency of the building envelope and ventilation equipment need to be considered when sizing new boiler equipment. The New York State Energy and Research Authority (NYSERDA) and/or the New York Power Authority (NYPA) should be engaged to develop comprehensive energy efficiency recommendations and proposals for incentives for efficiency upgrades before undertaking a major building project. Information on energy efficiency programs and incentives is included in the Resource Binder accompanying this report.
6. In order to effectively measure progress toward energy efficiency goals historical energy consumption data should be collected and updated frequently. There are many tools to help the School accomplish this. One such tool is the EPA Energy Star Portfolio Manager software. It is free public domain software that helps facility managers track energy and water use. This software can be downloaded at: http://www.energystar.gov/index.cfm?c=evaluate_performance.bus_portfoliomanager
7. The School should also consider the addition of solar hot water generation at the time of the boiler upgrade. Solar hot water with thermal storage could help to offset the School's heat load.
8. The School may want to consider converting the existing steam distribution system to a hot water system – this would depend on the existing condition of the distribution system. According to the US Department of Energy, steam systems are generally less efficient than hot water heating systems, but the efficiency gain of upgrading to hot water is probably not worth the expense. It is sometimes possible to convert existing steam distribution pipes to hot water heating, which would be less expensive – this is generally only feasible if the existing steam

system is a newer two-pipe system. The School should work with an engineer to understand the existing distribution system and opportunities for upgrades.

If the School does decide to move forward with a biomass project we also recommend taking the following steps:

1. Hire an engineering firm to help refine the project concept and to obtain firm local estimates on project costs. The US Forest Service may be able to provide some technical assistance from an engineering team with biomass experience. If the School moves forward with this project, they should contact Lew McCreery, the US Forest Service Biomass Coordinator for the Northeastern Area to see what assistance can be provided. Contact Lew at (304)285-1538 or lmccreery@fs.fed.us

2. The School should identify any heating system improvements it plans to undertake and include those projects with the biomass project. It is more cost effective to implement boiler room upgrades and heating distribution improvements at the same time a new boiler system is installed.

3. Key decision makers should tour facilities that have biomass energy systems and talk with systems operators to better understand the technology. Vermont has over forty schools that heat with wood and New York also has several biomass energy systems that could be comparable.

4. Concurrent with the design of the project, the School should cultivate potential biomass fuel suppliers. School staff should work with the State of New York Wood Utilization program staff to identify potential New York woodchip suppliers. Sloane Crawford is currently the leader of that program, his contact information is below.

   Sloane Crawford
   Program Leader
   NYS Forest Utilization Program
   625 Broadway
   Albany, NY 12233-4253
   Phone: (518) 402-9415
   Fax: (518) 402-9028
   sncrawfo@gw.dec.state.ny.us

WHO WE ARE

Yellow Wood Associates

Yellow Wood Associates (Yellow Wood) is a woman-owned small business specializing in rural community economic development since 1985. Yellow Wood has experience in green infrastructure, program evaluation, business development, market research, business plans, feasibility studies, and strategic planning for rural communities. Yellow Wood provides a range of services that include measurement training, facilitation, research, and program management.

Richmond Energy Associates, LLC

Richmond Energy Associates, LLC was created in 1997 to provide consulting services to business and organizations on energy efficiency and renewable energy program design and implementation. Richmond Energy has extensive experience in wood energy systems. Jeff Forward provides analysis and project management on specific biomass projects and works with state, regional and federal agencies to develop initiatives to promote biomass utilization around the country. In addition to his own consulting business, he is also a Senior Associate with Yellow Wood.

APPENDICES

APPENDIX A: SENSITIVITY ANALYSIS

Table 3 is a sensitivity analysis showing the Net Present Value (NPV) of the installation of a woodchip heating system based on varying percentages of state school construction aid and the price of natural gas. In this analysis all of the assumed values are the same as what is presented in Table 1 of this report, while the percentage of state aid and the cost of natural gas are adjusted. Everything to the left of the red line indicates that the 30-year NPV would be negative. Everything to the right of the red line shows a positive NPV. For example, if the school receives no state aid, the biomass project would only show a positive 30-year NPV if the school pays $1.00 per therm or more for natural gas.

