High Efficiency Low Emission Wood Fired Heating System Pre-Feasibility Report

July 28, 2015

Version: Final

Prepared for:
Rampart Village Council

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Table of Contents

1.0 EXECUTIVE SUMMARY

This preliminary feasibility study evaluates options for Rampart Village Council (RVC) to utilize high efficiency low emission wood fired technologies at the Multipurpose Building and Laundromat. Installation of a wood fired heating system would present RVC with the opportunity to reduce operating costs and utilize a renewable fuel for heating. The Multipurpose Building was previously used as a school and will be repurposed to accommodate offices for RVC employees and potentially sublet a portion to reopen a school. An aerial map of Rampart is provided in Appendix A that identifies the buildings evaluated in this study.

The multipurpose building was the school for the community from 1986 to 1999. The building was closed in 1999 and has been unused since. RVC received a grant to renovate and repurpose the building, which will begin in 2015. Hot water boilers firing on #1 fuel oil were used for space heating and domestic hot water when the building was in operation. The boilers are planned to be retrofitted with new burners and reused. Historic fuel use is unavailable.

The laundromat was constructed in 1998 and provides community access to showers, restrooms, and coin operated washers & dryers. Historic fuel oil use was provided by RVC. #1 fuel oil is used for space heating, domestic hot water heating, and for clothes dryers equipped with hot water coils.

Both buildings utilize #1 fuel oil fired boiler plants for space heating and domestic hot water heating. Three options are evaluated using factory containerized gasification style indoor cord wood boilers. Option 1 considers heating the RVC offices that are planned to be constructed in the unused Multipurpose Building, Option 2 considers heating the laundromat, and Option 3 considers heating both buildings using a district system. A summary of the costs and benefits for each option are listed in Table ES1.

Table ES1 – Cost and Benefit Summary

Option	Estimated Capital Cost	1st Year Net Annual Operating Savings	Simple Payback, Years	20 Year Net Present Value	20 Year B/C Ratio
1 : RVC Offices	$135,556	$4,343	31.2	$ (50,621)	0.63
2 : Laundromat	$158,700	$4,992	31.8	$ (61,031)	0.62
3 : District System	$324,013	$8,495	38.1	$ (157,704)	0.51

Notes:

1 – Net Annual Operating Savings include costs for wood fuel, supplemental fossil fuel, and operation & maintenance (O&M) costs.

2 – 20 Year Net Present Value takes the present value of the operating savings for each year using a nominal discount rate of 3.1% as published in the "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - 2014" and the initial capital outlay of the total project cost. A value greater than zero means that savings are greater than expenses over 20 years in the value of today's dollars.

3 – 20 Year Benefit/Cost (B/C) Ratio is calculated by dividing the present value of net annual operating savings over a 20 year period with a discount rate of 3.1% by the Estimated Capital Cost. A value greater than 1 means the benefits exceed the costs over a 20 year period.

2.0 EXISTING FUEL USAGE & HEATING SYSTEMS

Rampart is a high fuel cost community with prices for #1 fuel currently at $6.50 per gallon. Access to Rampart is limited to bush planes and boats. #1 fuel oil is flown in by plane, transferred to a portable storage tank, and towed from the air strip using a D8 bulldozer to fill above ground tanks in the community. Historic fuel use was provided for the Laundromat, however, fuel use for the Multipurpose Building is unavailable.

2.1 RVC OFFICES IN THE MULTIPURPOSE BUILDING

The Multipurpose Building is currently unoccupied and unheated. The building is planned for renovation in 2015 which will repurpose a portion of the building to accommodate RVC offices. The new offices are anticipated to be 2,600 ft^2. The remaining portion of the building is under consideration by Yukon Flats School District to set up a classroom, which would be sublet from RVC. A separate heating system will be used for the remainder of the building. Figures 2.1-1 and 2.1-2 show the exterior of the Multipurpose Building.

Figure 2.1-1 – Multipurpose Building Exterior

Figure 2.1-2 – Multipurpose Building Exterior

Two Burnham hot water boilers are decommissioned in the mechanical room of the Multipurpose Building. They have been inspected by the State Boiler Inspector and were deemed safe to reuse with new oil burners. Figure 2.1-3 shows a picture of the currently decommissioned boilers that will receive new oil burners with the renovation.

Figure 2.1-3 – Multipurpose Building Boilers

The renovation will abandon in place the existing hot water heating distribution system and install new piping and pumps from the boilers to baseboard heaters that will be installed in new offices. Glycol is used in the system since outdoor temperatures can reach -70°F. Drain pans underneath the boilers were full of glycol on the site visit. When the system was operational, fuel oil was pumped from the bulk storage tank into a day tank located in the boiler room. The Interior Regional Housing Authority (IRHA) is currently designing the renovation and new heating system, however this has not yet been completed.

The annual energy use for space heating in the RVC offices has been estimated based on the floor space anticipated for use, the annual heating degree days (HDD) using a base temperature of 65°F, and the Thermal Energy Use Intensity per HDD value of 7.4 Btus/Ft^2/HDD[1]. Table 2.1-1 shows the estimated annual energy use that would be used for space heating based on the anticipated floor space used for the RVC Offices.

Table 2.1-1 – Estimated Annual Energy Use for Heating the RVC Multipurpose Building Offices

Building	RVC Office Floor Space, Ft^2	April 2014 - March 2015 Annual HDD, 65F	Thermal EUI/HDD	Annual Boiler Input Energy Use for Space Heating, mmBtu	Estimated Boiler Efficiency	Estimated Annual Space Heating Energy Use, mmBtu
RVC Offices in MP Building	2,600	14,205	7.4	273.3	80%	219

Notes:

1- *Annual heating energy use considers only the floor space that is anticipated to be used for RVC offices as requested by RVC. Remaining floor space will be heated using a waste oil heater or a separate system by future tenants.*

2- *Thermal EUI/HDD value of 7.4 is used to estimate annual heating energy use in the building. This value is based on the Alaska Housing Finance Corporation report titled "Energy Efficiency of Public Buildings in Alaska : Metrics and Analysis".*

The estimated annual heating demand from Table 2.1-1 is then distributed across the year based on local weather data to develop a daily average heating demand curve. Figure 2.1-4 shows how the daily average heating demand for the RVC Offices would be expected to vary over the course of a year for space heating only. During a 24-hr period, the actual load will vary above and below this average value.

[1] Wiltse, N., Madden, D., Valentine, B. (2014). *Energy Efficiency of Public Buildings in Alaska: Metrics and Analysis.* Fairbanks, AK: Cold Climate Housing Research Center.

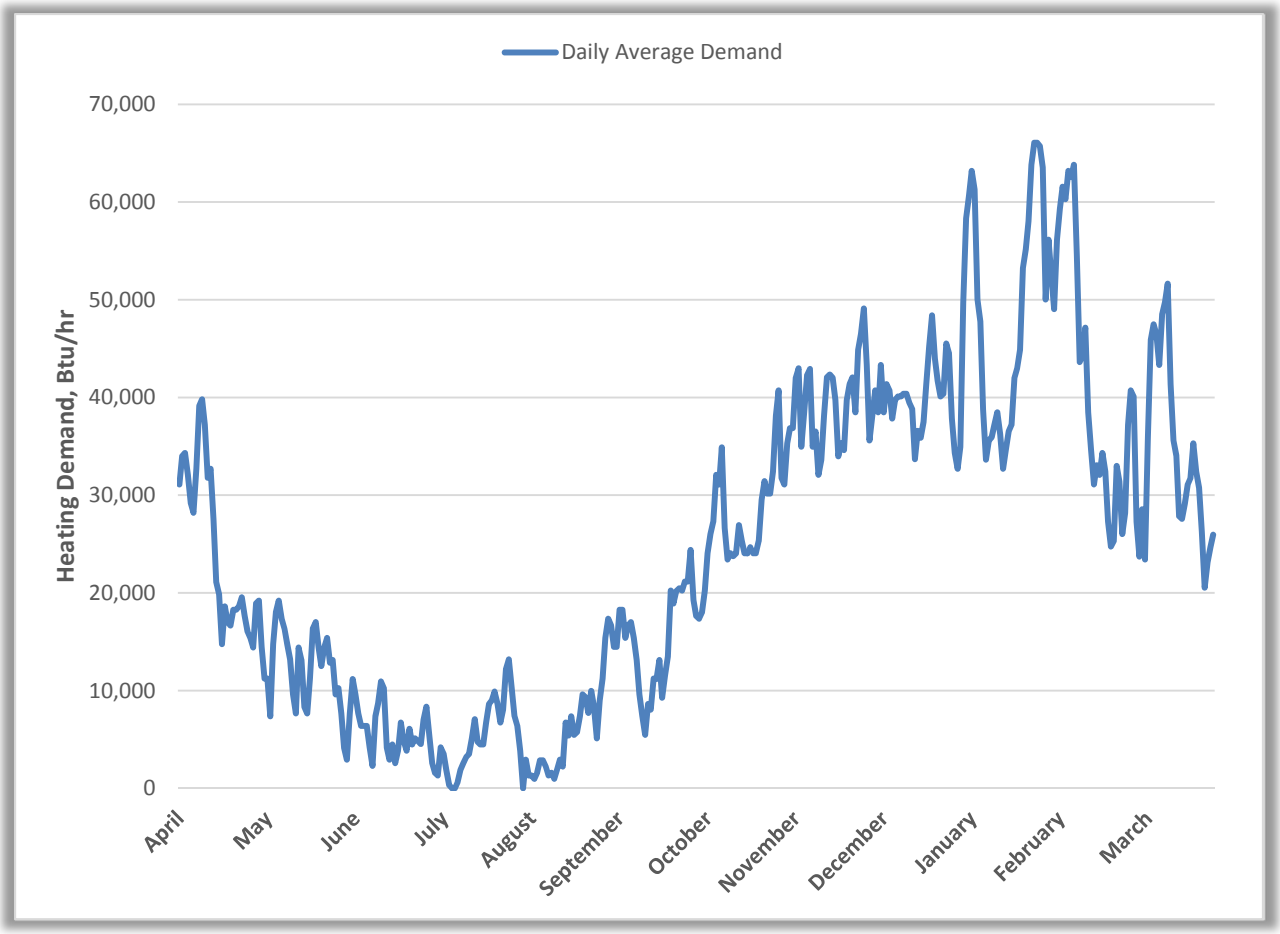


Figure 2.1-4 – RVC Offices Estimated Daily Average Space Heating Demand (4/2014 – 3/2015)
Note: The daily average heating demand model is based on local weather data and annual fuel usage provided by RVC. Actual demand would fluctuate above and below the average heating demand values shown over a 24-hr period.

A load duration curve was developed using the daily average heating demand curves. Load duration curves sort the daily average heating demand over the course of a year from highest to lowest and plot it over the number of days to show the annual range of facility heating demand. Figure 2.1-5 shows the estimated load duration curve for the RVC Offices in the Multipurpose Building.

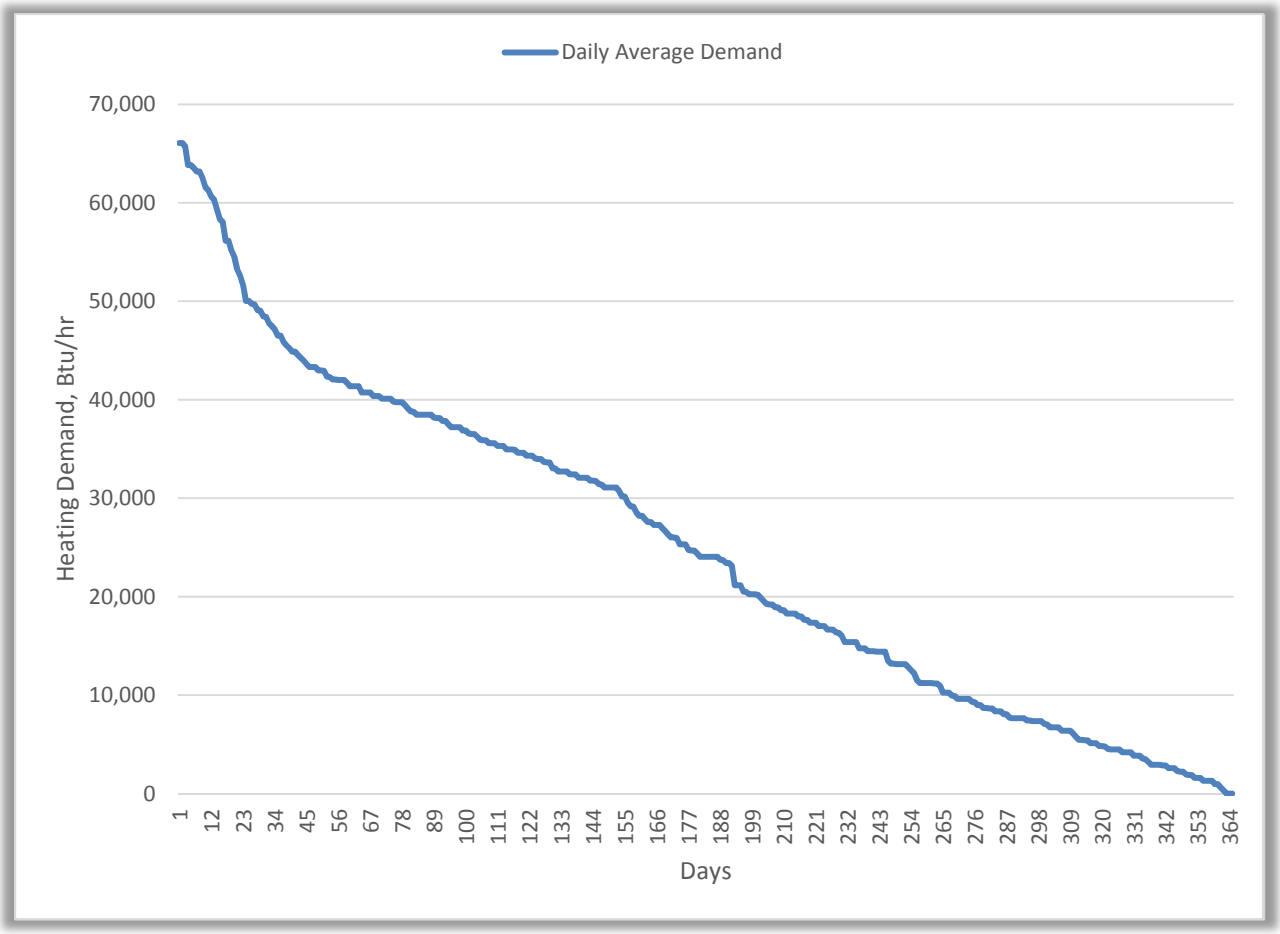


Figure 2.1-5 – RVC Offices Space Heating Load Duration Curve (4/2014 – 3/2015)

