Minnesota Department of Natural Resources

MNDNR

Paws and Claws Rescue and Resort

Biomass Energy System

Preliminary Feasibility Report

FINAL

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1.0 EXECUTIVE SUMMARY

The Paws and Claws Rescue & Resort (PCRR) is an animal shelter and boarding house currently under construction in Hackensack, MN. This facility will be heated by propane and is estimated to use an average of 29,492 gallons of propane per year for space heating, costing an average of approximately $44,239 per year, assuming a propane cost of $1.50/gal. A wood heating system utilizing wood energy has the potential to reduce fuel costs and greenhouse gas emissions for this facility, while utilizing a renewable, local fuel source.

Modern biomass combustion systems can efficiently and cleanly utilize a variety of fuels with a wide range of moisture content. While most wood burning appliances are flexible in the fuels they can burn, there are practical limits to range of fuels that can be handled by each appliance. Considerations in choosing a wood boiler are available forms and cost of fuel sources, convenience or staffing levels for servicing the boiler, and ability to cover the heating load. Fuels available for Paws and Claws and options evaluated in this report would require an estimated annual use of up to 132 cords of cordwood, 166 tons of wood pellets, or 178 tons of dry wood chips. Table ES1 compares the cost of delivered heat for wood and fossil fuels.

Table ES1 – Fuel Pricing and Cost per mmBtu

Technology, Unit	Cost/Unit	Input mmBtu /Unit	Assumed Efficiency	Output mmBtu /Unit	Output Cost /mmBtu
Dry Wood Chip[1], ton	$50	15.4	75%	11.6	$4.33
Dry Wood Scraps[2], ton	$30	15.4	60%	9.2	$3.25
Green Wood Chip[3], ton	$40	10.0	70%	7.0	$5.71
Cordwood[4], cord	$185	20.0	65%	13.0	$14.23
Wood Pellet[5], ton	$200	16.4	80%	13.1	$15.24
Propane, gal (estimated)	$1.50	0.091	85%	0.078	$19.32

Note 1: Cost assumes that dry wood scraps are chipped by PCRR staff on site.
Note 2: Dry wood scraps are potentially available from Mann Lake Ltd. and could be cofired with cordwood in a cordwood boiler.
Note 3: Green wood chips are not appropriate for this facility due to the relatively small size of the facility.
Note 4: Cost is for mixed hardwood. Equivalent cost is $116 per ton after wood has been seasoned to 20% moisture content wet basis.
Note 5: Wood pellets are 6-8% moisture content wet basis.

Three biomass boiler options are evaluated for this facility.

Option 1 – Cordwood Boiler System: Two cordwood boilers, sized at 500,000 Btu/hr and 300,000 Btu/hr, would be installed in a new boiler building. The boilers would heat a 2,000 gallon thermal storage tank, and would connect to the mezzanine boiler room via underground supply and return piping.

Option 2 – Pellet Boiler System: One pellet boiler sized at 700,000 Btu/hr would be installed in a new boiler building. The boiler would heat a 500 gallon thermal storage tank, and would connect to the mezzanine boiler room via underground supply and return piping. Pellets would be stored in a 30 ton silo, and would be conveyed to the boiler automatically via a flexible auger.

Option 3 – Dry Chip Boiler System: One dry wood chip boiler sized at 512,000 Btu/hr would be installed in a new boiler building. A 500 gallon thermal storage tank would be installed with the boiler. Wood chip fuel would be produced on site from scraps sourced from Mann Lake Ltd., and would be stored in a below-grade day bin, or an above grade silo. The fuel storage would provide automatic fuel feed to the boiler. The boiler and storage system would also be able to utilize wood pellets. The boiler system would connect to the mezzanine boiler room via underground supply and return piping.

A proposed system fuel use profile is provided in Table ES2 showing the estimated annual fuel use compared to the existing propane system.

