Preliminary Feasibility Report

Biomass Heating Analysis for Eminence Elementary School

Eminence, MO
The Wood Education and Resource Center is located in Princeton, W.Va., and administered by the

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EXECUTIVE SUMMARY

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

Eminence R-I Elementary School is located in Eminence, Missouri. The school has approximately 15,726 square feet of conditioned building space. The biomass scenario analyzed for this report envisions installing a cordwood boiler that is housed adjacent to the existing boiler room on the north side of the school. Hot water would be piped from the boiler to the existing boiler room where it would be connected to the existing system. Implementation of this wood system will require installation of new heating units and controls within each of the school rooms.

The school consumes about 14,100 gallons of propane for heat each year on average. At the average price paid last year in Missouri of $2.00 per gallon, the school can expect to pay more than $28,200 in propane costs next year to heat this building.

The analysis indicates the Eminence R-I Elementary School would need to spend $308,862 for a cordwood boiler plant and necessary heating distribution upgrades. The Eminence R-I Elementary School has been awarded $350,000 towards this project through the Missouri Fuels for Schools program. Preliminary estimates show that if Eminence Elementary accepts the Missouri Fuels for Schools Grant, it would cover all of the cost of installing this biomass heating system. If Eminence Elementary chooses to move forward with this project it could save nearly $600,000 in operating costs over 30 years in today's dollars even including the cost of financing equipment and installation. The analysis shows $22,000 in fuel savings in the first year alone.

The wood biomass scenario evaluated for this report appears cost effective and Yellow Wood recommends moving forward with a project. We recommend the school take the following steps to investigate this opportunity further:

1. Hire an architectural and/or 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 to the design team on biomass energy technologies and design suggestions for cordwood fuel storage and boiler house layouts.
2. This report recommends installing unit ventilators in every classroom. Unit ventilators can provide heating during the heating season and fresh air at all times during the year. Adequate fresh air is essential for the health of students and has been shown to improve student performance and reduce absenteeism. There is more information on Indoor Air Quality (IAQ)
and the importance of adequate ventilation in the Additional Issues section of this report and in the Biomass and Green Building Resources binder accompanying this report.

3. The school should consider other energy efficiency improvements simultaneously with the biomass energy project. The efficiency of the building envelope and ventilation equipment need to be considered when sizing new boiler equipment. The Energy Center at the Missouri Department of Natural Resources provides technical and financial assistance for energy efficiency and renewable energy projects to school districts and other consumers. Through the Energy Revolving Fund, the Energy Center provides low interest loans to public schools, universities, colleges, cities, counties, public hospitals and water treatment plants to help reduce energy costs. The Energy Center should be contacted and engaged regardless of whether or not the school moves ahead with a biomass project at this time. Information on energy efficiency programs and incentives is included in the Biomass and Green Building Resources binder accompanying this report.

4. It is recommended that a fully functioning fossil fuel boiler be in place to complement a cordwood boiler. The district should consider replacing the existing propane boiler at the same time as the biomass boiler is installed. The existing boiler is over 50 years old and appears to have serious maintenance problems. The district may want to just decommission and abandon the existing boiler in place and build the biomass boiler room a little large to accommodate a new propane back-up boiler.

5. 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:


6. The district may want to consider a pellet boiler system instead of a cordwood boiler system. While pellet fuel costs would be somewhat higher than cordwood, much of the fuel cost savings for this project will come from more efficient boiler systems and temperature control. Pellet boilers can be highly automated with bulk storage of pellet fuel in a silo and automatic fuel handling via augers. Operations and maintenance costs for a pellet boiler should be considerably less and project costs for a pellet boiler system would be similar or less since a woodshed would not be necessary and a back-up propane boiler may not even be necessary.
INTRODUCTION

There is a significant volume of low-grade biomass in the United States that represents a valuable economic and environmental opportunity if that biomass 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 the Eminence R-I Elementary School outlining whether or not biomass heating makes sense for this facility from a practical perspective. In November 2009, staff from Wilson Engineering Services visited Eminence Elementary to tour the facility. This assessment includes site specific fuel savings projections based on historic fuel consumption and provides facility decision-makers suggestions and recommendations on next steps to take based on site visits, data collection and interviews with stakeholders.

