DOVETAIL
PARTNERS, INC

U.S. Endowment for Forestry & Communities, Inc.

Regional School Unit 74
Maine, USA
Biomass Energy Case Study

Grant 2012-002: Next Steps in Scaling-up Woody Biomass Energy:
Learning & Priorities
March 25, 2013

Photos clockwise, from top left: Carrabec Community School, Garrett Schenk School, Carrabec High School, and Solon Elementary School

Table of Contents

Acknowledgements 1

Introduction 1

Project Background 1

Innovative Approach 2

- Strategy #1: Minimize Capital Costs and Demand Load by Implementing Energy Efficiency Improvements 3
- Strategy #2: Apply the 90/50 Rule for Boiler Sizing 3
- Strategy #3: Utilize a Modular Design 4
- Strategy #4: Implement a Collaborative, District-Wide Approach, That Includes Standardized Design and Material Reuse 4
- Strategy #5: Coordinate Engineering and Integrate Work Flow Between Projects 5

Project Economics 6

System Components 7

Fuel Supply 9

Co-Benefits 9

Conclusion 10

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Introduction

This case study describes how four schools in Maine (part of Regional School Unit 74) successfully converted to biomass pellet systems, outlining the complex process of retrofitting existing facilities to biomass systems. These schools illustrate a district-wide, aggregated approach to converting to biomass energy systems, and they present an especially systematic approach (emphasizing capital cost and demand load minimization) in the implementation of a biomass conversion project. The five interconnected strategies that the district relied on during the development of the project represent best practices that can help increase efficiencies and minimize the costs for carrying out biomass projects in other locations.

Project Background

Figure 1. RSU 74's Four Schools

GENERAL INFORMATION	
FACILITY	**Regional School Unit #74**
Total Building Area (ft^2)*	119,180
Experience Total (years)	1
Project Type	Retrofit
EQUIPMENT SPECIFICATIONS	
Boiler Manufacturer	ÖkoFEN
Boiler Model	PES56
Output MBtu/hr	191 x 8 Boilers
Biomass Percent of Building Heating	> 90%
Backup Unit	Heating Oil
FUEL SPECIFICATIONS	
Fuel Type	Wood Pellets
Supply Radius (miles)	15
Delivery Frequency	Biweekly/Bimonthly
Cost Per Ton Delivered	$ 175
Moisture Content	5%
Fuel Storage Capacity (tons)	11-21
Annual Consumption (tons)	375
Fuel Replaced by Biomass	Heating Oil
Annual Biomass Fuel Cost	$ 65,625
Annual Heating Cost Savings	$ 100,000
PROJECT ECONOMICS	
Project Total Funding	$ 697,000
Qualified School Construction Bond	$ 407,000
USDA Forest Service Grant	$ 250,000
Efficiency Maine Grant	$ 40,000
Project Total Cost	$ 697,000
Equipment Cost	$ 347,000
Installation Cost	$ 350,000
Annual O&M Costs	$ 15,000
Financial Analysis	
Annualized Rate of Return (10 yr)	14.8%
Internal Rate of Return (25 yr)	28.1%
Payback Period (years)**	7

*Building area includes all four schools
** Payback period does not include avoided costs

Beginning July 2011 and finishing in September that same year, it took Maine's Regional School Unit 74 (RSU 74) only a few months to successfully convert four of its schools to biomass pellet boilers. Much of the success can be attributed to what Ken Coville, the district's superintendent, describes as "a dramatic new approach that utilized and integrated a multi-facility plan." The plan included providing base-load heating through multiple smaller boiler units while also implementing a number of energy conservation measures that helped reduce the overall heat demand.

Around the time of this conversion, prices for heating oil were peaking at nearly $3.70 per gallon, which had a very negative impact on RSU 74's schools. As a result, the district began to research other options with which to heat their facilities. They were very interested in learning about the cost savings and maintenance reductions achieved by a neighboring school that had converted their heating oil-fueled systems to wood pellets. The nearby experience also provided an opportunity to evaluate potential problems associated with different feedstocks.

Figure 2. Operating Pellet Unit

Four years earlier, a neighboring school had decided to install a corn stove to heat their bus garage. After the system was installed, it became quickly apparent that corn was a poor fuel choice for their situation. The corn fuel had very high moisture content and this resulted in inconsistent heat, greater than expected maintenance, and over-reliance on backup oil heating. Rather than continue to deal with the issues using corn, the school decided to switch to wood pellets as a fuel source. After switching to the wood pellet system, the neighboring school did not experience any of the technical issues that had occurred with corn, and they were able to substantially reduce their heating costs. The school's success using wood pellet heating for their bus garage led to the development of additional projects to convert other school buildings to wood pellet boilers. The school was able to obtain USDA and DOE grants that covered eighty percent of the cost for the new pellet boilers.