Table ES2 – Proposed System Fuel Use Profile

Option	Estimated Annual Fuel Use	Estimated Annual Fuel Use with Proposed Biomass System		
	Propane (gal)	Biomass Demand Coverage	Estimated Biomass Use (tons)[1]	Estimated Propane Use with Biomass System (gal)
1 - Cordwood	29,492	75%	211	7,373
1 - Cordwood w/ 50% scraps	29,492	75%	199	7,373
2 - Pellet	29,492	95%	166	1,475
3 - Dry Chip	29,492	90%	178	2,949

Note 1: Fuel use in this table is in tons. Option 1 using cordwood would require 132 cords.
Note: Table 4 contains the assumptions used to develop the above values.

Table ES3 provides a comparison of fuel costs and operating costs for the options.

Table ES3 – Fuel and Operating Cost Comparison

Option	Estimated Annual Fuel Use	Estimated Annual Costs with Proposed Biomass System			Estimated First Year Operational Savings	Thermal Production Incentive[1]	Estimated Net Cash Flow
	Propane Cost	Biomass Cost	Propane Cost	O&M Increase			
1 - Cordwood	$44,239	$24,437	$11,060	$5,562	$3,180	$7,481	$10,661
1 - Cordwood w/ 50% scraps	$44,239	$15,006	$11,060	$8,162	$10,011	$7,481	$17,492
2 - Pellet	$44,239	$33,157	$2,212	$1,286	$7,584	$9,476	$17,059
3 - Dry Chip	$44,239	$8,920	$4,424	$2,193	$28,701	$8,977	$37,678

Note 1: Thermal Production Incentive payment assumes that 87% of heating takes place October-March, and that heating outside these 2 quarters is insufficient to qualify for the incentive.
Note: Table 4 contains the assumptions used to develop the above values.

A summary of the estimated capital costs and payback is provided in Table ES4. This table also evaluates the options with an assumed 25% grant. No specific grant funding opportunity has been identified. Detailed financial analyses were generated for all options and are included in Appendix C.

Table ES4 – Cost and Payback Analysis

Option	Estimated Capital Cost	Assumed Grant Funding	Financed Amount	Simple Payback Period[1] (years)	Net Present Value (25 years)
1 - Cordwood	$174,819	$0	$174,819	31	$67,540
1 - Cordwood w/ 50% scraps	$174,819	$0	$174,819	10	$230,361
2 - Pellet	$201,341	$0	$201,341	14	$181,060
3 - Dry Chip	$302,268	$0	$302,268	7	$563,408
1 - Cordwood w/ grant	$174,819	$43,705	$131,114	18	$111,245
1 - Cordwood w/ 50% scraps w/ grant	$174,819	$43,705	$131,114	6	$274,065
2 - Pellet w/ grant	$201,341	$50,335	$151,006	7	$231,395
3 - Dry Chip w/ grant	$302,268	$75,567	$226,701	5	$638,975

Note 1: Simple payback is calculated taking into account the assumption that thermal production incentive payments end after 10 years. Option 1 when fired on cordwood has a simple payback period significantly longer than the estimated useful life of the equipment.

A modern biomass boiler system would allow Paws and Claws to avoid fossil fuel usage while utilizing a local and renewable source of energy. The options evaluated in this report would provide benefits to the organization as summarized:

- Option 1 is a boiler system capable of utilizing cordwood or a percentage of dry wood scraps. This project would provide a first year net operating savings of $3,180 when utilizing cordwood only, or $10,011 when utilizing a mixture of cordwood and dry wood scraps, and would have a capital cost of $174,819.
- Option 2 is a boiler system capable of utilizing wood pellets. This project would provide a first year net operating savings of $7,584, and would have a capital cost of $201,341.
- Option 3 is a boiler system capable of utilizing dry wood chips or wood pellets. This project would provide a first year net operating savings of $28,701, and would have a capital cost of $302,268.

Financial performance of the evaluated options is heavily dependent on the cost of fossil fuels and wood fuels, as shown by the sensitivity analyses in Appendix C. If the cost of propane rises, then the savings will increase fairly dramatically.