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

This preliminary feasibility study was prepared by Yellow Wood Associates and Richmond Energy Associates, LLC with support from Wilson Engineering Services.

ANALYSIS

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
In addition, it is useful for decision makers to consider the impact of debt service if any local share of 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 base case scenario assumes that Eminence R-I Elementary School will continue to use the existing propane boiler essentially as it is now being used.

The alternative biomass scenario envisions installing a new cordwood boiler adjacent to the existing boiler room on the north side of the school. The biomass scenario includes all ancillary equipment and interconnection costs. Under the biomass scenario, the existing propane boiler 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 then projects current and future annual propane and electric heating bills and compares that cost against the cost of operating a biomass system plus debt service for the entire cost of new equipment over a 30-year horizon. 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. It is a standard method for using the time value of money to compare the cost effectiveness of long-term projects.

DESCRIPTION OF EXISTING HEATING SYSTEMS

The Eminence R-I Elementary School is located in Eminence, MO and consists of three main buildings, including the Main Elementary building (15,726sf) the Library (1,120sf) and the Art/Music building (1,120sf) as well as three ancillary buildings. Presently the school houses approximately 172 students and 15 faculty. For the purpose of this analysis only the Main Elementary building is considered.

The Main Elementary building is served by an open combustion boiler with a central 2-pipe hot water distribution system. The heat in the building is currently regulated by 4 thermostats with no individual room controls. The existing boiler is over 50 years old and is very inefficient. In addition there are few thermostats in the building and many rooms are so overheated, the occupants open the windows in the winter to cool the room down. The result is that the Main Elementary building shows an annual heat usage that is 3 times higher than would be expected for a school in this region.
CAPITAL COST ASSUMPTIONS FOR BIOMASS SCENARIO

It was not the intent of this project nor was it in the scope of work to develop detailed cost estimates for a biomass boiler facility. It is recommended that for a project of this scale, the 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.

The Library building, the Art/Music building, the Office, the Pre-K class building and the Maintenance building were not included in the proposed biomass scenario. It would not be practical or cost effective to install a central heating system for all these buildings on the campus. These buildings are too far from the Main Elementary building and the heating needs for these buildings are too small to offset the costs of retrofitting these buildings with hydronic heating distribution systems and connecting them to the main building with buried insulated piping.

Therefore the biomass scenario envisions installing a new cordwood boiler adjacent to the existing boiler room on the north side of the Main Elementary building or on the south side of the building. With higher efficiency equipment and proper room temperature controls, we are assuming that a 250,000 Btu/hr cordwood boiler will be sufficient to meet peak heating demand. This biomass boiler would interconnect with the existing 2-pipe hot water distribution system within the Main Elementary building. The cordwood boiler will need to be hand-loaded and a hot water thermal storage tank is included so that the boiler can run most efficiently. Thermal storage allows for the boiler to be run at higher fire, which is more efficient and cleaner burning. The building heat can then be modulated from the thermal storage tank.

Although wood storage was not included in the original preliminary conceptual project cost estimate, we recommend including a wood storage structure that can hold a years worth of firewood. Careful thought will need to go into the design of this storage space so that wood can be stacked easily and fresh wood does not get in the way of using seasoned dry wood. A discussion of proper cordwood storage is included in the appendices to this report.

For the analysis in this report, it was assumed that an entire year’s worth of firewood would be stored under cover. This will require 500 square feet of covered storage. This does not need to be expensive construction. It can even have a dirt floor if the site drains well. For the purposes of the analysis in this report we included $12,500 for a 500 sf wood shed assuming a $25/sf construction cost. If this project moves forward, the US Forest Service may be able to help design this structure.

The boiler and associated boiler room equipment will require approximately 500 square feet of space. Costs for a tall stack and boiler breaching were also included in the project cost estimate.
Below are two suggested boiler house locations.