This success inspired RSU 74 to research what it would take to convert to a similar wood system. In 2010, they learned that it would cost $450,000 to convert one of the four schools, the Carrabec High School, to pellets using the same system design of the neighboring district. Unfortunately, the grants that their neighboring school was able to take advantage of were not available to cover the cost of Carrabec's conversion, and the project's capital cost would offset the cost savings from converting to the lower cost fuel source.


Figure 3. Kenneth Coville by ÖkoFEN Pellet Boilers

Innovative Approach

Not to be deterred, the district decided to continue on without a grant by researching means to lower the capital conversion costs. When RSU 74 began implementing the project in July 2011, their effort to convert the heating systems in the multiple schools was guided by a number of central objectives:

- Reduce heating fuel costs
- Reduce heating system maintenance and replacement costs
- Support the local forestry industry

- Support the local biomass energy industry
- Reduce carbon footprint
- Reduce imported energy and enhance national security

To help achieve these goals, the district carried out the school biomass conversions using a set of five strategies that represent the best practices of the project. Each of the strategies are discussed in more detail below.

Strategy #1: Minimize Capital Costs and Demand Load by Implementing Energy Efficiency Improvements

To provide a better return on investment, the district realized that the best strategy would be to focus on reducing the project's capital costs and their demand load. To achieve this goal, they first carried out energy audits for each school to analyze energy flows and identify where improvements could be made to conserve energy and minimize their heating requirements.

Once the audits were complete, they shifted their focus to making energy efficiency improvements to the schools. They discovered that Solon Elementary School was very energy efficient. The building already had good insulation and benefited from solar passive gain in a tower that also has active heat transfer, so no additional work had to be done. The other schools, however, needed improvements. *Garret Schenck School was able to reduce their heating demand by forty-five percent by upgrading their heating controls with variable speed motors and modernizing the system by correcting design flaws. They used the same approach for the other schools, modernizing their setup and controls, which led to twelve percent reductions in their heat load.*

Figure 4. Pellet System Burner

Strategy #2: Apply the 90/50 Rule for Boiler Sizing

The second major strategy involved closely adhering to the 90/50 rule, which is a boiler sizing best practice that can significantly reduce project costs and the payback period while improving system efficiency. It can be costly and inefficient to size boilers to one hundred percent of peak demand. Instead, many facilities should be able to meet ninety percent of their annual heating demand by sizing a boiler to fifty percent of peak heating load demand and letting a backup system meet peak demand. *This change in sizing frequently results in being*

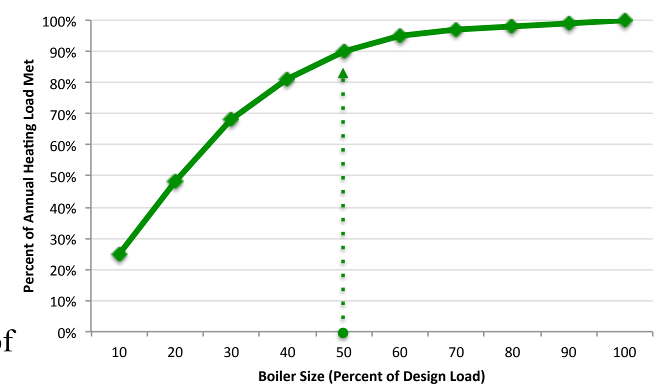

Figure 5. Percent of Annual Heating Load Met vs. Boiler Size

able to use a smaller, less expensive system and operating it more efficiently (e.g., using more of its operating capacity a greater percentage of the time).[1]

RSU 74 found that they could use their existing oil boilers as excess capacity to meet the occasional peak demand of the various school buildings, which meant that the required boiler size of the pellet systems could be reduced, thereby achieving significant capital cost savings. *Critically, because the pellet boilers could be smaller in size, the schools did not have to construct new buildings to house the boilers.* Other costs were also reduced through this approach including lower trenching, piping, mechanical, and stack costs (in one school, they were able to reuse their existing stack).

Overall, these first two strategies resulted in cutting the capital cost of the boiler conversions by an estimated forty percent.

Strategy #3: Utilize a Modular Design

Using a modular design consisting of numerous smaller units—rather than one large unit—was another key design choice that led to much higher system efficiencies. By using a modular design, the schools can alter the pellet boiler's demand/capacity based on what is needed at any given time. Consequently, this has allowed the schools to maximize their efficiency levels by operating fewer units at higher operating levels (and thus high efficiency) during frequent low demand times rather than operating a large unit at very low, and very inefficient, levels during those periods. This approach has led to a reduction in maintenance costs because less material is combusted and the material that is burned is much cleaner.