Payments from the Minnesota Biomass Thermal Production Incentive are a major driver of savings for this project. It is important to note that these payments only occur for 10 years following startup of the project. Payments from this incentive increase the annual savings in today's dollars by $7,481 for Option 1, $9,476 for Option 2, and $8,977 for Option 3. The amount of the incentive is proportional to the quantity of fossil fuel offset, and this is expected to vary depending on the biomass technology installed, as explained in Section 6.

The economics of Option 1, the cordwood option, vary considerably depending on whether the cordwood will be purchased as cut-and-split cordwood from a commercial cordwood processor, or whether scrap wood from Mann Lake will be used to offset some of the cordwood needs. However, use of dry scrap wood may degrade the performance of the cordwood boilers and may result in unsafe operation if too much dry wood is loaded at a time. In addition, Option 1 requires the greatest investment in ongoing staff time compared to the other 2 options. The savings projected for Option 1 will not be fully realized if facility staff are unable or unwilling to service and load the cordwood boilers several times per day.

Additional benefits which would be provided through the use of local biomass at the facility include:

- Net reduction of greenhouse gas emissions by approximately 115-143 metric tonnes annually,
- Keeping $9,000-$33,000/yr spent on energy within the region,
- Diversification of fuels used by the facility,
- Reduction in operating budget volatility due to wide fluctuations in fossil energy pricing,
- Creating markets for low-value woody biomass to enhance opportunities for forest management activities to reduce pests and disease, prevent fires, and manage for ecological diversity, soil health, and water quality.

Should Paws and Claws be interested in pursuing a biomass option, WES recommends that staff visit several types of modern biomass boiler installations to develop a detailed understanding of the equipment and its capabilities. The MN SWET is available to assist in arranging tours of existing facilities. As Paws and Claws continues to pursue renewable biomass energy options, WES recommends that the next level of evaluation includes detailed consideration of the following items:

- Evaluate domestic hot water loads for the facility and determine whether an indirect DHW tank heated by the propane boiler system could replace one of the two specified propane DHW heaters, to reduce capital and operating costs and provide seamless coverage of the DHW using the wood boiler system
- Work with the MN SWET to identify alternative funding sources (low interest loans, grants, and incentives)
- Discuss possible plant ownership or fuel sourcing agreements with local wood products manufacturers in order to leverage available grant programs.
- If biomass installation is delayed, carefully monitor building performance and fuel usage to inform sizing of biomass boilers.

2.0 INTRODUCTION

2.1 MN SWET PROGRAM

The Minnesota Statewide Wood Energy Team (MN SWET) is working to implement commercially available wood energy systems by strategically identifying businesses, government buildings and other institutions that are:

- Currently using propane or fuel oil for heating and do not have direct access to natural gas
- Located in an area of the state with sufficient wood resources and in need of forest market expansion and/or wildfire risk management
- Capable of meeting the space and operational requirements needed for contemporary wood heating systems, and
- Financially committed to thermal wood energy options.

Wilson Engineering Services, PC (WES) was contracted by the Minnesota Department of Natural Resources (MN DNR), on behalf of the MN SWET, to provide Intermediate Woody Biomass Thermal Energy feasibility assessments. The feasibility assessments provide a preliminary engineering and financial analysis for potential projects that are recommended by MN SWET after preliminary screening. The purpose of the feasibility assessments is to facilitate sound decision making by the facilities regarding the installation of wood energy systems. The feasibility assessments address key design parameter choices, such as fuel type (chips, pellets, and cord wood), layout, thermal storage needs, heat distribution, and estimated capital and operating costs.

2.2 PAWS AND CLAWS RESCUE AND RESORT OPPORTUNITY

The Paws and Claws Rescue & Resort (PCRR) is an animal shelter and boarding house currently under construction in Hackensack, MN. The facility, shown in Figure 1, is expected to open in early summer 2017. Because of the abundance of wood resources in the area, the shelter's board of directors is highly interested in the possibility of heating the facility with wood. The board desires that whenever possible, the shelter would cultivate relationships within Cass County, both economic and social. A wood heating system using renewable, locally sourced fuel, such as cordwood, pellets, chips, or industrial wood residues has the potential to keep heating dollars in the local economy and reduce fuel costs and greenhouse gas emissions for this facility.