**Figure 1 Suggested Biomass Boiler Location (Image Courtesy of Wilson Engineering Services)**

A redundant fossil fuel heating system is typically recommended with most biomass installations in order to provide back-up heat during the shoulder seasons and supplemental heat during the coldest nights of the year if necessary. For analysis purposes, the biomass scenario assumes the existing propane boiler will remain in place. Since the existing boiler is quite old and has had maintenance problems in recent years, the district may want to consider replacing the existing boiler with a new propane boiler at the same time a new biomass boiler is installed. In fact, if the district moves forward with a cordwood boiler project we recommend including a new propane back-up boiler. However, costs for a new propane boiler were not included in the cost estimates for the biomass scenario as it was beyond the scope for this project.

Hot water from the biomass boiler house would be piped to the existing boiler room by dual line insulated pipe where interconnection would be made with the existing system. The biomass scenario envisions installing new fan coil HVAC equipment, new Unit Ventilators and temperature controls in each classroom with provisions for economizer cooling and fresh air ventilation. The upgrades to the HVAC system will likely have a significant impact on the annual energy needs of the school, significantly reducing the overall energy output needed at Eminence Elementary. A healthy construction contingency, standard general contractor mark-up and professional design fees were also included.
PROPANE COST ASSUMPTIONS

During the 2007-2008 school year, the last year for which full consumption data is available, the Eminence R-I Elementary School used an estimated 13,400 gallons of propane to heat the Main Elementary School building. The total of 13,400 gallons of propane was the assumed annual fuel consumption used for the base case in the analysis. The average institutional price paid for propane in Missouri over the past twelve months was $2.00 per gallon according to U.S. Energy Information Administration data for the state of Missouri. At that price, the school will spend more than $26,800 to heat the building next year.

WOOD FUEL COST ASSUMPTIONS

The current energy use for the Main Elementary building is much higher than would be expected for a building this size in Missouri. We believe that new boiler systems, new HVAC equipment and temperature controls for each room will reduce the heating load for the Main Elementary School significantly. Currently we are estimating that the Elementary School is consuming approximately 72,595 Btu/sf/yr. With a higher efficiency boiler, proper HVAC equipment and room temperature controls we are projecting that consumption can be reduced to about 30,000 Btu/sf/yr. Therefore we are assuming
in our analysis that total annual heating need for this building will go from 871 mmBtu to 472 mmBtu based on an annual demand of 30,000 Btu/sf/yr.

It was assumed that the cordwood boiler would be used during the weekdays during the heating season and the propane boiler would be used on the weekends and during school vacations. During the school year about 70% of the days are schooldays and 30% are weekend and vacation days. Therefore for this analysis it was assumed that 70% of the annual heating demand would be covered by the cordwood boiler and the propane boiler would carry the remaining 30% of the annual heating needs.

On-site staff indicated that the district would be able to obtain cordwood at no cost using students, staff and community members. We felt we needed to include a cost for wood fuel in order to more accurately characterize a cordwood system. After consulting with on-site staff we are projecting a first year cost of $120 per cord for firewood which is equivalent to about $0.55 per gallon for propane. For this analysis, $120 per cord was the assumed first-year cordwood fuel cost, and that price was inflated each year at 4.9% annually.

**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 – 2009) using US Energy Information Agency data and found that the average annual increase for propane in Missouri was 4.9% per year. The analysis projects this average inflation rate for propane forward over the thirty year analysis period.

The cost of firewood is even more difficult to estimate, as there is very little historical data to reference. It is our experience that wood heating fuel prices in general tend to increase more slowly and have historically been much more stable in price over the past two decades than fossil fuels. Because wood fuel is locally produced from what is generally considered a waste product from some other forest product business, it does not tend to have the same geopolitical pressures that fossil fuels have. However, for the purposes of this analysis, because of the uncertainty and in order to be conservative, it was assumed that cordwood prices will escalate at the same 4.9% rate as propane over the analysis period.