Note: The load duration curve is based on local weather data and annual fuel usage provided by RVC. Actual demand would fluctuate above and below the average heating demand values shown over a 24-hr period.

2.2 LAUNDROMAT

A 2,140 ft^2 Laundromat was constructed in 1998 that contains washers, dryers, showers, and bathrooms for the community. The facility used approximately 2,450 gallons of #1 fuel oil annually for space heating, domestic hot water heating, and laundry services. Annual expenditures are approximately $15,925 at the current fuel price of $6.50 per gallon. An above ground 500 gallon fuel oil tank is used for onsite storage. Figure 2.2-1 shows the exterior of the Laundromat.

Figure 2.2-1 – Laundromat Building Exterior

The boiler room contains two Weil McLain model 678 hot water boilers rated at 643,000 Btu/hr each while firing on #1 fuel oil. One boiler can meet the heating demands of the building with the second boiler remaining for backup. The Laundromat boilers are shown in Figure 2.2-2.

Figure 2.2-2 – Laundromat Boilers

The heating distribution system uses a glycol/water mixture with a primary pumping system. There are 3 zones with pumps circulating water to a space heating zone, a dryer heating zone, and a domestic hot water heating zone. Baseboard fin tube heaters and unit heaters provide space heating for rooms. Thermostats in each room and control valves on the fin tube heaters are the only control for the system. Domestic hot water is heated indirectly using the heating boilers and stored in a 190 gallon Ajax Boiler, Inc DHW storage tank. There is no room in the existing boiler room to locate a wood fired boiler system or thermal storage tanks.

Two Huebsch Originators 25 pound front load commercial washers, two Speed Queen top load washers, and four Hoyt-Windsor II dryers with heating capacities of 95,000 Btu/hr each are provided for laundry services. The dryers are equipped with a hydronic package that uses hot water from the heating boilers as the heat source for drying. Figures 2.2-3 and 2.2-4 show the laundry equipment.

Figure 2.2-3 – RVC Laundromat Washing Machines

Figure 2.2-4 – RVC Laundromat Dryers

The laundry equipment is coin operated and coin collection records were provided by RVC for 1/1/2015 through 5/27/2015. The washers and dryers use tokens that are purchased for $0.50 apiece. Four washing machines are utilized in the laundromat with two large commercial front load washers and two top load washers. The washers require 12 tokens for front load washers and 6 tokens for top load washers per 23.5 minute cycle. The dryers require 1 token for 7 minutes of drying time. Table 2.2-1 shows the token collection records and estimated energy use for the laundry equipment. All energy use values are shown as energy used by the equipment and would correspond to boiler output energy.

Table 2.2-1 – 5 Month Laundry Token Collection Records and Estimated Energy Use

Usage Period	Washer Tokens Collected	Dryer Tokens Collected	Estimated Washer Energy Use, mmBtu	Estimated Dryer Energy Use, mmBtu	Total Estimated Laundry Energy Use, mmBtu	Extrapolated Annual Laundry Use, mmBtu
1/1-1/15/15	46	34	0.02	0.40	0.42	
1/16-1/28/15	12	14	0.01	0.16	0.17	
1/29-2/11/15	28	29	0.01	0.34	0.35	
2/12-2/16/15	14	14	0.01	0.16	0.17	
2/17-3/3/15	36	32	0.02	0.37	0.39	
3/4/-3/16/15	35	42	0.02	0.49	0.51	
3/17-3/29/15	38	43	0.02	0.50	0.52	
3/30-4/9/15	26	30	0.01	0.35	0.36	-
3/31-4/14/15	18	15	0.01	0.18	0.18	
4/15-4/23/15	29	14	0.01	0.16	0.18	
4/24-5/1/15	28	21	0.01	0.25	0.16	
5/2/-5/8/15	35	19	0.02	0.22	0.25	
5/9-5/14/15	21	26	0.01	0.30	0.30	
5/15-5/27/15	32	38	0.02	0.44	0.44	
	398	**371**	**0.21**	**4.33**	**4.53**	**10.88**

Laundry energy use is estimated using the assumptions provided in Table 2.2-2.

Table 2.2-2 – Laundry Energy Use Assumptions

Item	Value and Unit	Source
Front load washer use vs. top load washer	50%	RVC
Front load washer water use per cycle	35 gallons	WES E&E assumption
Top load washer water use per cycle	25 gallons	http://www.speedqueencommercial.com/vend/en-us/news/newsletter/2014-april-cost-per-cycle---front-load-washer-and-top-load-washer-.aspx
Percentage of Hot Water per Washer Cycle	25%	Water Management, Inc., et al. 2006. Report on the Monitoring and Assessment of Water Savings from the Coin-Operated Multi-Load Clothes Washer Voucher Initiative Program. Prepared for the San Diego Water Authority
Density of Water at 50°F	8.343 lbs/gallon	WES E&E assumption
Laundry hot water temperature rise	70°F	WES E&E assumption
Density of Water at 120°F	8.25 lbs/gallon	WES E&E assumption
Dryer Heating Demand	95,000 Btu/hr	Hoyt-Windsor
Front load washer token use per cycle	12 Tokens	RVC
Top load washer token use per cycle	6 Tokens	RVC
Dryer time per token	7 minutes	RVC
Cool down period of dryer cycle	0 Minutes	WES E&E assumption

Annual hot water use for showers and the associated energy use is estimated for the laundromat. Assumptions used to estimate annual energy use include a shower length of 8 minutes, 10 gallons of hot water use per shower, a hot water temperature rise of 70°F, and 20 showers per day. Table 2.2-3 shows the estimated annual shower hot water energy use.

Table 2.2-3 – Estimated Annual Shower Hot Water Energy Use

Estimated Shower Length, Minutes	Hot Water Use, Gallons	Estimated Energy Use per Shower, Btu	Estimated Energy Use per Year, Output mmBtu
8	10	5,775	42.2

Note: Average shower length and hot water use are based on the values provided by the DOE website http://energy.gov/eere/femp/energy-cost-calculator-electric-and-gas-water-heaters-0

Fuel deliveries for April 2014 through March 2015 were provided by RVC. Table 2.2-4 shows the annual fuel oil delivered to the Laundromat, estimated boiler efficiency, estimated total annual heating energy use, and the energy breakdown for laundry, showers, and space heating.

Table 2.2-4 – Laundromat Estimated Annual Energy Use Summary

April 2014 - March 2015 #1 Oil Use, Gallons	Annual Boiler Input Energy, mmBtu	Estimated Boiler Efficiency	Total Annual Boiler Output Energy, mmBtu	Estimated Annual Laundry Energy Use, mmBtu	Estimated Annual Shower Energy Use, mmBtu	Estimated Annual Space Heating Energy Use, mmBtu
2,450	328	80%	263	11.2	42.2	209

Note: Annual space heating energy is estimated by subtracting the Annual Laundry and Shower Energy Use from the Total Boiler Output Energy.

The Estimated Annual Space Heating Energy Use is used for the purposes of load modeling and boiler sizing in this memorandum. Figure 2.2-5 shows how the daily average heating demand for the Laundromat would be expected to vary over the course of a year for space heating only. During a 24-hr period, the actual load will vary above and below this average value. Potential peak loads are estimated to be much higher than the average load due to the potential to operate four dryers at the same time, however the duration is short and actual use of laundry equipment has been minimal compared to the heating demand of the building.

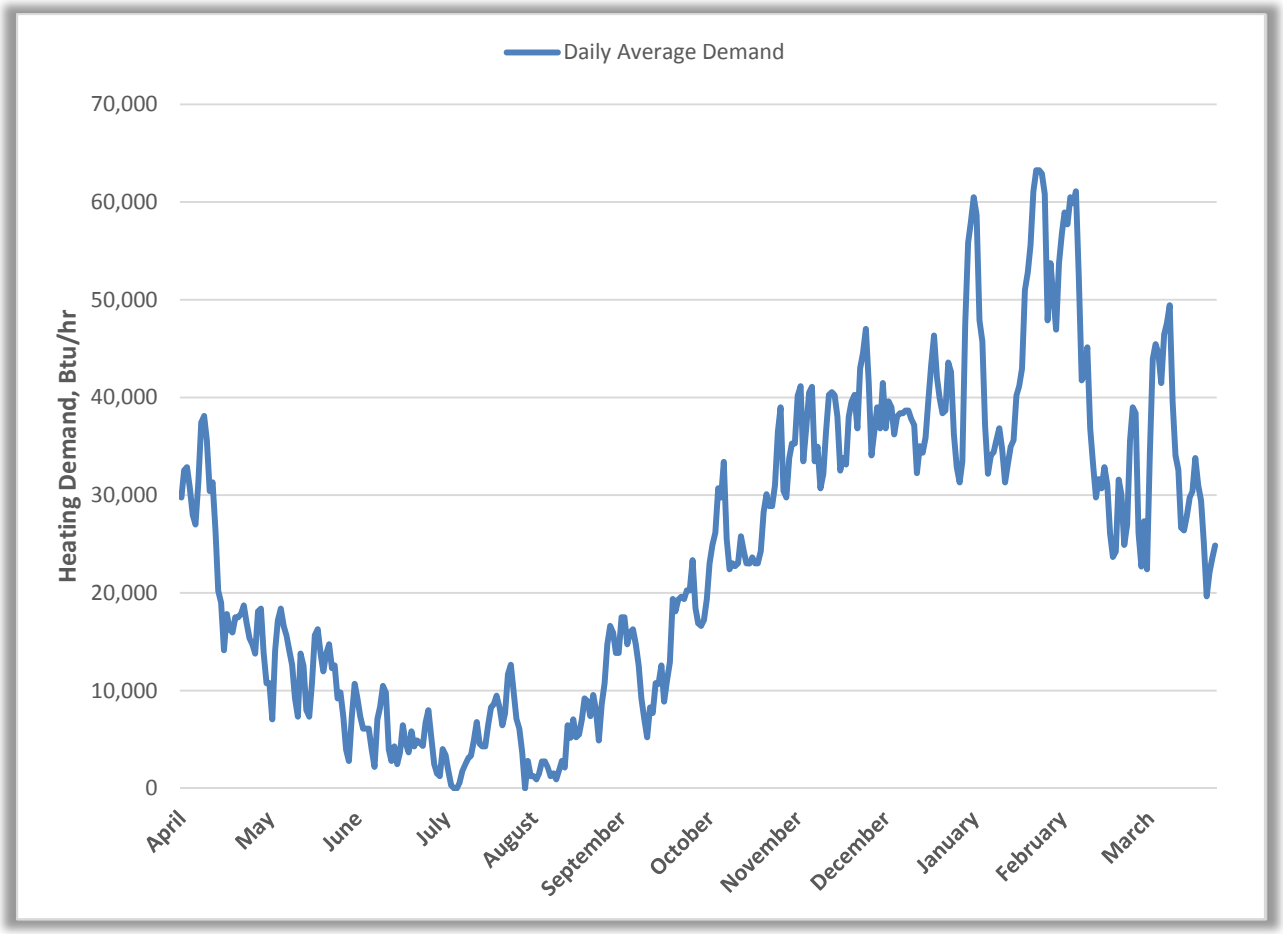


Figure 2.2-5 – Laundromat Estimated Daily Average Space Heating Demand (4/2014 – 3/2015)
Note: The daily average heating demand model is based on local weather data and annual fuel usage provided by RVC. Actual demand would fluctuate above and below the average heating demand values shown over a 24-hr period. Heating demands for the washers, dryers, and showers are not included in the curve since equipment use is minimal compared to the space heating demand.