Figure 6. Interconnected Modular Design

Counterintuitively the cost of multiple smaller units (three at one school) was actually lower than the projected cost of purchasing a single larger boiler. This is likely because the units that were selected used standardized assembly production rather than more custom production of larger units. *Also, by placing an order for eight standardized units, the school district received volume discounting on the per-unit cost and significantly reduced delivery costs.*

Strategy #4: Implement a Collaborative, District-Wide Approach, That Includes Standardized Design and Material Reuse

Having a district-wide approach for the project was another key strategy wherein each project was carried out simultaneously and with a coordinated workflow. "The project was designed to be viable independent of collaborative efforts," Superintendent Coville said, "but it was also designed where possible to be compatible with state-wide initiatives to promote energy conservation and wood to energy conversions." Consequently, a standardized design for the boiler systems was adopted that could be flexibly adapted to the individual schools.

[1] Plant, Andrew. "Sizing Your Biomass Boiler to Fit Your Needs." University of Maine, 2010.

Relying on a standardized design approach also helped maximize the use of situational opportunities. The school district focused heavily on refitting existing resources in each of the schools to reduce disposal or replacement costs. For instance, they relocated existing oil boilers between the four schools so that they better matched the peak demand of each school. They also had an underground fuel tank that would have had to be removed, but they decided to convert it to a diesel fueling station. This decision has saved 1,000 gallons per year in refueling and between $4,000-$5,000 in fuel-related costs because, previously, the closest place to refuel was thirty miles away. Interestingly, the conversion cost was actually less than the projected removal cost that would have been required by the Maine Department of Environmental Protection. Piping, pumps, and valves from the existing systems were also reutilized when possible, and any new purchases were standardized across the four schools to reduce down stream maintenance costs.

Figure 7. Heating Oil Backup System

Figure 8. Diesel Fueling Station

Strategy #5: Coordinate Engineering and Integrate Work Flow Between Projects

Related to the district's coordinated district-wide approach, Coville emphasized the benefits of relying on in-house engineering for the design of the projects. RSU 74 used one engineering firm to coordinate all of the installations at the various schools. *This approach helped ensure that all of the designs melded together well and a systematic workflow was carefully adhered to so that the work was carried out as efficiently as possible.* The school selected the firm that had completed the facility energy audits to coordinate the project based on their demonstrated competencies, intimate knowledge of the facility systems, and their independence from the other project vendors.

All in all, from the first workday to operational commissioning, RSU 74's biomass project only took three months to complete. Now, Carrabec Community School (45,000 ft^2), Carrabec High School (47,200 ft^2), Solon Elementary School (10,230 ft^2), and Garrett Schenk School (16,750 ft^2) have one full heating season under their belts using ÖkoFEN PES56 wood pellet boilers. The conversion went so smoothly that some people did not believe that anything had changed. As Ken Coville explained, the most common misperception about the systems was when people would ask, "Are you ever going to turn on those wood boilers?" This arose from an expectation of traditional wood smoke exhaust. Some community members had to actually be shown the boilers in operation to believe they were working.

Project Economics

Overall, the total project cost roughly $697,000: $172,000 for the eight boilers, $175,000 for other equipment (including boiler related piping insulation, stacks, heating controls, operation equipment, and diesel pumping station equipment), and $350,000 for installation, heating system retro-commissioning, and labor and engineering costs.

Because the project's predicted return on investment was very favorable, the school district did not encounter any significant hurdles in obtaining project funding. Additionally, this calculated investment return did not take into account any avoided costs, such as the replacement of aging equipment, which was a further benefit of the conversion. To help fund the project, RSU 74 received a $250,000 USDA Forest Service grant and a $40,000 Efficiency Maine Grant. The Forestry Department and Efficiency Maine also provided technical assistance and support. A Qualified School Construction Bond covered the remaining $407,000 project cost.

Qualified School Construction Bonds
Tax credit bonds for public school facilities used for construction, rehabilitation, or repair activities. Rather than receiving interest payments from schools, lenders receive tax credits issued by the federal government.