The overall Consumer Price Index for the period between 1989 and 2009, the last year for which data is available, increased an average of 2.8% 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

Cordwood systems require a significant investment of labor to operate and maintain. It was assumed that the school would purchase cordwood at $120/cord. But that wood still needs to be stacked, the boiler needs to be fed several times per day and annual maintenance will need to be performed on the boiler. The assumptions for how much labor would be involved are outlined below.

For this analysis it was assumed that it takes about an hour and a half to stack one cord of wood. Twenty cords of wood will then take 30 hours to stack. It will be necessary to load the boiler with firewood at least four times per day during the winter months. It was assumed that each load would take fifteen minutes and therefore it was assumed an hour per day of daily maintenance for every day the boiler was used. It was assumed that there are about 100 school days during the year that require heat. Therefore it was assumed 100 hours per year of labor would be needed for daily loading. Finally it was assumed that summer maintenance would require twenty hours to clean and inspect all boiler equipment. A total of 150 hours of labor was used in the analysis for operations and maintenance. At a loaded labor rate of $25/hr, this equals $3,750 annually.

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, $5,000 of scheduled maintenance was anticipated in years 10, 20 and 30 and then annualized at $500 per year to simulate a sinking fund for major repairs. This $500 was then inflated at the general annual inflation rate.

Under any biomass scenario, a case could be made that the existing heating units will require less maintenance and may last longer since they will only be used for a small portion of the heating season. However, all heating equipment should be serviced at least annually no matter how much it is used. Additionally it is very difficult to estimate how long the replacement of the existing units might be delayed. For these reasons, no annual maintenance, scheduled repair or planned replacement costs for the existing propane boiler were taken into consideration as these are considered costs that the school would have paid anyway. It was assumed that all costs for the operation and maintenance of a cordwood boiler are incremental additional costs.

FINANCING ASSUMPTIONS

The Eminence R-I Elementary School has been awarded a $350,000 grant towards this project through the Missouri Fuels for Schools program. Preliminary estimates show that if Eminence Elementary accepts the Missouri Fuels for Schools Grant, it would cover all of the cost of installing this biomass heating system. Therefore no financing costs were included in the analysis for this project.
BIOMASS SCENARIO ANALYSIS RESULTS

The analysis shows that the Eminence R-I Elementary School could save nearly $650,000 in today's dollars in operating costs over the next 30 years by installing a cordwood heating system. Annual fuel savings alone are projected to be more than $20,000 per year in the first year and will increase over time as propane prices continue to climb.

Table 1 Wood Scenario Analysis Assumptions

<table>
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<th>Eminence R-I Elementary School</th>
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<td><strong>Capital Cost Assumptions</strong></td>
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<td>Total estimated project costs</td>
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| State Grant                     | $350,000|

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<td>Propane (gal)/cord ratio</td>
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<td>Assumed wood price in 1st year (per cord)</td>
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<td>Net 1st year fuel savings</td>
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<td>Total 30 year NPV cumulative savings</td>
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Figure 3 Annual Cash Flow Graph for Wood Scenario
## Preliminary Life Cycle Cost Analysis

### Wood Chip - Heat Only

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<th>Wood Cost</th>
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<th>Simple Payback (yr)</th>
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### O & M:
- Cost: $3,750 per year
- Total: $11,250 in Year 1

**Note:** Estimates of additional electricity for feed system motors and additional maintenance staff time in contingency for major repair (e.g., reflection replacement) at Years 10, 20, and 30 are assumed.

### Summary
- **Total Annual Heating Costs:** $28,800
- **Wood System O&M Cost per Year:** $3,750
- **Contingency Allowance per Year:** $500
- **Wood + Fuel O&M Contingency:** $11,027
- **Annual Fuel Cost Savings:** $20,023
- **Simple Payback (yr):** 0.0
- **30 Yr. NPV Savings:** $647,674