Figure 1 – Paws and Claws Rescue & Resort Architectural Rendering

3.0 FACILITY OVERVIEW

WES personnel conducted a site visit on November 1, 2016 in order to meet with key staff and review the progress of construction. WES also reviewed mechanical and electrical construction drawings. The building will be approximately 12,400 ft^2 and has been carefully designed to include the following rooms/uses:

- Reception area
- Conference room
- Administration area
- Break room
- Kitchen
- Retail store
- Storage
- Adoption dog holding
- Adoption cat holding
- Adoption support room
- Cat colony
- Exam room
- Dog, cat, puppy, and kitten isolation and quarantine rooms
- Dog boarding suites
- Dog boarding
- Cat boarding
- Boarding support room
- Grooming
- 4 restrooms
- Mechanical mezzanine

The building will be heated and cooled using 11 separate air handlers which will be located in the mezzanine above each zone. Supply fans of these air handlers will operate at all times in order to provide air circulation in the building. Some zones will also be environmentally controlled through air pressurization to keep contaminated air contained in the desired zone. Each air handler will have an exterior condensing unit to provide air conditioning. Aggregate cooling capacity for the building will be 58.5 tons. Each air handler will also have a hot water coil for heating. Hot water for heating will be supplied by 2 propane boilers located in a mezzanine, above the garage in the central part of the building. There will also be 9 separate radiant floor zones, controlled by thermostats with slab sensors, to maintain the slab at 60-70°F.

Dehumidification will be satisfied by wall mounted dehumidification units which will be controlled by humidity sensors mounted above the space. The building will feature several energy recovery ventilators to capture energy from conditioned air being exhausted outside.

The 2 propane condensing boilers are specified as Lochinvar KBL801, which are rated for 800 MBH maximum input, 160 MBH minimum input, 94% thermal efficiency, and 752 MBH maximum output. Each propane boiler will have a Taco 2400-70 circulator. The main building loop serving the air handlers will have 2 Bell and Gossett PL-55 circulators in a lead-lag configuration. The radiant floor system is served by a Bell and Gossett Ecocirc XL 36-45 circulator.

According to Design Learned Inc. (DLI), the mechanical design engineer on the project, the design water temperature for the hydronic coils in the air handlers is 120°F. This is an excellent design choice as it maximizes the efficiency of the propane boilers, as well as the capacity of any thermal storage installed with the biomass plant.

Most of the domestic hot water (DHW) for the facility will be supplied by two A. O. Smith BTH-120 propane hot water heaters, each rated for 120,000 Btu/hr input. These will be located in the mezzanine adjacent to the propane boilers. Domestic hot water for the restrooms near the main entrance will be supplied by a 9 kW (30,708 Btu/hr) instant electric hot water heater.

Boilers, AHU's, and other mechanical equipment will be located on the mezzanine level of the facility. Sleeves have been installed under the building footer to accommodate future heating water, domestic water, electric power, and communications to a potential biomass building.

The facility is expected to be staffed from 8:00 AM to 6:00 PM, seven days per week. A significant amount of volunteer help is also expected.

4.0 BUILDING HEAT DEMAND

Weather data of daily mean temperatures from Longville Municipal Airport (16 miles northeast of the facility) were obtained for the past 3 heating seasons. Daily temperatures are used to calculate the heating degree days (HDD) for each day of the year, using a HDD base temperature of 60°F. The results are shown in Table 1, grouped by quarter, for the past 3 heating seasons (July-June).