A load duration curve was developed using the daily average heating demand curves. Load duration curves sort the daily average heating demand over the course of a year from highest to lowest and plot it over the number of days to show the annual range of facility heating demand. Figure 2.2-6 shows the estimated load duration curve for the Laundromat's space heating demand.

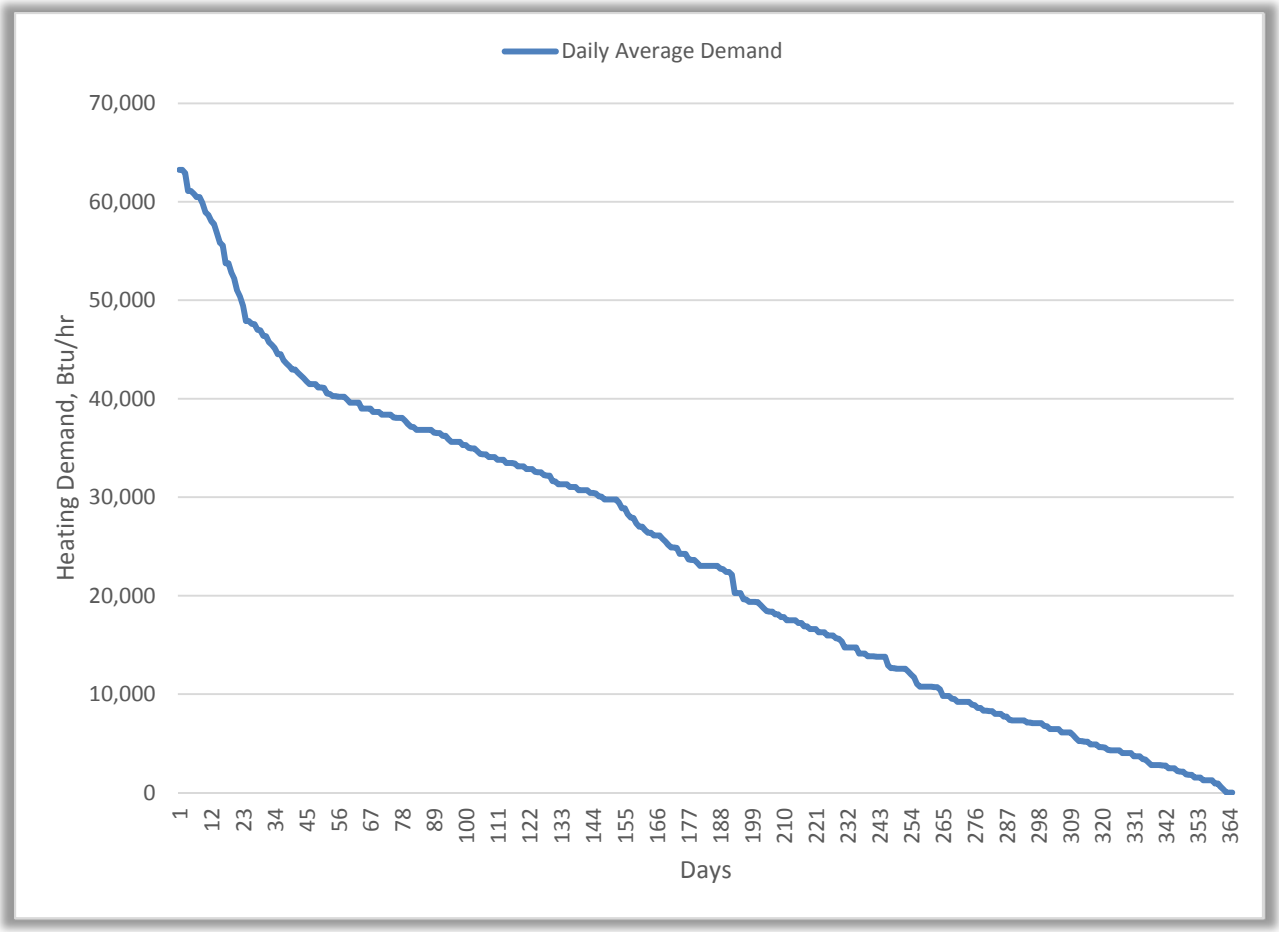


Figure 2.2-6 – Laundromat Space Heating Load Duration Curve (4/2014 – 3/2015)

Note: The load duration curve is based on local weather data and annual fuel usage provided by RVC. Actual demand would fluctuate above and below the average heating demand values shown over a 24-hr period. Heating demands for the washers, dryers, and showers are not included in the curve since equipment use is minimal compared to the space heating demand.

3.0 FOREST RESOURCE AND FUEL AVAILABILITY

The area surrounding Rampart is heavily forested. RVC plans to set up harvesting plans with private residents, Native Corporations, and the Alaska DOT to sustainably harvest wood for fuel. Landowners were contacted and no existing Forest Stewardship Plans are in place.

A management plan could incorporate setting up a fire break to help protect the village from fire hazards. Additionally, large quantities of drift wood are available after the ice breakup on the Yukon River. This driftwood could be harvested and air dried over the course of a season to be used as fuel. RVC anticipates that cord wood can be purchased from local harvesters for $300 per cord. Table 3.0-1 summarizes the available fuels for heating as well as their cost per 1 million Btu's (mmBtu) of boiler output comparison.

Table 3.0-1 – Fuel Pricing and Cost of Energy for Heating

Fuel, Unit	Boiler Type	Cost per Unit	Input Heating Value, mmBtu per Unit	Estimated Boiler Efficiency	Appliance Output Heating Value, mmBtu/Unit	Appliance Output Heating Cost, $/mmBtu
Seasoned Cord Wood, Cord	Indoor Gasification Boiler	$300.00	17.0	70.0%	11.9	$25.21
#1 Fuel Oil, Gallon	Vented Space Heater	$6.50	0.134	80.0%	0.107	$60.63

Note: Assumes 20% moisture content wet basis for cord wood and assumes that wood use is made up of 50% black spruce at 15.9 mmBtu/cord and 50% white spruce at 18.1 mmBtu/cord.

4.0 PROPOSED BIOMASS SYSTEMS

High efficiency low emission cord wood boilers are evaluated for use in the Laundromat and the RVC offices planned for construction in the Multipurpose Building. The economics are considered for using dedicated systems serving each building as well as a district system that interconnects the heating systems for both buildings. Space within each building is limited for locating a new wood fired boiler, therefor containerized systems are considered for each option.

4.1 MULTIPURPOSE BUILDING

An advanced combustion unit and hot water boiler capable of firing on seasoned cord wood sized at approximately 100,000 Btu/hr of heat output is evaluated. The boiler would be combined with approximately 800 gallons of thermal storage to efficiently meet the RVC office space range of heating needs. This boiler size was chosen because typically it is the smallest boiler offered by manufacturers. The boiler operator would have to take care to charge the firebox based on expected load to ensure that the boiler does not idle and produce excess smoke.

Due to space constraints in the building, the system will be located in a containerized system adjacent to the Multipurpose Building. The containerized system will include the cord wood boiler, hot water thermal storage system, and circulation pumps. The system will interconnect with the hydronic system using distribution piping in a utilidor. Propylene glycol should be used as the heating fluid due to extreme cold temperatures experience throughout the winter. Additionally, heat trace wiring should be installed in the utilidor as a safety precaution.

The hot water thermal storage will hold approximately 180,000 Btu assuming a 60% propylene glycol concentration, 190°F storage temperature, and 160°F distribution return temperature. This would provide 1 hours and 50 minutes of load to charge the tank from 160°F to 190°F. The boiler will be over sized but is typically the smallest size available for an ASME rated cord wood boiler. The large volume of thermal storage will mitigate the effects of an oversized boiler. The estimated coverage using the cord wood boiler for the RVC Offices planned for construction in the Multipurpose Building is shown in Figure 4.2-1.

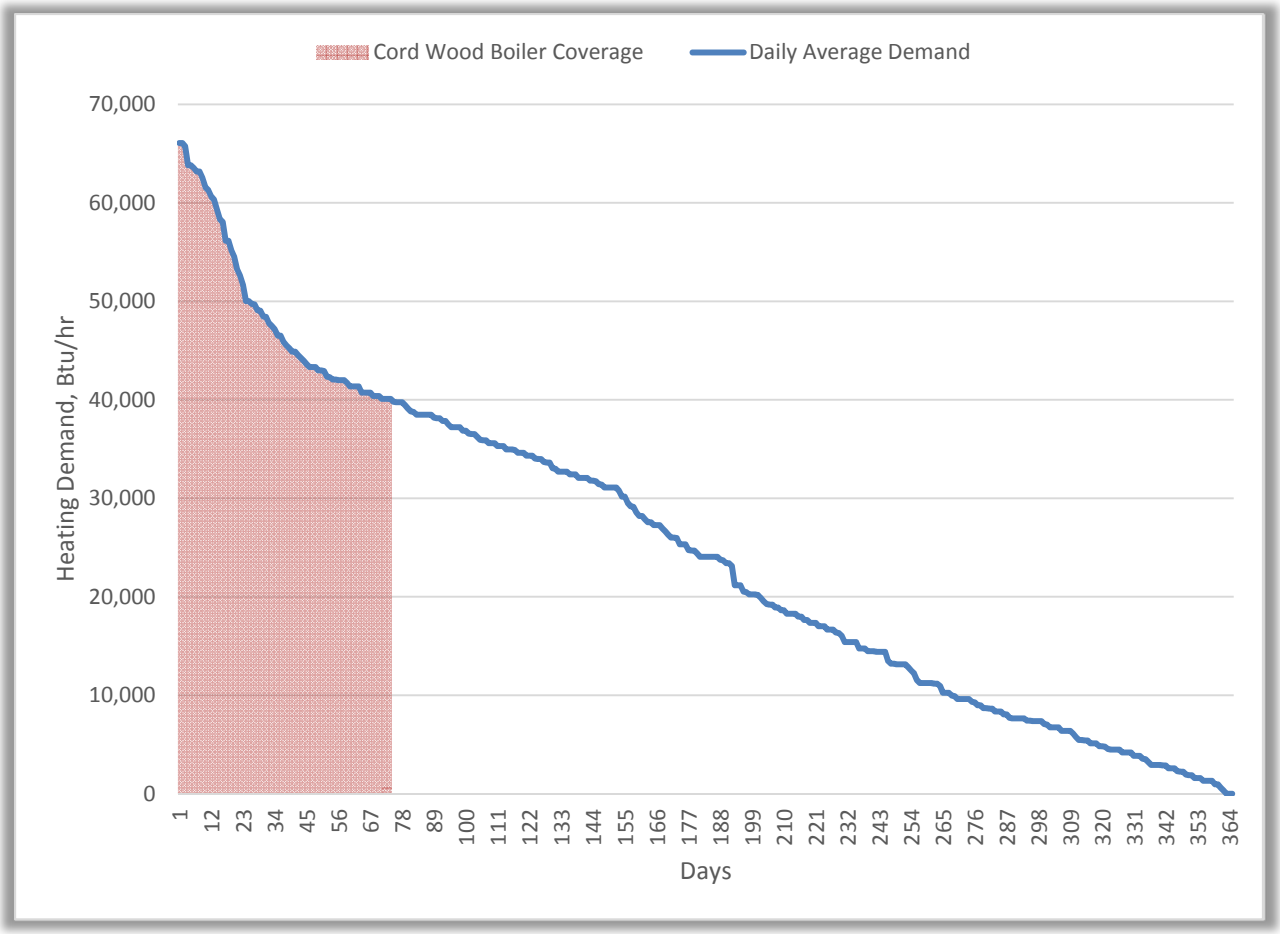


Figure 4.1-1 – Estimated Cord Wood System Coverage of Load Duration Curve

Note: The load duration curve model is based on local weather data and annual fuel delivery volumes provided by RVC. Potential coverage of 40% is shown while estimating a minimum turndown of 40%. Actual coverage will depend on management of loads and the use of thermal storage.

Figure 4.1-1 shows 40% coverage of the space heating load duration curve using the cord wood system. The existing fuel oil system in the boiler room will supplement the cord wood system as needed. Actual coverage will vary depending on weather conditions, peak demands, equipment operation schedules, and periods when the boilers are shut down for maintenance. The 100,000 Btu/hr system is large for the building heating demand, but is typically the smallest size offered by manufacturers. The coverage assumes a minimum boiler turndown of 40% with the cord wood system. Cord wood boilers can turndown more than 40%, however efficiency drops off quickly below this point. The 800 gallon thermal storage system will provide a large buffer on the system and reduce periods operating below 40% boiler output. This report assumes 70% coverage for the cord wood system for estimating the potential fuel use and savings for the Multipurpose Building.