The schools also took advantage of a number of co-benefits associated with biomass energy that acted as "application enhancers" for the project funding. For instance, full-time employment (created or retained) was an important criterion of the USDA Forest Service grant and a reduction of the schools' base heating demand was key to the Efficiency Maine grant

Maintaining the systems has provided cost savings. The pellet systems require less maintenance time with lower maintenance costs. Total cleaning of the units is only required on an annual basis. These are very automated boilers and on average require no more than an hour of maintenance per week. Gross maintenance for all of RSU 74's pellet systems totals roughly $15,000 per year, which includes the labor for daily checks, ash removal, and so on. This maintenance is carried out by existing in-house staff that received maintenance training as part of the project. As such, while this maintenance is an attributable cost, it is not a net new expense. In fact, overall maintenance has been less expensive with the new pellet units compared to what it previously cost to maintain the school's old heating oil boilers.

In addition to operational cost savings on an annual basis, the conversion allowed RSU 74 to finance the replacement of aging equipment through those same annual savings. Therefore, the avoided costs of not having to replace the existing obsolete systems is an additional uncredited, but significant, savings (at Carrabec High School alone, it would have cost an estimated $250,000 to replace its aging oil boiler).

As mentioned earlier, before converting to biomass pellets, all four of RSU 74's schools depended on expensive heating oil, which was rising in cost during the conversions. Before switching to pellets, oil costs were around $3.50 per gallon and cost $227,000 annually. In total, the district saves around $100,000 annually (including the debt service costs) using pellets versus heating oil, representing a net savings of around forty-four percent.

During the first year of using the new pellet boilers, the school district expected to turn on the oil during the summer, but this did not end up being the case. Because of the modular design, wood pellet heating of summer domestic hot water can now be achieved through efficient burn rates.

Now, RSU 74 does not have to purchase imported fuel oil, which helps benefit the local economy (according to the U.S. Energy Information Administration, close to eighty percent of every dollar spent on heating oil in Maine leaves the state).[2]

There are various methods that can be employed to analyze a project's financial viability. One financial analysis tool is the annualized rate of return (ARR). The purpose of the ARR is to identify the potential rate at which an investment will increase (or decrease) each year. Calculating a ten year ARR is valuable for investors because this timeframe best reflects their shorter term focus. The ARR is calculated using a project's return on investment (ROI), which acts as a multiplier at which an investment is estimated to grow over a set time period.[3]

Another useful financial analysis calculation is the internal rate of return (IRR). The IRR estimates a facility's expected return from an investment over time (a measurement of the efficiency of the investment). The IRR is useful for facility owners and calculating it over a twenty-five year time period coincides with the typical projected life of a wood-energy system (twenty-five to thirty years). It is calculated as comparison of fuel savings for term to total project investment.[4]

A basic financial analysis of RSU 74's biomass project shows that it has a payback period of 6.9 years, a ten year annualized rate of return equal to 14.8%, and a twenty-five year internal rate of return of 28.1% (assuming inflation varies by source of energy). In this analysis, inflation rates of 3.3% for wood and 10.7% for heating oil were used.[5] Overall, these calculations indicate that RSU 74's project is favorable from a financial investment perspective (current markets are looking for an ARR between five to ten percent and the project's IRR indicates positive growth).

It should be noted that a limitation of these financial calculations is that they do not take into account the avoided costs, such as the replacement of aging equipment, that the district was able to take advantage of. Accounting for the avoided costs would only improve the favorability of these calculations. For example, factoring in these avoided costs, Coville explained that the district initially projected a five-year payback period for the systems. However, they are currently on track to beat this payback period by close to a full year. "At the current rate, we will have return on investment in approximately 4.2 years," Coville said.

System Components

The school district carefully planned out which biomass system manufacturer would best meet their needs. "The key determining factor was the capability of the units to meet or exceed our base load heating requirements with an installation that could be accomplished within existing boiler room facilities," Superintendent Coville said. "The second critical factor was unit capabilities in terms of reliability, self cleaning, auto start, low maintenance requirements, fuel

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[2] "Home Heating Oil Report." EIA, 2010.
[3] ARR Formula: $((1+ROI)^{1/N})-1$
N = # of years   ROI = Return on investment = B – C/P
B – C = Cumulative fuel cost savings added up over a set period of time   P = Total project investment.
[4] IRR Formula: $PNW = 0 = F_a/(1 + R)^a$
PNW = Present Net Worth = 0   F = Income Each Year = Fuel Savings Each Year   a = Year   R = Rate of Return
[5] Inflation rates based on the Maine ARRA Study, D. Atkins, USDA Forest Service.

compatibility, integrity of design, etc. The third critical factor was capital cost. Finally, the fourth critical factor was the availability from a Maine supplier. It also didn't hurt that [the boilers] look great and come in our school colors."

All of the pellet boilers ended up being assembled by Maine Energy Systems based on the design of the Swedish pellet boiler company ÖkoFEN. Maine Energy Systems assembles the pellet systems at its headquarters in Bethel, Maine, and acts as the distributor and licensed manufacturer for ÖkoFEN.