Table 1 – Heating Degree Day Annual Distribution

	Heating Degree Days				
Year	**Jul-Sep**	**Oct-Dec**	**Jan-Mar**	**Apr-Jun**	**TOTAL**
2013-2014	126	3,405	4,864	1,000	9,395
2014-2015	183	2,965	4,025	821	7,994
2015-2016	131	2,332	3,543	861	6,867
AVERAGE	**147**	**2,901**	**4,144**	**894**	**8,085**
% of TOTAL	**2%**	**36%**	**51%**	**11%**	

Note: The sum of the "% of TOTAL" values for Oct-Dec and Jan-Mar is 87%. This is roughly the "winter heating load" relative to the annual heating load.

Figure 2 shows the HDDs plotted as a load duration curve (LDC) for the past 3 heating seasons. This chart is sorted to present the daily heating loads in order from largest to smallest, not the order in which they actually occurred in time.

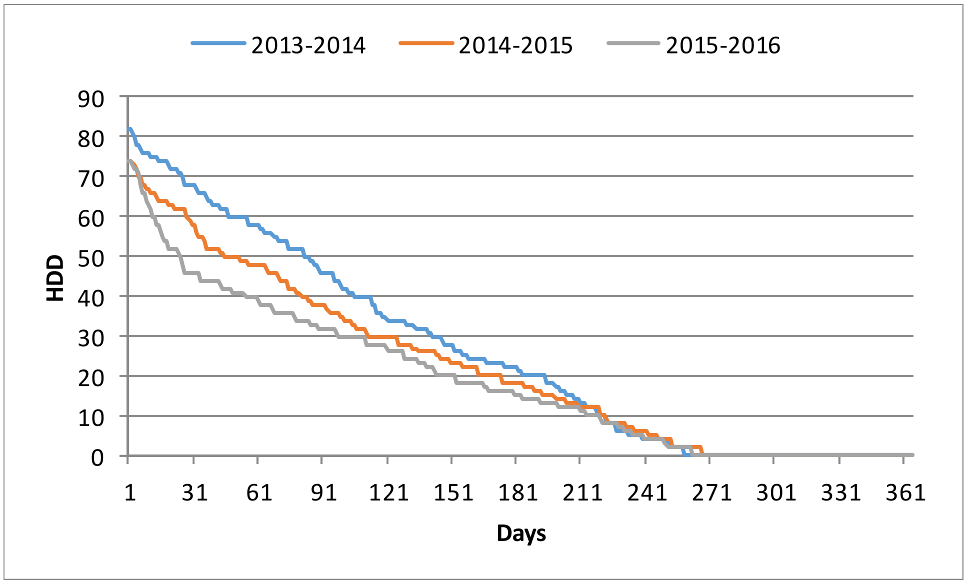

Figure 2 – HDD LDC Chart for the Past 3 Heating Seasons

Note: The HDD value indicates the average number of °F below the base temperature for each day. For example, a HDD value of 80 indicates an outside air temperature of -20°F, based on the 60°F base temperature.

The expected heat demand of the building was calculated based on design data and assumptions about building performance. Three separate outdoor air temperatures were selected as representative of the heating season: -15°F, 15°F, and 40°F.

Table 2 – Calculated Heat Loss

	Heat Loss in Btu/hr at Outdoor Air Temperature		
	-15°F	**15°F**	**40°F**
Conduction	165,750	120,834	83,404
Infiltration	93,255	64,916	36,247
Ventilation	465,853	324,286	181,073
TOTAL	**724,857**	**510,036**	**300,725**

Conductive heat loss estimates were based on R20 walls, R45 roof, R10 slab, R15 foundation, U0.5 windows, and a window to wall ratio of 15%. Infiltration heat loss assumed 0.3 air changes per hour. Ventilation heat loss assumed 8,129 cfm of ventilation exhaust air and an ERV effectiveness of 55% (winter total, sensible and latent).

Figure 3 shows a modeled load duration curve for the facility based on the values calculated in Table 2. The positions of the three load points, and the point at which the demand equals zero, were inferred from the weather data in Figure 2.