Cord wood used in the system should be stacked and seasoned (air dried) for at least a year to reduce to moisture content in the wood. A 500 ft^2 covered pole style building with walls that allow air to flow through is recommended to store the 13 cords of wood that would be required

over the course of a year to offset 70% of the anticipated fuel oil use for heating the RVC offices in the Multipurpose Building. Cribbing would be used to keep the stacked wood off of the ground. This building is sized based on stacking the wood 6' high, 4' wide, and 3' aisles to walk between the rows.

4.2 LAUNDROMAT

An advanced combustion unit and hot water boiler capable of firing on seasoned cord wood sized at approximately 100,000 Btu/hr of heat output is evaluated. The boiler would be combined with approximately 1,500 gallons of thermal storage to efficiently meet the Laundromat's range of heating needs. This boiler size was chosen because typically it is the smallest boiler offered by manufacturers. The boiler operator would have to take care to charge the firebox based on expected load to ensure that the boiler does not idle and produce excess smoke.

The building experiences two drastically different heating loads. The space heating demand for the building is relatively small in comparison to the potential heating demand of operating all of the laundry equipment at the same time. However, the fuel use for the laundry equipment is a small portion of the total fuel use based on coin collection records provided by RVC. Because of this, the heating system is sized to optimize the coverage of the space heating demand.

Due to space constraints in the building, the system will be located in a containerized system adjacent to the Laundromat. The containerized system will include the cord wood boiler, hot water thermal storage system, and circulation pumps. The system will interconnect using distribution piping in a utilidor. Propylene glycol should be used as the heating fluid due to extreme cold temperatures experience throughout the winter. Additionally, heat trace wiring should be installed in the utilidor as a safety precaution.

The hot water thermal storage will hold approximately 335,000 Btu assuming a 60% propylene glycol concentration, 190°F storage temperature, and 160°F distribution return temperature. This would provide 3 hours and 20 minutes of load to charge the tank from 160°F to 190°F as well as allow the operation of four dryers for 50 minute dry cycles with a fully charged tank. The boiler will be over sized but is typically the smallest size available for an ASME rated cord wood boiler. The large thermal storage tank will mitigate the effects of an oversized boiler. The estimated coverage using the cord wood boiler for the Laundromat is shown in Figure 4.2-1.

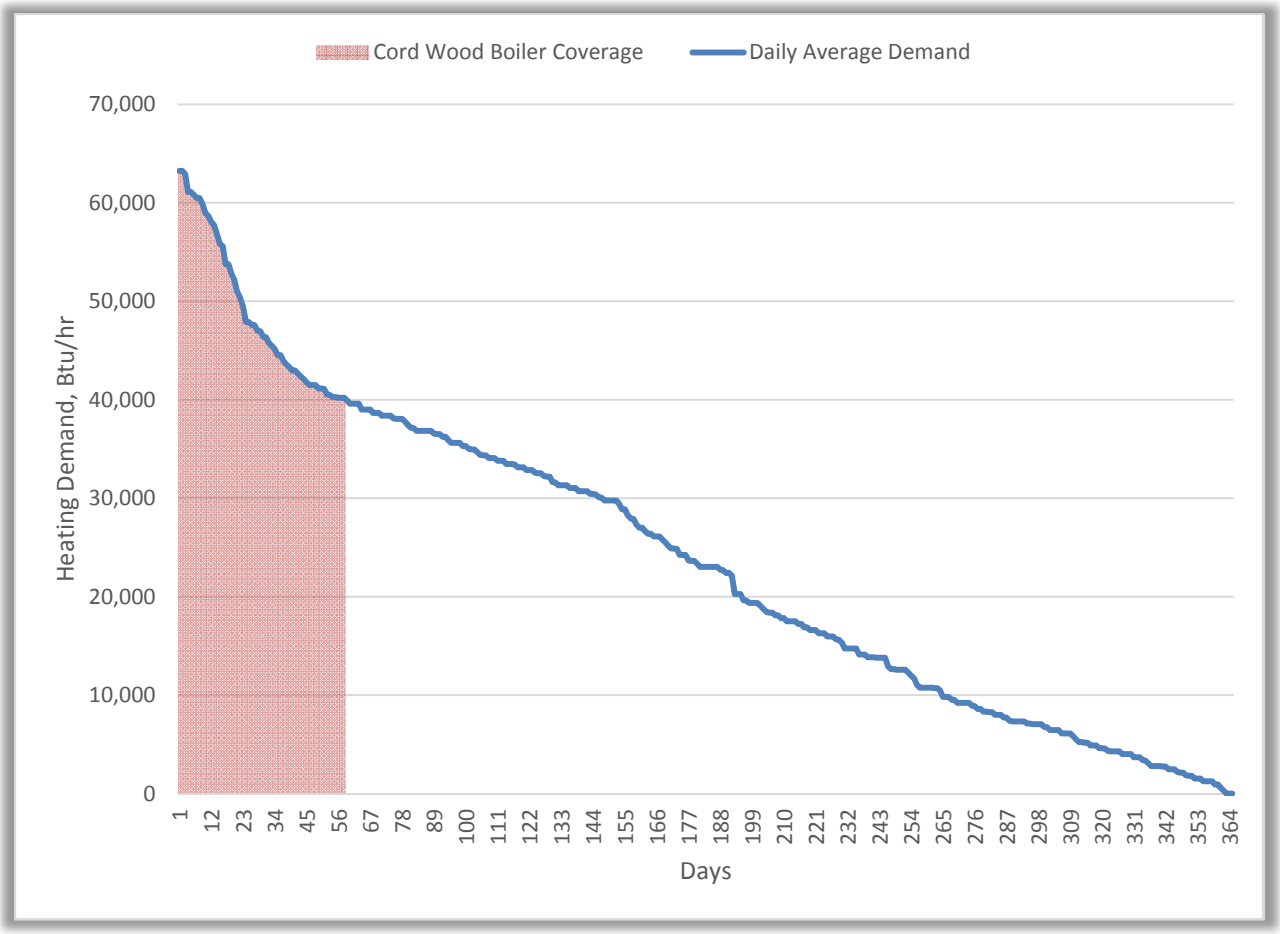


Figure 4.2-1 – Estimated Cord Wood System Coverage of Load Duration Curve

Note: The load duration curve model is based on local weather data and annual fuel delivery volumes provided by RVC. Potential coverage of 33% is shown while estimating a minimum turndown of 40%. Actual coverage will depend on management of loads and the use of thermal storage.

Figure 4.2-1 shows 33% coverage of the space heating load duration curve using the cord wood system. The existing fuel oil system in the boiler room will supplement the cord wood system as needed. Actual coverage will vary depending on weather conditions, peak demands, equipment operation schedules, and periods when the boilers are shut down for maintenance. The 100,000 Btu/hr system is large for the building heating demand, but is typically the smallest size offered by manufacturers. The coverage assumes a minimum boiler turndown of 40% with the cord wood system. Cord wood boilers can turndown more than 40%, however efficiency drops off quickly below this point. The 1,500 gallon thermal storage system will provide a large buffer on the system and reduce periods operating below 40% boiler output. This report assumes 70% coverage for the cord wood system for estimating the potential fuel use and savings for the Laundromat.

Laundry and shower use is not included in the coverage graph. The Laundry and shower energy use is estimated to account for 20% of the total fuel use. This portion of the load is not consistent since laundry and shower schedules are not defined. A larger portion of the laundry

and shower loads could be covered by the cord wood system if RVC provided an incentive (such as half priced laundry) to do laundry or take showers during defined periods. RVC could then make sure the boiler is loaded with wood and the thermal storage is charged to cover the laundry and drying loads during these periods.

A 600 ft^2 covered pole style building with walls that allow air to flow through is recommended to store the 15.5 cords of wood that would be required over the course of a year to offset 70% of the anticipated fuel oil use for heating the Laundromat. Cribbing would be used to keep the stacked wood off of the ground. This building is sized based on an estimated stack height of 6' and width of 4' and 3' aisles to walk between the rows.

4.3 DISTRICT SYSTEM SERVING THE MULTIPURPOSE BUILDING AND THE LAUNDROMAT

A district system that would connect to the heating systems for the RVC Offices planned for construction in the Multipurpose Building and the Laundromat are evaluated. A containerized cordwood boiler system would be located next to the laundromat since this would be a year round heating load.

An advanced combustion unit and hot water boiler capable of firing on seasoned cord wood sized at approximately 150,000 Btu/hr of heat output is evaluated. The boiler would be combined with approximately 1,500 gallons of thermal storage to efficiently meet the range of heating needs for both buildings. The capacity of the system will provide added flexibility of operation for both buildings. The large volume of thermal storage will require multiple firings per day during the coldest times of the year which will allow the boiler to maintain an efficient firing rate during operation. The boiler operator should manage how full the firebox is charged depending on outside air temperature, thermal storage tank temperature, and anticipated laundry loads. A firebox sized at 23" x 16" x 28" that is fully loaded will hold approximately 635,000 Btu's of wood assuming 80% of the volume is occupied with wood and a density of 2,500 lbs/cord, which will be able to transfer 445,000 Btu's to the glycol heating system assuming a 70% efficiency.

The system will interconnect to the heating systems of both buildings using insulated distribution piping in a utilidor. Propylene glycol should be used as the heating fluid due to extreme cold temperatures experienced throughout the winter. Additionally, heat trace wiring should be installed in the utilidor as a safety precaution.

The hot water thermal storage will hold approximately 335,000 Btu assuming a 60% propylene glycol concentration, 190°F storage temperature, and 160°F distribution return temperature. This would provide 2 hours and 15 minutes of load to charge the tank from 160°F to 190°and allow the operation of four dryers for 50 minute dry cycles with a fully charged tank. The small increase in boiler output compared to the individual systems will provide additional flexibility for operation and charging the system and offsetting fuel oil use. The anticipated duration of operation below the efficient firing rate will be mitigated by the large volume of thermal storage. The estimated coverage using the cord wood boiler for both buildings is shown in Figure 4.3-1.

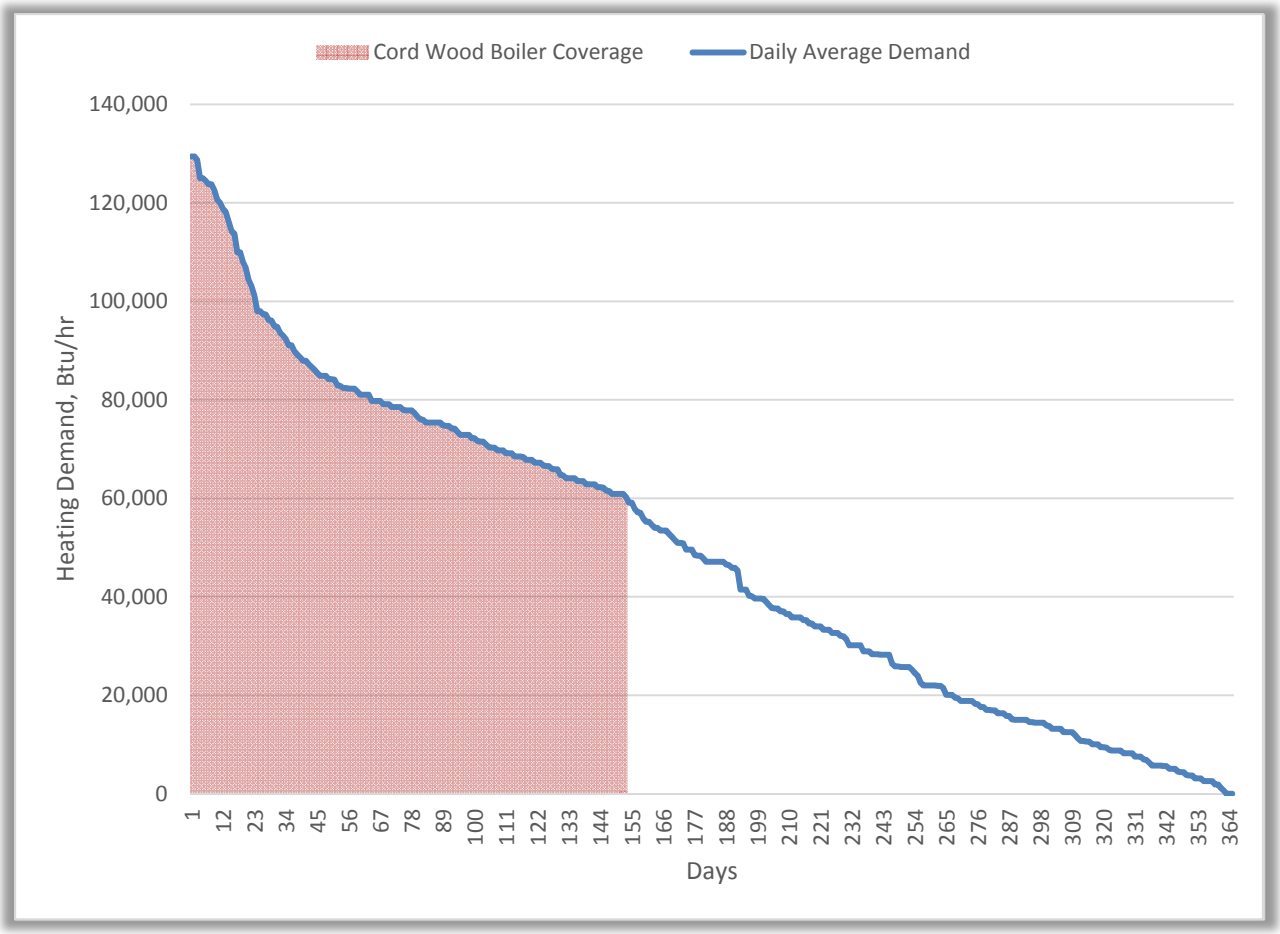


Figure 4.3-1 – Estimated Cord Wood System Coverage of Load Duration Curve

Note: The load duration curve model is based on local weather data and annual fuel delivery volumes provided by RVC. Potential coverage of 70% is shown while estimating a minimum turndown of 40%. Actual coverage will depend on management of loads and the use of thermal storage.