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**Disclaimer:**

The information provided in this document is hypothetical and for illustrative purposes only. Actual costs and savings may vary based on specific site conditions and market rates.
ADDITONAL 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 US Environmental Protection Agency (EPA) 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 building owners set efficiency priorities, identify under-performing buildings, verify efficiency improvements, and receive EPA recognition for superior energy performance. We recommend that the school input several years’ worth of energy and water use data for all of its schools into Portfolio Manager as soon as it can. The EPA Portfolio Manager software can be downloaded at the following address:


ENERGY EFFICIENCY

No matter whether the school converts to biomass or stays with propane, the school should use its heating fuel efficiently. The Energy Center at the Missouri Department of Natural Resources can help identify and prioritize appropriate energy efficiency projects that will improve the school’s infrastructure and save money. Through the Energy Revolving Fund, the Energy Center provides low interest loans to public schools, universities, colleges, cities, counties, public hospitals and water treatment plants to help reduce energy costs. This loan financing may be used for various energy-saving investments, including projects such as upgrading insulation, lighting systems, heating and cooling systems, windows and other items that affect energy use. Loan recipients repay the loan with money saved on energy costs as a result of implementing the energy-efficiency projects. These loans are not defined as debt. Thus, this loan financing does not count against debt limits or require a public vote or bond issuance.

To give an idea of the benefits of energy efficiency in schools, an Energy Efficiency Case Study for the U-32 Junior/Senior High School is included in the Biomass and Green Building Resources binder accompanying this report.

INDOOR AIR QUALITY

Recent studies have shown that poor Indoor Air Quality (IAQ) in schools can lead to a number of health problems, including asthmas aggravation, and impact both staff and student performance. The U.S. Environmental Protection Agency has created an Indoor Air Quality Action Kit to help schools understand how IAQ problems develop, the importance of good IAQ and practical actions schools can take to identify and address IAQ issues in their buildings. Appropriately designed HVAC equipment is a key component in creating good indoor air quality. Unit ventilators are one practical approach to
providing necessary fresh air into individual rooms without investing in central air handling systems. Eminence R-I Elementary School would benefit from review of the EPA’s *Indoor Air Quality Tools for Schools Reference Guide Backgrounder* and the EPA *Indoor Air Quality Checklist*, which are included in the *Biomass and Green Building Resources* binder accompanying this report.
CONCLUSIONS AND RECOMMENDATIONS

The wood biomass scenario evaluated for this report appears cost effective and Yellow Wood recommends moving forward with a project. We recommend the school take the following steps to investigate this opportunity further:

1. Hire an architectural and/or 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 to the design team on biomass energy technologies and design suggestions for cordwood storage and boiler house layouts.

2. This report recommends installing unit ventilators in every classroom. Unit ventilators can provide heating during the heating season and fresh air at all times during the year. Adequate fresh air is essential for the health of students and has been shown to improve student performance and reduce absenteeism. There is more information on Indoor Air Quality (IAQ) and the importance of adequate ventilation in the Additional Issues section of this report and in the Biomass and Green Building Resources binder accompanying this report.

3. The school should consider other energy efficiency improvements simultaneously with the biomass energy project. The efficiency of the building envelope and ventilation equipment need to be considered when sizing new boiler equipment. The Energy Center at the Missouri Department of Natural Resources provides technical and financial assistance for energy efficiency and renewable energy projects to school districts and other consumers. Through the Energy Revolving Fund, the Energy Center provides low interest loans to public schools, universities, colleges, cities, counties, public hospitals and water treatment plants to help reduce energy costs. The Energy Center should be contacted and engaged regardless of whether or not the school moves ahead with a biomass project at this time. Information on energy efficiency programs and incentives is included in the Biomass and Green Building Resources binder accompanying this report.

4. It is recommended that a fully functioning fossil fuel boiler be in place to complement a cordwood boiler. The district should consider replacing the existing propane boiler at the same time as the biomass boiler is installed. The existing boiler is over 50 years old and appears to have serious maintenance problems. The district may want to just decommission and abandon the existing boiler in place and build the biomass boiler room a little large to accommodate a new propane back-up boiler.