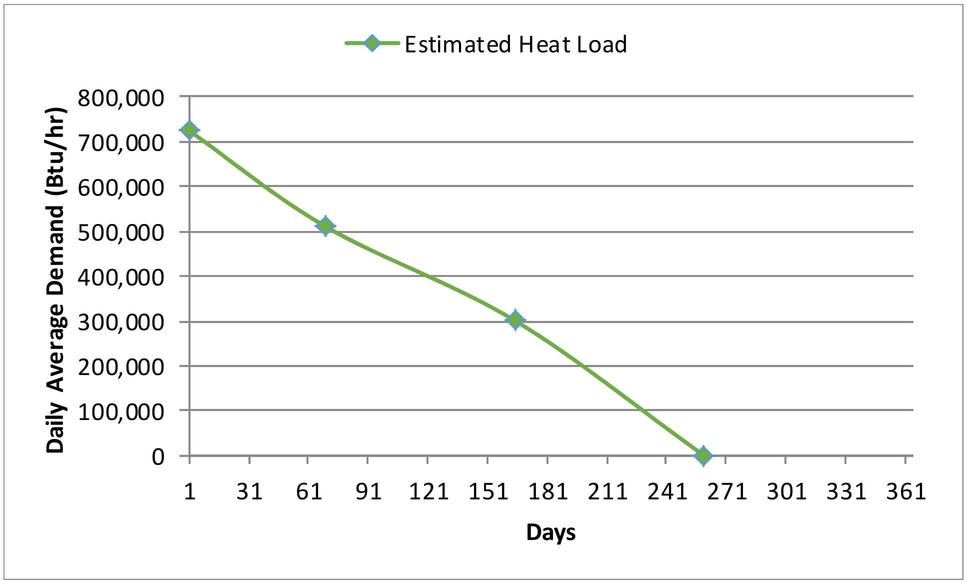

Figure 3 – Estimated Daily Average Demand Load Duration Curve

Note: Values shown are daily average demands. During the course of a 24-hr period, it is anticipated that the hourly demand would fluctuate both above and below the values shown.

This chart is sorted to present the daily heating loads in order from largest to smallest, not the order in which they actually occurred in time. It is important to note how this curve can be used appropriately. The curves shown in Figure 3 present the daily average demand. Over the course of a 24 hour period the loads at each facility will vary above and below the daily averages. Thus, the load curves are useful for sizing a biomass boiler to ensure it will run efficiently and cover significant portions of the system demand, but they do not indicate the peak or minimum demands.

Design Learned was consulted regarding the heat load estimations. DLI estimated a design-day heat load of 898,400 Btu/hr. Overall, WES and DLI expressed agreement that the goal of a biomass boiler installation should not be to cover 100% of the heat load of the building, but that a biomass boiler should be carefully sized to cover less than the peak heating load of the building, so that it would be able to run more efficiently over the entire heating season.

5.0 BIOMASS AVAILABILITY AND PRICE

Modern biomass combustion systems can efficiently and cleanly utilize a variety of fuels with a wide range of moisture content. While most wood burning appliances are flexible in the fuels they can burn, the wide differences in size and moistures of wood fuels require different systems. Wood pellet systems are commonly limited to firing on pelletized fuel or dry wood chips with allowable moisture content (wet basis) typically in the range of 5-30%. Systems capable of utilizing green wood chips are typically designed for fuel with a moisture content of 20-50%. Some manufacturers offer equipment able to utilize pellets or green chips, although the control parameters and system options may need to be adjusted when targeting one of these fuels in order to maintain efficiency. Cordwood systems are typically designed to use cordwood with a moisture content of approximately 20% wet basis, which is achieved by air drying. Some cordwood systems are able to also use wood pellets following a manual adjustment of the grates.

The options evaluated in this report would require an estimated annual use of up to 132 cords of cordwood, 166 tons of wood pellets, or 178 tons of dry wood chips, depending on the option selected.

Table 3 compares the cost of delivered heat for wood and fossil fuel (propane). The propane cost shown is an estimate for the purpose of comparison with wood fuels.