Table 3: 30-Year Net Present Value (NPV) when State School Construction Aid and Natural Gas Prices Vary

Natural Gas Price	30 year NPV Relative to % of State School Construction Aid				
	0%	30%	50%	75%	90%
$0.70	($1,013,954)	($464,590)	($98,347)	$359,456	$634,138
$0.75	($765,323)	($215,959)	$150,284	$608,087	$882,769
$0.80	($516,692)	$32,672	$398,915	$856,718	$1,131,400
$0.85	($268,061)	$281,303	$647,546	$1,105,349	$1,380,031
$0.90	($19,430)	$529,934	$896,177	$1,353,980	$1,628,662
$1.00	$477,832	$1,027,196	$1,393,439	$1,851,242	$2,125,924

APPENDIX B: DISCUSSION OF BIOMASS FUELS

Purchasing wood fuel is a different exercise than purchasing fossil fuels. While conventional fuels are delivered to the site with little interaction from facility managers, biomass fuel suppliers will need to be cultivated and educated about the type of fuel needed, its characteristics and the frequency of deliveries. Concurrently with designing a wood-energy system, Canton Central School should also be cultivating potential biomass fuel suppliers.

Potential wood fuel suppliers include sawmills, loggers, chip brokers and large industrial users such as paper mills or power plants. Many of these forest products producers already make woodchips for pulp and to reduce waste, but may not have much experience dealing with the needs of smaller volume customers. Woodchips produced for institutional/commercial biomass boilers have more stringent specifications than those produced for large industrial customers. And woodchip fuel may need to be delivered in different trailers.

When talking to potential woodchip fuel suppliers, it is important to have the wood fuel specification in mind. A one to three inch square chip is ideal. If possible, woodchips for institutional/commercial biomass systems will come from logs that are debarked prior to chipping because bark produces more ash which translates into a little more daily maintenance. Pieces or small branches that are six inches or longer can jam augers and conveyors which will interrupt the operation of automated fuel handling equipment. Institutional/commercial scale biomass boiler systems in the Northeast are typically designed to operate with wood fuel that is within a 35% to 45% range for moisture content.

Typically institutional/commercial biomass systems of this scale have limited chip storage capacity which means they may need deliveries on relatively short notice. Woodchip fuel suppliers will need to be within a 100 to 150 mile radius or so of the user, the closer the better, as transportation costs will affect price. Chip deliveries are typically made in "live bottom" trailers that will self unload into below-grade chip storage bins. Therefore, potential suppliers must have access to a self-unloading trailer for deliveries.

It is possible to design a wood-energy system that uses any one of a variety of biomass fuels, but green hardwood chips make the best fuel. If it is readily available, it should be the fuel of choice. In addition, users should focus on reliability of supply and consistency of the fuel rather than just lowest cost. The goal should be to minimize maintenance and optimize system performance.

Whichever fuel is used, the fuel needs to be part of the combustion system design process, and the wood system should be operated using the fuel it is set up to use. Ideally, sample fuel chips should be sent to the manufacturer of the biomass heating equipment so that they can design the fuel handling equipment around the type of fuel and calibrate the system properly when setting the system up. No system handles widely varying fuel types at the same time very well. A system can be re-calibrated for a different fuel, but the most practical approach is to stick with one fuel, at least for a given heating season. If, for some reason, that fuel becomes unavailable, the manufacturer of the equipment should be consulted to help reconfigure or retune the system for another fuel.

It is best to try to locate several potential suppliers. By doing so, Canton Central School will have the security of knowing there will be back-up in case of an interruption from their primary supplier. This will also generate some competition. Contact the New York State Forest Utilization Program (http://www.dec.ny.gov/lands/4963.html) for a list of local suppliers. Contact information for the current lead of the program is provided below.

Sloane Crawford
Program Leader
NYS Forest Utilization Program
625 Broadway
Albany, NY 12233-4253
Phone: (518) 402-9415
Fax: (518) 402-9028
sncrawfo@gw.dec.state.ny.us

The bottom line is that both Canton Central School and fuel suppliers need to clearly understand the characteristics of fuel needed for their particular system. Consistent particle size and moisture content is particularly important for institutional/commercial customers, and Canton Central School should insist on the quality of the chip. A sample fuel specification is included in the *Biomass and Green Building Resources Binder* to give an idea of the types of characteristics to look for in woodchip fuel. Below is a description of the advantages and disadvantages of different types of biomass fuels in order of preference.

Green Hardwood Chips

A consistent green hardwood chip is the easiest fuel for institutional/commercial scale automated biomass heating systems to handle. Rarely will they jam an auger or conveyor. Green chips burn somewhat cooler than most other biomass fuels making it easier to control the combustion. With proper controls, they burn very cleanly with minimal particulate emissions and little ash. They have less dust than other biomass fuels so they are less messy and safer to handle. Ideally moisture content will be between 35% and 45% on a wet basis. Green hardwood chips can come from sawmill residues or timber harvest operations.