5. 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:


6. The district may want to consider a pellet boiler system instead of a cordwood boiler system. While pellet fuel costs would be somewhat higher than cordwood, much of the fuel cost savings
for this project will come from more efficient boiler systems and temperature control. Pellet boilers can be highly automated with bulk storage of pellet fuel in a silo and automatic fuel handling via augers. Operations and maintenance costs for a pellet boiler should be considerably less and project costs for a pellet boiler system would be similar or less since a woodshed would not be necessary and a back-up propane boiler may not even be necessary.
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
Richmond Energy Associates 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.

Wilson Engineering Services, PC
Wilson Engineering Services (WES) is a multidisciplinary firm providing engineering and consulting services for a wide range of projects and programs. WES combines extensive experience in the following areas to provide clients with sustainable solutions to energy and environmental related issues, including agri-business; application of technology projects related to energy production and distribution, waste handling and environmental remediation; and engineering consulting project and program management.
Purchasing and burning cordwood is an entirely different exercise than purchasing propane. There are good and very bad cordwood boiler technologies on the market. Most wood burning appliances fail to create high combustion efficiency for two reasons: not enough heat to burn all of the fuel and cutting the air supply to try to control the rate of combustion. The last is intuitive for anyone who has ever seen the air cut off from a fire - the result is a lot of smoke and reduced heat.

In order to get a clean and efficient burn, the cordwood heating system should include induced draft. Substantial thermal storage should also be designed into the system to allow for a high temperature burn. Wood fuel should be seasoned and dry. Wood storage needs to be carefully thought out so that the driest wood is easy to use and freshly stacked wood is not in the way of seasoned wood. Below is a quick primer on elements to consider when designing a cordwood heating system for a user that will use more than ten cords of wood.

**Induced Draft**

One of the most challenging aspects of heating with cordwood is controlling the output of the heating appliance. An induced draft system includes a fan that drives air into the combustion chamber. This ensures there is adequate combustion air for a high temperature burn.

Many outdoor wood boilers on the market control heat output by dampening down combustion air. When a fire is starved of combustion air, it smolders and smokes. In addition to wasting wood fuel, a moldering, smoky fire can produce tremendous quantities of fine particulates, which are the pollutant of most concern from wood burning appliances. Minimizing particulate emissions should always be one of the goals of any biomass heating application.

**Thermal Storage**

The best way to burn chunk firewood hot is to have a hot fire and to control the heat output of the system by storing heat in a large water tank. An induced fan will help produce a high temperature burn. The heat energy can then be transferred to a large insulated hot water storage tank. Building demand can be regulated through a heat exchanger in the storage tank. There are many reasons why thermal storage for a cordwood boiler system is desirable.

- It eliminates short cycling which reduces emissions. In conventional wood heating equipment wood combustion produces maximum emissions during the “idle” cycle.
- Minimizing the on/off cycle reduces maintenance.
- Batch burning with controlled combustion into thermal storage allows any burner to be set up for steady state continuous peak combustion efficiency because the burner does not have to cycle as demand for heat increases. The burner simply “charges” the thermal storage.
- Thermal storage allows a continuous exact match of heat output to widely varying loads of any building or process. This is very important during the “fringes” of any heating season when a typical wood burner is grossly oversized because it is based upon the largest heating load during winter conditions.
- Thermal storage allows for burner maintenance, repair or cleaning without a loss of heating ability because the thermal storage can carry the load for a period of hours without burner input.

Thermal energy storage may be provided via a separate storage tank piped to the burner unit (boiler), or as an integral unit with the burner.

**How To Burn Firewood**

**Species of wood**
The species of wood you receive makes a significant difference. The potential heat value of wood is directly proportional to its weight, and there is wide variation in weight for equal volumes of wood. For example, a cord of pine weighs about 2,700 pounds at 20 percent moisture content. An equal volume of oak weighs about 3,700 pounds at 20 percent moisture content. The pine, therefore, has about 73% of the potential heat value as the oak, yet you may pay the same price for the wood.