The school district has four schools with setups ranging from one to three ÖkoFEN PES56 wood pellet boilers. Solon Elementary School has one 191 MBtu/hr boiler, the other three schools have two to three boilers each. In total, there are eight pellet units and each boiler produces up to 191 MBtu/hr, and together they provide for a range by facility of 191 MBtu/hr-573 MBtu/hr.

The pellet boilers provide the base load heating for all four of the schools and act as their primary heating source throughout the heating season (beginning in late September through late April or early May). "The multiple boilers are arranged in tandem operation with rotating lead lag to equalize the total burn times between the units," Coville said. The boilers are also very hands free and only require "around ten to fifteen minutes [of maintenance] per school, per day." In combination with other conservation measures, the boilers have eliminated 90-96% of the school district's heating oil consumption.

Figure 9. Fuel Storage Components

The storage systems installed at the different schools include two external silos and two internal flexilo storage systems. Storage capacity varies between eleven and twenty-one tons. Coville explained that the type of storage equipment they installed at each site was based on individual facility features, with internal storage being the preferred setup where possible. The storage units are designed for bulk deliveries and can store up to sixty tons, allowing the schools to arrange to take full truck loads. Coville said that they wanted this large storage capacity to ensure a sufficient on hand supply so facilities could mange through potential fuel delivery interruptions and to provide greater bargaining power in case of fuel quality issues. Fuel delivery frequency is also reduced with bulk delivery and full truckload capability, which helps lower the costs of both the pellets and the handling of fuel deliveries.

Fuel Supply

The district pays $175 per ton of pellets delivered and consumes 375 tons of pellets annually, representing an annual biomass fuel cost of around $65,625 (RSU 74 paid $227,000 in annual fuel costs prior to the conversion).[6] RSU 74 is able to purchase its fuel supply from multiple pellet vendors that are in close proximity to the schools. The district is located halfway between Athens Pellet and Geneva Pellet (which are approximately fifteen miles away in each direction) and both companies are comparable in terms of fuel quality. As such, RSU 74 was able to decide which vendor to go with based mostly on cost. The schools require pellet shipments between a biweekly and bimonthly basis (it depends on the seasonal demand rate). To make fuel deliveries efficient and reduce fuel costs, they stage refueling so that the pellet company delivers to all four schools at the same run, allowing the truck to unload a full load on each circuit delivery.

Co-Benefits

The benefits of converting from a heating oil system to a wood pellet system have been "huge." Superintendent Coville highlighted benefits such as achieving cost reductions from twenty-five to forty-five percent per building.

Beyond the significant heating cost savings, RSU 74 has also experienced a number of environmental benefits adopting a pellet system. For instance, the schools have a dramatically smaller carbon footprint, with approximately 50,000 gallons of fuel oil displaced and accounting for a reduction of 1,535,800 pounds of CO_2 emissions per year. Furthermore, Coville explained, because the replacement wood pellet fuel comes from certified, sustainable forests, RSU 74's overall heating carbon footprint is virtually zero. Even the approximately 1,750 pounds per year of low metal ash produced by the system is put to productive use as a lime substitute on athletic fields.

Also, Coville stated, because the project was comprehensive and integrated, the facilities' life spans have been extended in this infrastructure area and the quality of life for occupants in terms of heating control and consistency of environment has improved. In addition, the purchase of locally produced renewable wood pellets supports the local economy and reduces foreign oil imports thereby enhancing national security.

[6] As of 8/24/12

Conclusion

Coville does not want to stop with the great success of their pellet boiler conversions. Now, the district is planning to install a transpiring solar collection system at the high school, which would be beneficial in addressing the significant number of air exchanges the school is required to have each day. The schools are now working to integrate transpiring solar collectors into their ventilation systems, which will reduce winter heat load by preheating ventilation air by twenty to forty degrees Fahrenheit. Coville said, "With a time machine, we would go back and include this in the integrated project thereby further downsizing both the boiler capacity needs at one school, [and] the storage capacity and fuel consumption needs at two schools."

The pellet systems are exceeding Coville's expectations—they are working very well and are paying off. He said the most important factors that other facilities should consider when thinking about converting to biomass are, "Situational characteristics of your facility and long term fuel cost/availability. We anticipate wood pellet heating to be our primary low-cost heating option until they get that small scale cold fusion stuff working." Overall, the most important lesson he says was learned through the biomass project is that people should not be limited by the standard vendor designs they see, instead "Do your own research and demand system designs that are both customized to your facility and represent an integrated comprehensive approach rather than simple fuel source swap."