Mill Residues vs. Harvest Residues

Woodchips can be produced at sawmills or other primary wood products industrial sites as part of their waste wood disposal process. Mill residues are typically the most desirable source of fuel woodchips. Mills can produce a bark-free chip with few long pieces or branches that can jam augers and fuel conveyors. A mill supplier can easily calculate trucking costs and can negotiate dependable delivery at a consistent price.

Another potential type of wood fuel is whole tree chips which are produced as part of tree harvesting. Whole tree chips tend to be a dirtier fuel than sawmill residues and may contain small branches, bark, twigs and leaves. The longer pieces can jam the relatively small augers of an institutional/commercial scale biomass system and can add to the daily maintenance because they produce more ash.

The bole of a tree is the de-limbed trunk or stem. Chips made from boles are in-between the quality of a sawmill chip and a whole tree chip. Bole-tree chips tend to have fewer twigs and long stringers than whole tree chips. Both bole-chips and whole-tree chips can be potentially good sources for biomass fuels, although they have a greater likelihood of including oversized chips and they will produce somewhat more ash, compared to mill residues.

Softwood Chips

Green softwood chips will generally have less energy and more water content per truckload, and therefore they will be more expensive to transport than hardwood chips. As long as the combustion and fuel handling equipment is properly calibrated for softwood chips, an automated woodchip heating system can operate satisfactorily with softwood chips. Softwoods tend to have higher moisture contents and can range up to 60% moisture on a wet basis. The best biomass fuel will have less than 50% moisture. One species to avoid altogether is white pine. It has a very high moisture content and therefore relatively low bulk density. The experience in Vermont schools with white pine is that it is a poor biomass fuel for institutional/commercial-scale woodchip systems.

Dry Chips vs. Green Chips

Dry chips (less than 20% moisture on a wet basis) burn considerably hotter than green chips and typically have more dust. The increased operating temperature can deteriorate furnace refractory faster increasing maintenance costs slightly. The dust can make for a somewhat dirtier boiler room which will be a problem for some maintenance staff. Dry chips are also easier to accidentally ignite in the fuel storage bin or fuel handling system. If dry chips are used, the combustion equipment needs to be carefully calibrated to handle these higher temperatures. Dry chips are not generally recommended for institutional/commercial settings.

Bark

Bark has a high energy value, but it also comes with significant maintenance costs. It produces a considerable amount of ash that needs disposal; it can create more smoke than green chips; and it can cause other routine maintenance problems such as frequent jamming of augers from rocks. Bark can be an inexpensive fuel, but the additional maintenance costs make it unattractive for institutional/commercial biomass systems.

Sawdust and Shavings

Sawdust and shavings should ordinarily be ruled out for the institutional/commercial wood heating market. Dry sawdust can be dusty to handle and raises fire safety and explosion issues. Shavings are also dusty and easily ignited and are difficult to handle with typical fuel handling equipment. This fuel type can work fine in an industrial setting, but institutions typically do not have the maintenance staff that can provide the supervision that these fuels need.

Ground or "Hog" Fuel

Ground or "Hog" fuel is common in the logging industry. It is typically made by grinding any manner of woody material by using a "tub grinder." Hog fuel does not typically make good wood fuel for institutional scale biomass energy systems. The fuel is "dirty" meaning there are many contaminants such as bark, dirt, gravel and foreign objects. The material is typically rough and is irregularly shaped making it difficult to handle in the relatively small augers and conveyors of institutional scale wood fuel handling equipment. Additionally, since the fuel might come from a variety of sources, hog fuel can have a wider range of moisture content than wood chip fuel. Hog fuel can work well in industrial biomass energy systems, but institutions typically do not have the maintenance staff that can deal with these kinds of fuels.

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  - USDA Rural Energy For America Program (REAP)
  - NYSERDA Existing Facilities Program
  - National Clearinghouse for Educational Facilities Stimulus Funding and Tax Credit Bonds for School Construction
  - *Native*Energy
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  - Advanced Energy Design Guide (ON ENCLOSED CD)
  - Collaborative for High Performance Schools and Green Schools Resources (ON ENCLOSED CD)
  - EPA Indoor Air Quality Tools for Schools Reference Guide (ON ENCLOSED CD)
  - US Department of Energy K-12 Energy Lessons and Activities (ON ENCLOSED CD)
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  - Biomass Boiler and Furnace Emissions and Safety Regulations in the Northeast States (ON ENCLOSED CD)
  - Woodchip Heating Systems, *A Guide for Institutional and Commercial Installations* (ON ENCLOSED CD)