Figure 4.3-1 shows 70% coverage of the space heating load duration curve using the cord wood system. The existing fuel oil system in the boiler rooms will supplement the cord wood system as needed. Actual coverage will vary depending on weather conditions, peak demands, equipment operation schedules, and periods when the boilers are shut down for maintenance. This report assumes 70% coverage for estimating the potential fuel use and savings for the district system.

Laundry and shower use is not included in the coverage graph. The Laundry and shower energy use is estimated to account for 20% of the total fuel use. This portion of the load is not consistent since laundry and shower schedules are not defined. A larger portion of the laundry and shower loads could be covered by the cord wood system if RVC provided an incentive (such as half priced laundry) to do laundry or take showers during defined periods. RVC could then make sure the boiler is loaded with wood and the thermal storage is charged to cover the laundry and drying loads during these periods.

A 1,000 ft^2 covered pole style building with walls that allow air to flow through is recommended to store the 28.4 cords of wood that would be required over the course of a year to offset 70% of the anticipated fuel oil use for both buildings. Cribbing would be used to keep the stacked wood off of the ground. This building is sized based on an estimated stack height of 6' and width of 4' and 3' aisles to walk between the rows.

Additionally, the existing fuel oil boilers in both buildings seem to be very large in respect to the anticipated heating loads. If a district system is considered for further evaluation, the heating capacity of the Laundromat boilers may be large enough to heat both buildings. The Multipurpose Building boilers could be abandoned in place or removed to reduce annual maintenance and inspection costs. Further analysis should be completed to verify building loads and if the Laundromat boilers have sufficient capacity if a district system is pursued as an option.

5.0 BENEFIT/COST ANALYSIS

Capital costs are estimated for each option based on recent quotations and bids provided by cord wood boiler manufacturers. These costs include a covered fuel storage building, containerized cord wood hot water boiler system, hot water thermal storage, and installation. The estimated capital costs are listed in Table 5.0-1. Tables showing the detailed cost breakdowns are found in Appendix B.

Table 5.0-1 – Estimated Project Capital Costs

Project Description	Estimated Capital Cost
1 : RVC Offices	$135,556
2 : Laundromat	$158,700
3 : District System	$324,013

Operation and maintenance costs were estimated for each option. It is assumed that RVC would use existing staff to load the boiler and perform maintenance as needed and additional labor costs for maintenance are not considered. Ash removal costs are not considered since ash can be a valuable resource to improve soil quality and is assumed to be land applied. Additional electricity costs are estimated for each option assuming electricity costs of $0.70/kWh.

Table 5.0-2 – Estimated Annual Operating & Maintenance Costs

Item	Option 1	Option 2	Option 3
Electricity	$966	$1,405	$3,311
Annual Maintenance	$100	$100	$100
Totals	**$1,066**	**$1,505**	**$3,411**

Notes:

1 – Electricity costs assume 10 days of full power operation and 200 days at part load for Option 1, 6 hours a day of full power operation and 4 hours a day of part load operation for Options 2 and 3, and an electricity price of $0.70/kWh to estimate electricity costs.

2 – Option 3 includes an additional 1 hp district pump during hours of operation.

3 – Annual maintenance costs are annualized over the lifespan of manufacturer recommended replacement parts. Replacement is assumed by RVC staff and costs for labor are not included.

A fuel use summary was developed for each option showing the current annual oil use, estimated offset with the cord wood system, estimated annual wood use, and estimated annual oil use to supplement the wood system. Table 5.0-3 shows the estimated annual fuel use summary.

Table 5.0-3 – Estimated Annual Fuel Use Summary

Option	Estimated Current Annual Oil Use, Gallons	Estimated Offset with Cord Wood System	Estimated Annual Cord Wood Use, Cords	Estimated Annual Fuel Oil Use with Cord Wood System, Gallons
1 : RVC Offices	2,040	70%	12.9	612
2 : Laundromat	2,450	70%	15.5	735
3 : District System	4,490	70%	28.4	1,347

Annual operating savings are estimated considering fuel costs and O&M costs. Table 5.0-4 shows the estimated annual operating savings for each option.

Table 5.0-4 – Estimated Annual Operating Savings

Option	Current Annual Fuel Oil Cost	Estimated Costs and Savings with Cord Wood System			
		Estimated Annual Cord Wood Cost	Estimated Annual Oil Cost with Cord Wood System	Estimated Annual O&M Costs	Estimated Annual Savings
1 : RVC Offices	$13,257	$3,870	$3,978	$1,066	$4,343
2 : Laundromat	$15,925	$4,650	$4,778	$1,505	$4,992
3 : District System	$29,182	$8,520	$8,756	$3,411	$8,495

A benefits summary is listed in Table 5.0-5 showing the estimated capital cost, 1st year net operating savings, simple payback, 20 year Net Present Value, and 20 Year Benefits to Cost (B/C) ratio.

Table 5.0-5 – Cost and Benefit Summary

Option	Estimated Capital Cost	1st Year Net Annual Operating Savings	Simple Payback, Years	20 Year Net Present Value	20 Year B/C Ratio
1 : RVC Offices	$135,556	$4,343	31.2	$ (50,621)	0.63
2 : Laundromat	$158,700	$4,992	31.8	$ (61,031)	0.62
3 : District System	$324,013	$8,495	38.1	$ (157,704)	0.51

Notes:

1 – Net Annual Operating Savings include costs for wood fuel, supplemental fossil fuel, and operation & maintenance (O&M) costs.

2 – 20 Year Net Present Value takes the present value of the operating savings for each year using a nominal discount rate of 3.1% as published in the "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - 2014" and the initial capital outlay of the total project cost. A value greater than zero means that savings are greater than expenses over 20 years in the value of today's dollars.

3 – 20 Year Benefit/Cost (B/C) Ratio is calculated by dividing the present value of net annual operating savings over a 20 year period with a discount rate of 3.1% by the Estimated Capital Cost. A value greater than 1 means the benefits exceed the costs over a 20 year period.

A cash flow analysis was completed for financing the projects assuming a 20 year financing term at a 4.0% interest rate. None of the Options had a positive first year cash flow after annual payments. First year cash flow for all three options would break even or be slightly positive with 65% grant funding of project costs. The detailed analyses are shown in Appendix C. Table 5.0-6 lists the assumptions and values used to develop costs and savings in this study.

Table 5.0-6 – Assumptions and Values Used in the Report

Item	Value and Unit	Source
Cord wood moisture content, wet basis	20%	WES E&E assumption
#1 Fuel oil high heating value	134,000 Btu/gal	WES E&E assumption
High heating value of 50/50 mix of White Spruce (18.1 mmBtu/cord) and Black Spruce (15.9 mmBtu/cord)	17.0 mmBtu/Cord	University of Alaska Fairbanks Cooperative Extension Service
#1 Fuel oil boiler efficiency (HHV)	80%	WES E&E assumption
Cord wood gasification boiler efficiency (HHV)	70%	WES E&E assumption
RVC Offices oil offset with cord wood system	70%	WES E&E assumption
Laundromat oil offset with cord wood system	70%	WES E&E assumption
District system oil offset with cord wood system	70%	WES E&E assumption
Electricity price	$0.70/kWh	WES E&E assumption
#1 Fuel oil price	$6.50/gallon	RVC
Cord wood price	$300/cord	RVC
#1 Fuel oil inflation rate	3.1%	NISTIR 85-3273-29
O&M inflation rate	3.0%	WES E&E assumption
Cord wood inflation rate	3.0%	WES E&E assumption
Discount rate	3.1%	NISTIR 85-3273-29

6.0 CONCLUSIONS & RECOMMENDATIONS

This study concludes that Rampart Village Council can reduce annual operating costs for space heating and laundry services by installing a high efficiency, low emission cord wood boiler system. Based on the current economics, capital costs may be too high for RVC to justify proceeding with a project. The proposed systems will offset 70% of the current fuel oil use for space heating, laundry, and domestic hot water at capital costs ranging from ~$135,000 - ~$325,000 depending on the option selected. This would provide Rampart Village Council with net operating savings ranging from ~$4,000 to ~$8,500 in the first year of operation. If 75% of the project costs were funded through grants, the simple payback for RVC funds would range from 8 - 10 years for the proposed options. Additional benefits that would be provided by proceeding with a project include:

- Purchase of cord wood will immediately impact the local economy;
- Decreased dependence on fossil fuels by replacing 1,500 to 3,150 gallons of #1 fuel oil with renewable biomass fuel;
- A hedge against volatility of the fossil fuel market;

As Rampart Village Council continues to pursue biomass energy options, WES Energy & Environment recommends that the next level of evaluation includes detailed consideration of the following items:

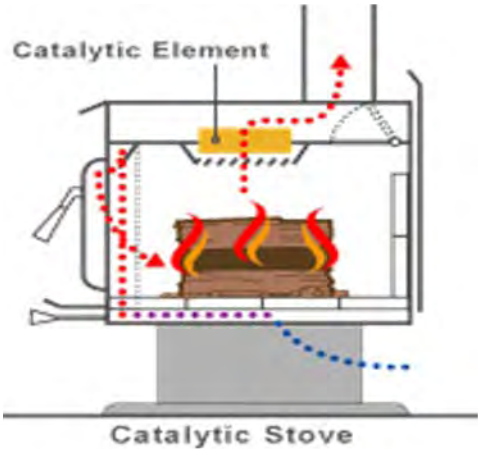
- Siting of the biomass plant and covered cord wood storage area.
- Biomass system capital costs based on detailed site investigations, initial plant layout and design, and direct quotes from manufacturers.
- Alternative funding sources (low interest loans, grants, and incentives).
- Evaluate in further detail the potential to interconnect the Multipurpose Building and Laundromat heating systems and use the Laundromat boiler for heating both buildings.
- Capital avoidance costs for not refurbishing the Multipurpose Building boilers if the Laundromat boilers are used for heating.
- Acceptable district piping routes between evaluated buildings.
- The potential to install a bypass, lint trap, and alternate dryer vent discharge into the Laundromat. The bypass damper could be controlled by a humidistat in the laundromat. This would reduce the heating demand of the building by recovering the heat from the dryer exhaust.

7.0 GENERAL BIOMASS TECHNOLOGY INFORMATION

This section describes technologies that can be used for efficiently using wood for space heating and domestic hot water heating. Manufacturers of each technology are available both domestically and abroad. A partial list of manufacturers is provided for technologies and does not constitute an endorsement. Other manufacturers are available and individual investigations should be completed prior to purchase. Local codes and regulations may require modifications or additional components for compliance depending on the system considered.

High Efficiency Catalytic Wood Stoves

High efficiency catalytic wood stoves can be used to heat spaces efficiently using cord wood. They are typically used for smaller buildings and rooms with open layouts. The catalytic element reburns the smoke to increase efficiency and reduce air emissions. Efficiencies can reach 70% and higher. Equipment costs can range from $4,000 to $6,000 plus installation. Annual savings can range from $3,000 to $5,000 per year based on a facility using 1,500 gallons of propane per year at current prices. Catalytic elements will require periodic replacement every 5-7 years depending on frequency of use and will cost $200 - $400 for the replacement element. Wood loading and ash removal is manual. A partial list of manufacturers include Woodstock Soapstone, Blaze King, Vermont Castings, and Lopi.