Table 3 – Fuel Pricing and Cost per mmBtu

Technology, Unit	Cost/Unit	Input mmBtu /Unit	Assumed Efficiency	Output mmBtu /Unit	Output Cost /mmBtu
Dry Wood Chip[1], ton	$50	15.4	75%	11.6	$4.33
Dry Wood Scraps[2], ton	$30	15.4	60%	9.2	$3.25
Green Wood Chip[3], ton	$40	10.0	70%	7.0	$5.71
Cordwood[4], cord	$185	20.0	65%	13.0	$14.23
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Propane, gal (estimated)	$1.50	0.091	85%	0.078	$19.32

Note 1: Cost assumes that dry wood scraps are chipped by PCRR staff on site.
Note 2: Dry wood scraps are potentially available from Mann Lake Ltd. and could be cofired with cordwood in a cordwood boiler.
Note 3: Green wood chips are not appropriate for this facility due to the relatively small size of the facility.
Note 4: Cost is for mixed hardwood. Equivalent cost is $116 per ton after wood has been seasoned to 20% moisture content wet basis.
Note 5: Wood pellets are 6-8% moisture content wet basis.

5.1 PELLETS

Wood pellets are typically delivered in bulk loads of 10–30 tons. Wood pellets can be delivered in a variety of ways, depending on the storage system at the facility, and the capabilities of local truckers. Options include:

- End dump tractor trailer
- Walking floor tractor trailer
- Grain truck or trailer with auger
- Grain truck with pneumatic hose discharge (not available in MN)

Delivery by grain truck is often the most convenient, because the pellets can be discharged directly into the top of a silo. Auger trucks in this region generally have a maximum height capability of 24'. Deliveries by a pneumatic delivery truck would involve the driver attaching a hose to a tube near the base of the silo. This tube would be permanently attached to the silo and would run up to the top to discharge the pellets. The higher cost and/or lower capacity of grain trucks can make walking floor or end dump delivery slightly cheaper. These methods would require a conveyor system to carry the pellets up to the top of the silo. Due to space constraints at the facility, a pellet silo using auger delivery trucks is the storage and delivery method considered. Wood pellets would be stored in the silo and conveyed to the pellet boilers automatically via a flexible auger.

The only known wood pellet plant in northern MN is Hull's Sawmill, located in Two Harbors. This small pellet plant produces approximately 200 tons per year, and only sells pellets in the vicinity of the plant.

Great Lakes Renewable Energy (GLRE), which supplies most of the pellets used in northern Minnesota, is located in Hayward, WI. Bulk pricing at the gate is approximately $170/ton, and trucking costs are in the range of $4-$5 per loaded mile, depending on the delivery vehicle. The most appropriate delivery vehicle for this site would be a grain auger truck, which can carry up to 24 tons of pellets. The cost of this type of vehicle would be closer to $5 per loaded mile.

Propellet is another pellet plant, located in Minneapolis, which is actually closer to Hackensack than GLRE. They are quoting in the range of $140-$150/ton at the gate for bulk loads. Trucking costs per loaded mile would be similar to those from GLRE, resulting in savings both at the gate and on account of the shorter distance. However, this is a relatively new pellet plant and therefore long term pricing could be uncertain.

GLRE has an established customer base in MN, and WES has discussed pellet pricing with GLRE as well as several GLRE customers in order to estimate pellet pricing for feasibility studies. For the purposes of this study, pellet pricing is estimated in between GLRE and Propellet prices.

Although there are no pellet plants that could be called "local" to Hackensack, pellets are still a viable fuel and provide significant labor savings in comparison to cordwood. The US Forest Service Ranger Station in Walker, MN, built in 2014, is utilizing wood pellets for heating. There are numerous other pellet boilers in operation in northern MN. As more pellet projects are implemented in northern Minnesota, the market for pellets will develop, with the hope that they will be able to support a regional pellet plant in the future.