The term "mixed hardwoods" has very little meaning because many hardwoods grow in Missouri. Some have high densities and others, such as cottonwood and silver maple, have relatively low densities. In Missouri, the most common species cut for firewood are red and white oak, hickory, and ash. They are all relatively heavy woods and are considered to be among the best cordwood species.

**Moisture content of cordwood**
Moisture content is another important factor to consider if you use wood as an energy source and want to operate at maximum efficiency. When trees are cut, the wood contains a lot of water. This quantity of water is generally called the "green moisture content." The amount of water in green wood varies with species. After cordwood is cut to length, split, and stacked in a sunny and well ventilated spot, it loses moisture rapidly. Wood dried for one year may be near the 20 percent moisture content. At this level, it is considered air dried.

When you buy wood, assume it is green and dry accordingly. Green wood burns more slowly than air dried wood and may be somewhat slower on the "uptake" when you start a fire. If you burn green wood, you stand to lose 10 to 12 percent of the original heat potential of the wood.
Cordwood storage
Cordwood should be air dried or “seasoned” under cover for at least six months before it is burned. Woodshed storage should be carefully designed so that it is easy to stack and manage dry and fresh wood. It should allow for plenty of air movement to promote drying. The woodshed should be sized to store a full year’s worth of wood if possible and should allow for rotation so that fresh wood isn’t in the way of seasoned dry wood.

In order to correctly size a wood storage shed, a definition for cordwood must be understood. As defined by the National Conference on Weights and Measures and Missouri rules and regulations, a gross cord of firewood is the amount of wood, ranked and well stowed, contained in a space of 128 cubic feet. "Ranked and well stowed" means pieces are placed in a line or row with pieces touching on their ends and parallel to each other and stacked in a compact manner. Wood storage can be a very inexpensive pole barn type structure. It can even have a dirt floor if there is good drainage. But it should be carefully thought out so that it is easy to load, is easy to access from the boiler room and so that any fresh wood does not get in the way of using the driest wood.

A common way to measure cordwood is to stack it 4 feet wide by 4 feet tall by 8 feet long. For the purposes of the analysis done in this study we assumed a cord of wood was 128 cubic feet of seasoned hardwood dried to a 20% moisture content. If this volume is stacked 6 feet tall, a minimum of a 500 square foot structure should be built for wood storage.

A cord of wood is typically 4 feet wide by 4 feet tall by 8 feet long or 128 cubic feet once it is stacked. Wood can be stacked somewhat higher to reduce the footprint of a woodshed, but it is not recommended to stack wood higher than six feet. Therefore the smallest recommended footprint for a cord of wood is 21 square feet. For 20 cords of wood we recommend at least 500 square feet of wood storage under cover.

If possible the woodshed should be adjacent to the boiler room so that the boiler can be loaded while remaining under cover. Wood can be stacked so as to form “walls” to minimize exposure to the elements. Careful thought should be given to the pattern of stacking so that the first stacked is the first used.

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1 Other descriptions of volumes of cordwood such as rick, rank, pickup load, and face cord should not be used. The only legal terms are "cord" and fractions of a cord.
This list is for informational purposes only and does not imply a recommendation or endorsement of any manufacturer, nor is this list represented as being a complete list of all companies that may offer these products. When selecting a manufacturer, the customer should perform due diligence by checking references at existing installations and comparing warranties. Features such as the degree of automation, combustion and thermal efficiencies, the ability to handle the fuel source selected and pollution control devices should be compared.

**Seton Wood Boilers**
13830 McBeth Rd.
New Hampshire, OH 45870
866-372-6287 toll free
419-568-1100
www.setonboilers.com

**Garn Wood Heat Stoves**
Dectra Corporation
3425 33rd Ave. NE
St. Anthony, MN 55418
612-781-3585
612-781-4236 fax
www.dectra.net/garn/

**BIOHEAT, USA**
5 Main Street
Lyme, NH 03768
800-782-9927
603-795-4740 fax
www.WoodBoilers.com

**New Horizon Corp. Inc.**
151 McGregor Drive
Sutton, WV 26601
800-987-3974
304-765-5963 fax
www.newhorizoncorp.com