Source:
http://www.epa.gov/burnwise/woodstoves.html

Wood Pellet Stoves

High efficiency wood pellet stoves can be used to heat spaces efficiently using wood pellets. They are typically used for smaller buildings and rooms with open layouts. Efficiencies can reach 80% and higher. Equipment costs can range from $4,000 to $7,000 plus installation. Annual savings can range from $1,500 to $2,500 per year based on a facility using 1,500 gallons of propane per year at current prices. Fuel loading and ash removal is manual. A partial list of manufacturers include England Stove Works, Sherwood Industries, Harman, and Lopi.

Source:
http://www.forgreenheat.org/consumer_resources/reliablepellet.html

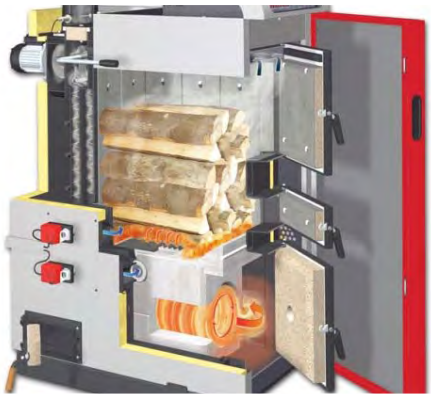
High Efficiency Indoor Wood Pellet Boiler

High efficiency indoor wood pellet boilers utilize premium wood pellets as a renewable biomass fuel source for hot water space heating systems. Wood pellets are automatically fed from an adjacent storage hopper into the firebox based on heating demand. Efficiencies can exceed 80% when coupled with a hot water thermal storage system that allows the boiler to operate at high fire to charge the hot water thermal storage tank. Multiple boilers can be operated to increase heating capacity. Equipment costs can vary depending on the heating capacity required. Annual savings can range from $3,000 to $6,000 per year based on a facility using 5,000 gallons of #1 fuel oil per year at current prices. Manual and automatic hopper loading is available. Ash removal is manual. A partial list of manufacturers include ACT Bioenergy, Froling, MESys, Evo World, Windhager, Kedel, and Wood Master.

Source:
http://www.woodboilers.com/products/pellet-boilers/froling-p4-pellet.html

High Efficiency Indoor Cord Wood Boiler

High efficiency indoor cordwood boilers utilize split cordwood as a renewable biomass fuel source for hot water space heating systems. Efficiencies can exceed 70% when coupled with a hot water thermal storage system that allows the cordwood boiler to operate at high fire to charge the hot water thermal storage tank. Equipment costs can range from $7,000 to $15,000 plus installation. Annual savings can range from $1,800 to $2,200 per year based on an average building using 1,500 gallons of #1 fuel oil per year at current prices. Manual loading and ash removal are required. A partial list of manufacturers include Wood Gun, Econoburn, Froling, Windhager, and Wood Master.



Source:
http://www.woodboilers.com/products/woodboilers/froeling-fhg.html

Advanced Biomass Combustion Units and Boilers

Advanced biomass combustion units and boilers are typically an engineered product capable of firing on wood chips, saw mill residue, wood pellets, and saw dust. Fuel is typically delivered in bulk semi-trailer loads and automatically conveyed to the combustion unit. Efficiencies can exceed 70% when coupled with a hot water thermal storage system. Emission controls are typically required to clean up exhaust gasses. Capital costs are high and vary depending on many factors. Annual fuel cost savings can range from $100,000 to $120,000 per year based on a facility using 50,000 gallons of #1 fuel oil per year at current prices. High fuel costs and high fuel usage can potentially make a project feasible. A partial list of manufacturers include Viessman, ACT Bioenergy, Froling, MESys, Evo World, Wood Master, Messersmith Manufacturing, AFS Energy Systems, Solagen, Wellons FEI, and Hurst.

Source:
http://www.afsenergy.com/Biomass%20Energy.htm

Hot Water Thermal Storage System

Thermal storage tanks, also known as accumulator tanks or buffer tanks, can raise the efficiency of hot water heating systems firing on wood. Solid fuels burn more efficiently at higher firing rates than at lower rates or idle modes where the fuel smolders, smokes, and wastes energy. Hot water thermal storage allows the solid fuel boiler to fire efficiently at full output to store the heat at elevated temperatures in storage tanks. For optimum operation a mixing valve is installed to blend cold water returning from the facility with hot water stored in the thermal storage tank. Hot water is sent back to the facility at a temperature that is lower than the storage tanks, providing heat storage and a buffer for short periods of high demand. This method of operation reduces smoldering and smoking from inefficient operation, fuel use, creosote buildup, and the need for frequent stoking.

Source:
http://www.viessmann-us.com/en/District_Heating/Products/dhw/Storage_Tanks.html

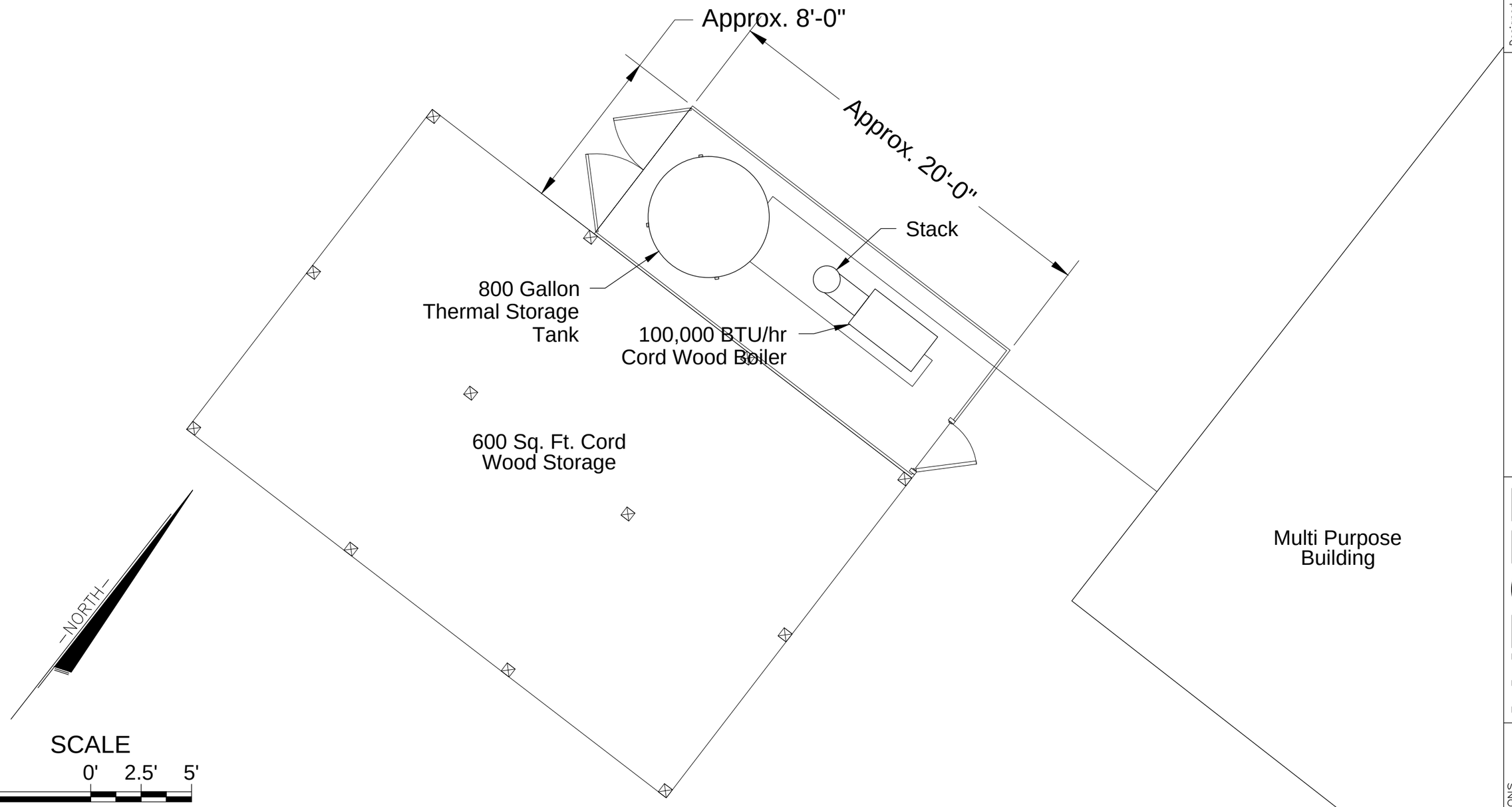
District Piping Systems

It can often be cost effective to connect multiple buildings to one central wood fired heating plant. Long runs of buried piping can be installed cost effectively using pre-insulated PEX piping. It is important to use factory injected close cell foam insulation with a High Density Polyethylene (HDPE) insulation jacket to prevent the insulation from being compromised from ground water or leaks. Pipe sizes can range from 3/4" to 5" with roll lengths up to 600 feet. Pipe material costs can be more expensive than traditional iron pipe, however installation costs can be reduced due to longer runs between splices and connections.

Source:
WES Energy & Environment File Photo

Appendix A

Conceptual Drawings



Notes

1. This drawing is a conceptual layout for the purposes of showing one option for layout of a biomass system. Final design and layout will change based on equipment selected, designer, and site conditions.

Designed DHB 6/18/15
Drawn DHB 6/18/15
Checked GJF
Approved
Date
Title
Job Class

Proposed Biomass
Rampart Village, AK

Option 1 Plan View

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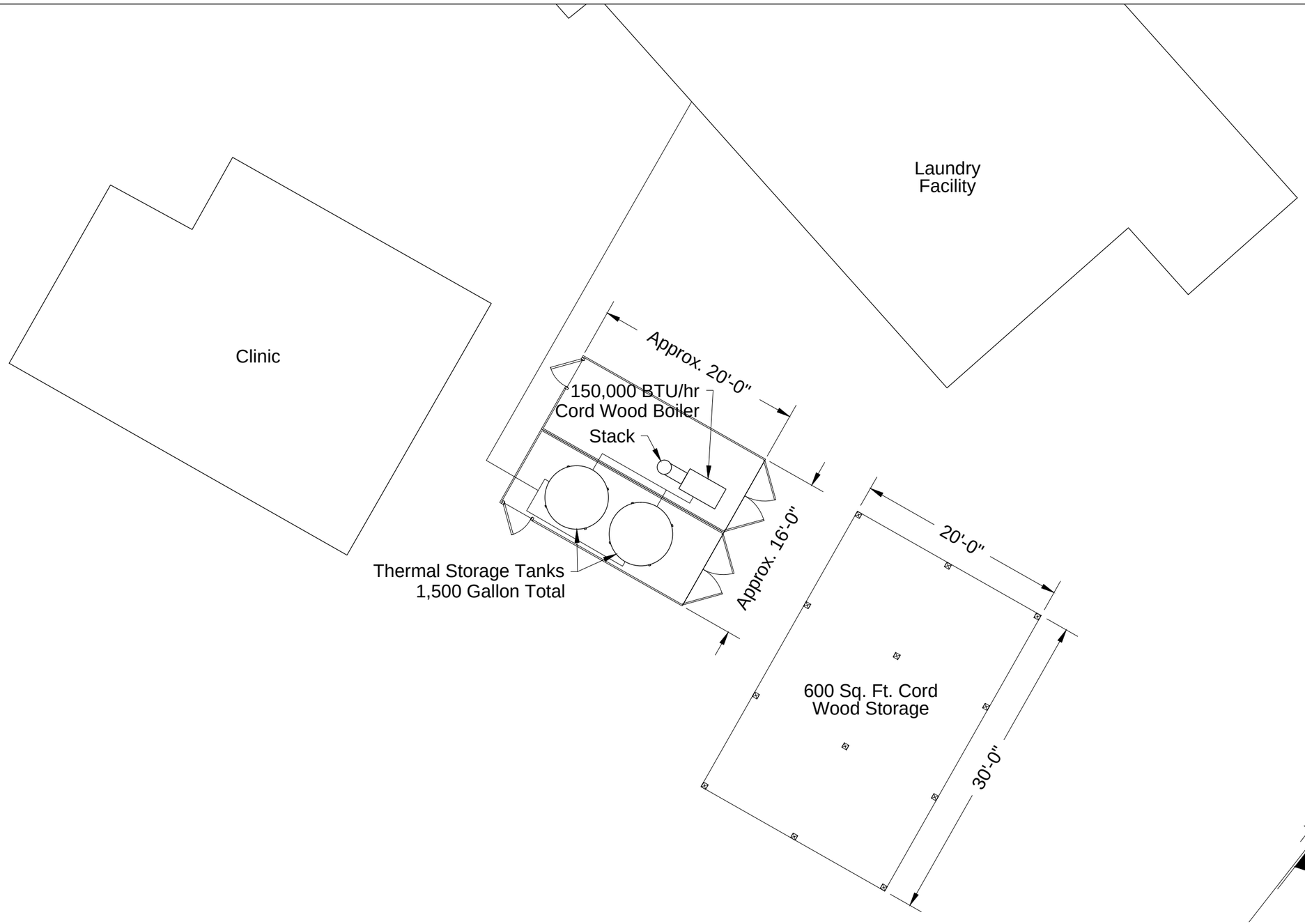
WES Energy and Environment
wesEnergyAndEnvironment.com
902 Market St. Meadville, PA 16335

REVISIONS

Date	Description	Approved

A.1



Notes

1. This drawing is a conceptual layout for the purposes of showing one option for layout of a biomass system. Final design and layout will change based on equipment selected, designer, and site conditions.

SCALE

10' 0' 5' 10'

Proposed Biomass
Rampart Village, AK

Option 2 Plan View

Designed DHB 6/18/15
Drawn DHB 6/18/15
Checked GJF
Approved
Date
Title
Job Class

REVISIONS

Date	Description	Approved

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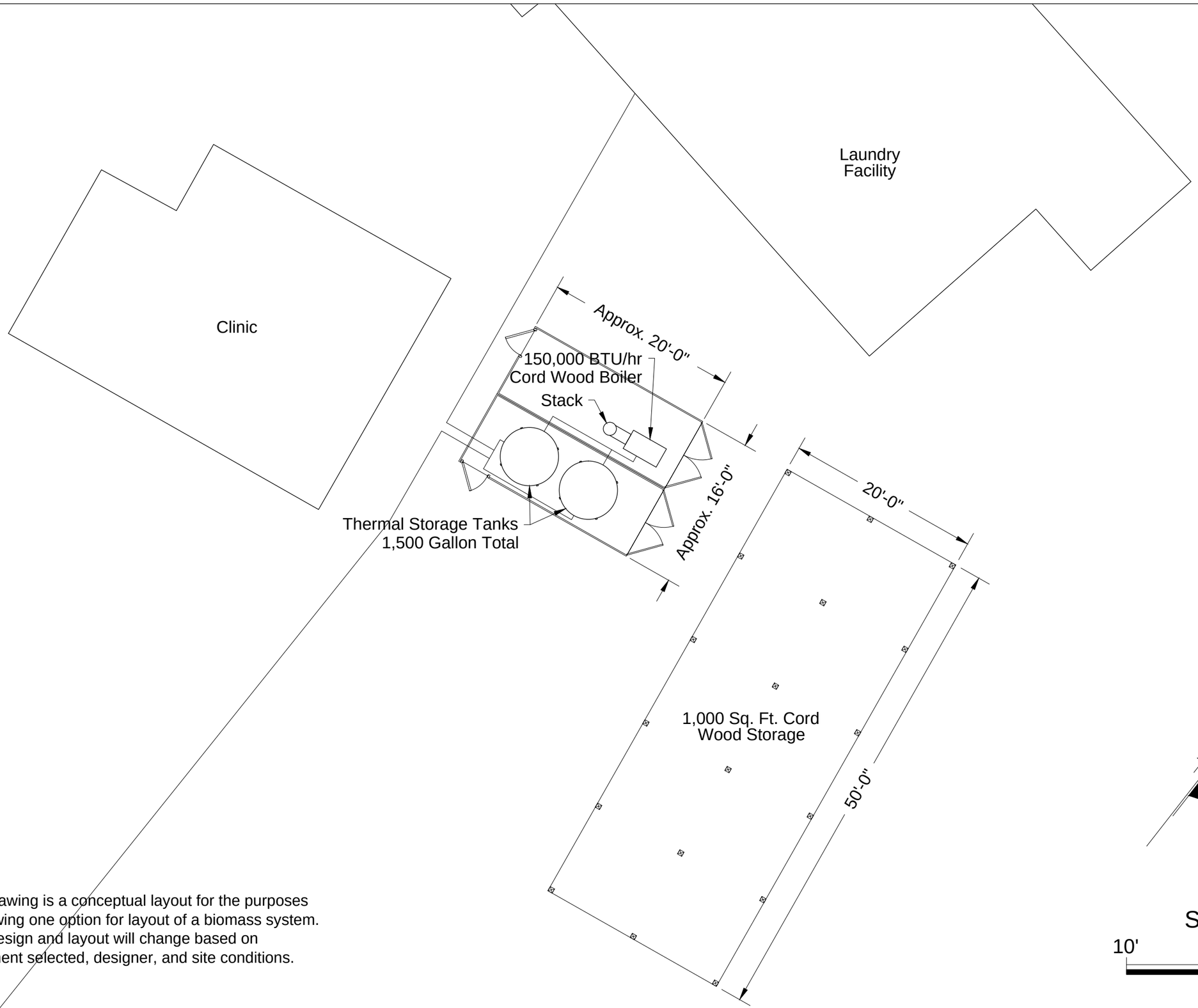
WES Energy and Environment
wesEnergyAndEnvironment.com
902 Market St. Meadville, PA 16335



Notes

1. This drawing is a conceptual layout for the purposes of showing one option for layout of a biomass system. Final design and layout will change based on equipment selected, designer, and site conditions.

SCALE

10' 0' 5' 10'

Proposed Biomass
Rampart Village, AK

Option 3 Plan View

Designed DHB 6/18/15
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Checked GJF
Approved
Date
Title
Job Class

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wesEnergyAndEnvironment.com
902 Market St. Meadville, PA 16335

REVISIONS

Date	Description	Approved

A.3

Designed DHB 6/18/15
Drawn DHB 6/18/15
Checked GJF

Approved ____ Date ____
Title ____ Job Class ____

Proposed Biomass

Rampart Village, AK

Option 3 Site Plan

WESEE

WES Energy and Environment
wesEnergyAndEnvironment.com
902 Market St. Meadville, PA 16335

REVISIONS		
Date	Description	Approved

A.4

Appendix B

Preliminary Capital Cost Estimates

Appendix B

Option 1 - Cord Wood Boiler System for RVC Offices in the Multipurpose Building

Line Item				Cost
One (1) - 100,000 Btu/hr cord wood boiler, freight, containerized, and installed			$	45,000
Stick frame storage building with cribbing floor to stack wood, 500 ft^2 @ \$25/ft^2			$	12,500
Thermal storage 800 gallon with insulation			$	15,000
Inhibited Propylene Glycol			$	10,000
Interconnection with existing boiler room, pumps, installation			$	10,000
Electrical			$	5,000
Mechanical			$	5,000
Sub-Total			*$*	*102,500*
	Contingency	*15%*	*$*	*15,375*
Sub-Total			*$*	*117,875*
	Profesional Services	*15%*	*$*	*17,681*
Total			**$**	**135,556**

Notes:

1 - The boiler system is to be installed next to the existing boiler room. Pricing is based on a one-boiler solution. There are multiple manufacturers that can provide varying boiler sizes. Other boiler sizing combinations to meet a similar output range may also be selected.

2 - Professional Services includes permitting, legal, engineering, & project management. (Assumed that minimal engineering is required.)

3 - Estimate is based on competitive bidding.

Option 2 - Cord Wood Boiler System for Laundromat

Line Item				Cost
One (1) - 100,000 Btu/hr cord wood boiler, freight, containerized, and installed			$	45,000
Stick frame storage building with cribbing floor to stack wood, 600 ft^2 @ \$25/ft^2			$	15,000
Thermal storage 1,500 gallon with insulation			$	20,000
Inhibited Propylene Glycol			$	20,000
Interconnection with existing boiler room, pumps, installation			$	10,000
Electrical			$	5,000
Mechanical			$	5,000
Sub-Total			*$*	*120,000*
	Contingency	*15%*	*$*	*18,000*
Sub-Total			*$*	*138,000*
	Profesional Services	*15%*	*$*	*20,700*
Total			**$**	**158,700**

Notes:

1 - The boiler system is to be installed next to the existing boiler room. Pricing is based on a one-boiler solution. There are multiple manufacturers that can provide varying boiler sizes. Other boiler sizing combinations to meet a similar output range may also be selected.

2 - Professional Services includes permitting, legal, engineering, & project management. (Assumed that minimal engineering is required.)

3 - Estimate is based on competitive bidding.

Option 3 - District Cord Wood Boiler System for Laundromat & RVC Offices in the Multipurpose Building

Line Item				Cost
One (1) - 150,000 Btu/hr cord wood boiler, freight, containerized, and installed			$	50,000
Stick frame storage building with cribbing floor to stack wood, 1,000 ft^2 @ $25/$ft^2$			$	25,000
Thermal storage 1,500 gallon with insulation			$	20,000
Inhibited Propylene Glycol			$	20,000
360 linear feet of 1.5" utilidor district piping to Laundry & Multipurpose Building @ $250/lf			$	90,000
Interconnection with both boiler rooms, pumps, installation			$	20,000
Electrical			$	10,000
Mechanical			$	10,000
Sub-Total			*$*	*245,000*
	Contingency	*15%*	*$*	*36,750*
Sub-Total			*$*	*281,750*
	Profesional Services	*15%*	*$*	*42,263*
Total			**$**	**324,013**

Notes:

1 - The boiler system is to be installed between the Multipurpose Building and the Laundromat. Pricing is based on a one-boiler solution. There are multiple manufacturers that can provide varying boiler sizes. Other boiler sizing combinations to meet a similar output range may also be selected.

2 - Professional Services includes permitting, legal, engineering, & project management. (Assumed that minimal engineering is required.)

3 - Estimate is based on competitive bidding.

Appendix C

20 Year Financing at 4% APR Cash Flow Analysis

Appendix C Option 1 - Cord Wood Boiler System for RVC Offices in the Multipurpose Building
20 Year, 4% Financing

Input Variables	Value	Units
Project Costs Financed	135,556	$
Financing Term	20	# years
Financing Rate (apr)	4.0%	Percent
Current #1 Fuel Oil Usage	2,040	gal
Year 1 #1 Fuel Oil Average Price	$6.50	$/gal
Proposed Annual Cord Wood Usage	12.9	Cords/yr
Year 1 Cord Wood Purchase Price	$300	$/Cord
Annual #1 Fuel Oil Usage w/ Wood System	612	gal/yr
Fossil Fuel Inflation Rate (apr)	3.1%	Percent
Cord Wood Inflation Rate (apr)	3.0%	Percent
O&M Inflation Rate	3.0%	Percent
Discount Rate (apr)	3.1%	Percent
Added Annual O&M Costs for Biomass Plant	$1,066	$/yr

Year	#1 Fuel Oil Cost, Current System	Cord Wood Cost	#1 Fuel Oil Cost, w/ Wood System	Added O&M Cost	Net Operating Savings	Annual Financing Payment	Net Cash Flow	Present Value of Cash Flow
1	$ 13,257	$ (3,870)	$ (3,978)	$ (1,066)	$ 4,343	$ (9,974)	$ (5,632)	$ (5,462)
2	$ 13,668	$ (3,986)	$ (4,101)	$ (1,099)	$ 4,481	$ (9,974)	$ (5,493)	$ (5,168)
3	$ 14,092	$ (4,106)	$ (4,228)	$ (1,133)	$ 4,624	$ (9,974)	$ (5,350)	$ (4,882)
4	$ 14,528	$ (4,229)	$ (4,360)	$ (1,168)	$ 4,772	$ (9,974)	$ (5,203)	$ (4,605)
5	$ 14,979	$ (4,356)	$ (4,495)	$ (1,204)	$ 4,924	$ (9,974)	$ (5,050)	$ (4,336)
6	$ 15,443	$ (4,486)	$ (4,634)	$ (1,242)	$ 5,081	$ (9,974)	$ (4,893)	$ (4,074)
7	$ 15,922	$ (4,621)	$ (4,778)	$ (1,280)	$ 5,243	$ (9,974)	$ (4,731)	$ (3,821)
8	$ 16,416	$ (4,760)	$ (4,926)	$ (1,320)	$ 5,410	$ (9,974)	$ (4,564)	$ (3,575)
9	$ 16,924	$ (4,902)	$ (5,078)	$ (1,361)	$ 5,583	$ (9,974)	$ (4,392)	$ (3,337)
10	$ 17,449	$ (5,049)	$ (5,236)	$ (1,403)	$ 5,761	$ (9,974)	$ (4,214)	$ (3,105)
11	$ 17,990	$ (5,201)	$ (5,398)	$ (1,447)	$ 5,944	$ (9,974)	$ (4,030)	$ (2,881)
12	$ 18,548	$ (5,357)	$ (5,566)	$ (1,491)	$ 6,134	$ (9,974)	$ (3,841)	$ (2,663)
13	$ 19,123	$ (5,518)	$ (5,738)	$ (1,538)	$ 6,329	$ (9,974)	$ (3,645)	$ (2,451)
14	$ 19,715	$ (5,683)	$ (5,916)	$ (1,585)	$ 6,531	$ (9,974)	$ (3,444)	$ (2,246)
15	$ 20,327	$ (5,854)	$ (6,099)	$ (1,634)	$ 6,739	$ (9,974)	$ (3,235)	$ (2,047)
16	$ 20,957	$ (6,029)	$ (6,288)	$ (1,685)	$ 6,954	$ (9,974)	$ (3,021)	$ (1,853)
17	$ 21,606	$ (6,210)	$ (6,483)	$ (1,737)	$ 7,175	$ (9,974)	$ (2,799)	$ (1,666)
18	$ 22,276	$ (6,397)	$ (6,684)	$ (1,791)	$ 7,404	$ (9,974)	$ (2,570)	$ (1,484)
19	$ 22,967	$ (6,588)	$ (6,892)	$ (1,847)	$ 7,640	$ (9,974)	$ (2,334)	$ (1,307)
20	$ 23,679	$ (6,786)	$ (7,105)	$ (1,904)	$ 7,883	$ (9,974)	$ (2,091)	$ (1,136)
							Present Value	**$ (62,097)**

Appendix C

Option 2 - Cord Wood Boiler System for Laundromat
20 Year, 4% Financing

Input Variables	Value	Units
Project Costs Financed	158,700	$
Financing Term	20	# years
Financing Rate (apr)	4.0%	Percent
Current #1 Fuel Oil Usage	2,450	gal
Year 1 #1 Fuel Oil Average Price	$6.50	$/gal
Proposed Annual Cord Wood Usage	16	Cords/yr
Year 1 Cord Wood Purchase Price	$300	$/Cord
Annual #1 Fuel Oil Usage w/ Wood System	735	gal/yr
Fossil Fuel Inflation Rate (apr)	3.1%	Percent
Cord Wood Inflation Rate (apr)	3.0%	Percent
O&M Inflation Rate	3.0%	Percent
Discount Rate (apr)	3.1%	Percent
Added Annual O&M Costs for Biomass Plant	$1,505	$/yr

Year	#1 Fuel Oil Cost, Current System	Cord Wood Cost	#1 Fuel Oil Cost, w/ Wood System	Added O&M Cost	Net Operating Savings	Annual Financing Payment	Net Cash Flow	Present Value of Cash Flow
1	$ 15,925	$ (4,650)	$ (4,778)	$ (1,505)	$ 4,992	$ (11,677)	$ (6,685)	$ (6,484)
2	$ 16,419	$ (4,790)	$ (4,926)	$ (1,552)	$ 5,152	$ (11,677)	$ (6,526)	$ (6,139)
3	$ 16,928	$ (4,933)	$ (5,078)	$ (1,600)	$ 5,316	$ (11,677)	$ (6,361)	$ (5,805)
4	$ 17,452	$ (5,081)	$ (5,236)	$ (1,650)	$ 5,486	$ (11,677)	$ (6,192)	$ (5,480)
5	$ 17,993	$ (5,234)	$ (5,398)	$ (1,701)	$ 5,661	$ (11,677)	$ (6,016)	$ (5,165)
6	$ 18,551	$ (5,391)	$ (5,565)	$ (1,753)	$ 5,842	$ (11,677)	$ (5,836)	$ (4,859)
7	$ 19,126	$ (5,552)	$ (5,738)	$ (1,808)	$ 6,028	$ (11,677)	$ (5,649)	$ (4,562)
8	$ 19,719	$ (5,719)	$ (5,916)	$ (1,864)	$ 6,221	$ (11,677)	$ (5,457)	$ (4,274)
9	$ 20,331	$ (5,890)	$ (6,099)	$ (1,922)	$ 6,419	$ (11,677)	$ (5,258)	$ (3,995)
10	$ 20,961	$ (6,067)	$ (6,288)	$ (1,981)	$ 6,624	$ (11,677)	$ (5,053)	$ (3,724)
11	$ 21,611	$ (6,249)	$ (6,483)	$ (2,043)	$ 6,836	$ (11,677)	$ (4,842)	$ (3,461)
12	$ 22,280	$ (6,437)	$ (6,684)	$ (2,106)	$ 7,054	$ (11,677)	$ (4,624)	$ (3,205)
13	$ 22,971	$ (6,630)	$ (6,891)	$ (2,171)	$ 7,279	$ (11,677)	$ (4,399)	$ (2,958)
14	$ 23,683	$ (6,829)	$ (7,105)	$ (2,239)	$ 7,511	$ (11,677)	$ (4,166)	$ (2,717)
15	$ 24,417	$ (7,034)	$ (7,325)	$ (2,308)	$ 7,751	$ (11,677)	$ (3,927)	$ (2,484)
16	$ 25,174	$ (7,245)	$ (7,552)	$ (2,380)	$ 7,998	$ (11,677)	$ (3,679)	$ (2,258)
17	$ 25,955	$ (7,462)	$ (7,786)	$ (2,453)	$ 8,253	$ (11,677)	$ (3,424)	$ (2,038)
18	$ 26,759	$ (7,686)	$ (8,028)	$ (2,529)	$ 8,517	$ (11,677)	$ (3,161)	$ (1,825)
19	$ 27,589	$ (7,916)	$ (8,277)	$ (2,608)	$ 8,788	$ (11,677)	$ (2,889)	$ (1,618)
20	$ 28,444	$ (8,154)	$ (8,533)	$ (2,689)	$ 9,069	$ (11,677)	$ (2,609)	$ (1,417)
							Present Value	**$ (74,466)**

Appendix C

Option 3 - District Cord Wood Boiler System for Laundromat & RVC Offices in the Multipurpose Building
20 Year, 4% Financing

Input Variables	Value	Units
Project Costs Financed	324,013	$
Financing Term	20	# years
Financing Rate (apr)	4.0%	Percent
Current #1 Fuel Oil Usage	4,490	gal
Year 1 #1 Fuel Oil Average Price	$6.50	$/gal
Proposed Annual Cord Wood Usage	28	Cords/yr
Year 1 Cord Wood Purchase Price	$300	$/Cord
Annual #1 Fuel Oil Usage w/ Wood System	1,347	gal/yr
Fossil Fuel Inflation Rate (apr)	3.1%	Percent
Cord Wood Inflation Rate (apr)	3.0%	Percent
O&M Inflation Rate	3.0%	Percent
Discount Rate (apr)	3.1%	Percent
Added Annual O&M Costs for Biomass Plant	$3,411	$/yr

Year	#1 Fuel Oil Cost, Current System	Cord Wood Cost	#1 Fuel Oil Cost, w/ Wood System	Added O&M Cost	Net Operating Savings	Annual Financing Payment	Net Cash Flow	Present Value of Cash Flow
1	$ 29,182	$ (8,520)	$ (8,756)	$ (3,411)	$ 8,495	$ (23,841)	$ (15,346)	$ (14,885)
2	$ 30,087	$ (8,776)	$ (9,027)	$ (3,517)	$ 8,767	$ (23,841)	$ (15,074)	$ (14,181)
3	$ 31,019	$ (9,039)	$ (9,307)	$ (3,626)	$ 9,048	$ (23,841)	$ (14,794)	$ (13,499)
4	$ 31,981	$ (9,310)	$ (9,595)	$ (3,738)	$ 9,337	$ (23,841)	$ (14,504)	$ (12,837)
5	$ 32,972	$ (9,589)	$ (9,893)	$ (3,854)	$ 9,636	$ (23,841)	$ (14,206)	$ (12,195)
6	$ 33,994	$ (9,877)	$ (10,199)	$ (3,974)	$ 9,944	$ (23,841)	$ (13,897)	$ (11,571)
7	$ 35,048	$ (10,173)	$ (10,516)	$ (4,097)	$ 10,262	$ (23,841)	$ (13,579)	$ (10,966)
8	$ 36,135	$ (10,479)	$ (10,842)	$ (4,224)	$ 10,591	$ (23,841)	$ (13,251)	$ (10,379)
9	$ 37,255	$ (10,793)	$ (11,178)	$ (4,355)	$ 10,929	$ (23,841)	$ (12,912)	$ (9,810)
10	$ 38,410	$ (11,117)	$ (11,524)	$ (4,490)	$ 11,279	$ (23,841)	$ (12,562)	$ (9,257)
11	$ 39,601	$ (11,450)	$ (11,881)	$ (4,629)	$ 11,640	$ (23,841)	$ (12,202)	$ (8,721)
12	$ 40,828	$ (11,794)	$ (12,250)	$ (4,773)	$ 12,012	$ (23,841)	$ (11,829)	$ (8,201)
13	$ 42,094	$ (12,147)	$ (12,629)	$ (4,921)	$ 12,396	$ (23,841)	$ (11,445)	$ (7,696)
14	$ 43,399	$ (12,512)	$ (13,021)	$ (5,073)	$ 12,793	$ (23,841)	$ (11,049)	$ (7,206)
15	$ 44,744	$ (12,887)	$ (13,425)	$ (5,230)	$ 13,202	$ (23,841)	$ (10,640)	$ (6,731)
16	$ 46,131	$ (13,274)	$ (13,841)	$ (5,393)	$ 13,624	$ (23,841)	$ (10,218)	$ (6,269)
17	$ 47,561	$ (13,672)	$ (14,270)	$ (5,560)	$ 14,060	$ (23,841)	$ (9,782)	$ (5,821)
18	$ 49,036	$ (14,082)	$ (14,712)	$ (5,732)	$ 14,509	$ (23,841)	$ (9,332)	$ (5,387)
19	$ 50,556	$ (14,505)	$ (15,168)	$ (5,910)	$ 14,973	$ (23,841)	$ (8,869)	$ (4,965)
20	$ 52,123	$ (14,940)	$ (15,639)	$ (6,093)	$ 15,452	$ (23,841)	$ (8,390)	$ (4,556)
							Present Value	**$ (185,134)**

Appendix D

Sensitivity Analysis of Estimated Annual Operating Savings to Oil and Biomass Fuel Prices

Appendix D

Option 1 - Cord Wood Boiler System for RVC Offices in the Multipurpose Building
First Year Net Operating Savings Sensitivity Analysis

Price of Cord Wood per Cord	Price of Fuel Oil per Gallon							
	$5.00	**$5.50**	**$6.00**	**$6.50**	**$7.00**	**$7.50**	**$8.00**	**$8.50**
$225	$3,169	$3,883	$4,597	$5,310	$6,024	$6,738	$7,452	$8,166
$250	$2,847	$3,560	$4,274	$4,988	$5,702	$6,415	$7,129	$7,843
$275	$2,524	$3,238	$3,952	$4,665	$5,379	$6,093	$6,807	$7,521
$300	$2,202	$2,915	$3,629	$4,343	$5,057	$5,770	$6,484	$7,198
$325	$1,879	$2,593	$3,307	$4,020	$4,734	$5,448	$6,162	$6,876
$350	$1,557	$2,270	$2,984	$3,698	$4,412	$5,125	$5,839	$6,553
$375	$1,234	$1,948	$2,662	$3,375	$4,089	$4,803	$5,517	$6,231

**Note: Excludes financing costs.*

Appendix D

Option 2 - Cord Wood Boiler System for Laundromat
First Year Net Operating Savings Sensitivity Analysis

Price of Cord Wood per Cord	Price of Fuel Oil per Gallon							
	$5.00	**$5.50**	**$6.00**	**$6.50**	**$7.00**	**$7.50**	**$8.00**	**$8.50**
$225	$3,582	$4,440	$5,297	$6,155	$7,012	$7,870	$8,727	$9,585
$250	$3,195	$4,052	$4,910	$5,767	$6,625	$7,482	$8,340	$9,197
$275	$2,807	$3,665	$4,522	$5,380	$6,237	$7,095	$7,952	$8,810
$300	$2,420	$3,277	$4,135	$4,992	$5,850	$6,707	$7,565	$8,422
$325	$2,032	$2,890	$3,747	$4,605	$5,462	$6,320	$7,177	$8,035
$350	$1,645	$2,502	$3,360	$4,217	$5,075	$5,932	$6,790	$7,647
$375	$1,257	$2,115	$2,972	$3,830	$4,687	$5,545	$6,402	$7,260

**Note: Excludes financing costs.*

Option 3 - District Cord Wood Boiler System for Laundromat & RVC Offices in the Multipurpose Building
First Year Net Operating Savings Sensitivity Analysis

Price of Cord Wood per Cord	Price of Fuel Oil per Gallon							
	$5.00	**$5.50**	**$6.00**	**$6.50**	**$7.00**	**$7.50**	**$8.00**	**$8.50**
$225	$5,911	$7,483	$9,054	$10,625	$12,196	$13,768	$15,339	$16,910
$250	$5,201	$6,773	$8,344	$9,915	$11,486	$13,058	$14,629	$16,200
$275	$4,491	$6,063	$7,634	$9,205	$10,776	$12,348	$13,919	$15,490
$300	$3,781	$5,353	$6,924	$8,495	$10,066	$11,638	$13,209	$14,780
$325	$3,071	$4,643	$6,214	$7,785	$9,356	$10,928	$12,499	$14,070
$350	$2,361	$3,933	$5,504	$7,075	$8,646	$10,218	$11,789	$13,360
$375	$1,651	$3,223	$4,794	$6,365	$7,936	$9,508	$11,079	$12,650

**Note: Excludes financing costs.*