5.2 CORDWOOD

Pricing for mixed hardwood is estimated by Paws and Claws staff to be approximately $185/cord, based on information they have gathered locally. Firewood suppliers often sell "semi-seasoned" cordwood which means that the wood has been seasoned incidentally during handling and storage, but has not been stockpiled for at least a year. Normally, WES recommends purchasing wood fuel no later than spring and stacking it on site so that it can dry during the summer months. Wood stacks should be covered on top, but left open on the sides to allow for airflow. In the case of this facility, the required volumes of cordwood are substantial and could present a logistical challenge.

5.3 WOOD CHIPS

Dried or partially dried chips are able to be used in many commercial pellet boilers, and represent a lower-cost fuel compared to wood pellets. Several logging companies are operating in northern MN and produce 2" whole tree green chips using in-woods chippers, which are used for electric generation at power plants in Viginia and Hibbing. Compared to these green chips, dry chips must be sized less than 1.5" and oversize pieces must be removed. Chips require more specialized handing equipment than pellets. Pellets flow freely through grain truck augers and storage silos, which are widely used in the agricultural industry. Chips on the other hand are typically transported by walking floor trailer and either dumped directly into large storage areas which have automated reclaim equipment, or stored under cover and then loaded into a day bin using a skid steer loader. Wood chips may also be blown into storage using specialty blower trucks that are common in the commercial mulch industry.

Wood chip moisture content and quality are important considerations when selecting a biomass boiler and fuel handling system. Some boilers require moisture contents of 30% (wet basis) or less and chip size of 1-1/2" or less, while others can tolerate wetter/larger chips. In addition to moisture content, ash content is another quality measure. Bark, leaves, and twigs all have higher ash content than debarked roundwood or lumber scraps.

Mann Lake Ltd., which is located approximately 1 mile northwest of Paws and Claws, had initially been considered as a potential source of dry chips. Mann Lake is a wood products manufacturer which uses kiln dried pine wood to produce beehives and associated equipment. The shavings and wood scraps from this manufacturing operation are ground up and shipped by truck to be used as animal bedding. All material is processed through a grinder with a 1/2" screen. The rate of waste production is approximately 2.5 truckloads per week, where a truckload holds about 100 yards and weighs about 17 tons. In the 12 month period ending June 2016, 127 truckloads of residue were shipped, netting $103,000 ($48/ton). Anecdotal information from Mann Lake is that 25-40% of the residue is wood chips, although whether that is a volume or weight basis is not known. Assuming that 1/3 by weight is chips, annual production would be approximately 700 tons. This is more than enough to supply the heating needs of Paws and Claws. However, Mann Lake does not have a good way of separating the wood chips from the sander dust and sawdust. This presents a problem because large amounts of dust would present a safety hazard at the Paws and Claws boiler plant, and could interfere with proper operation of a dry wood chip boiler. Mann Lake does not have the capability or space to reconfigure the process to produce clean wood chips, but it does have the ability to provide the un-chipped wood scraps to Paws and Claws.

Mann Lake is confirmed to be a good source of kiln-dried wood scraps that could potentially be utilized in a cordwood system. The scraps would have to be cut to approximately 24” long depending on the cord wood boiler chosen.

Alternatively, the wood scraps could be chipped by Paws and Claws staff after delivery from Mann Lake, and utilized in a dry chip boiler. Because of the wood scraps’ small cross-sectional area, a relatively small grinder could be utilized for this purpose. The cost of dry wood chips is estimated to be about $50/ton. This assumes use of a grinder at Paws and Claws, including labor, to process 2-3 tons/hour of dry wood scraps. The capital cost of the grinder is not included in this fuel cost, but is included in the capital cost of the appropriate project option.

6.0 EVALUATED BIOMASS SYSTEMS

Three biomass hot water boiler systems are evaluated for the Paws and Claws Rescue and Resort. These biomass system options were sized and evaluated using the analysis in Section 4. The options include the following equipment:

Option 1 – Cordwood Boiler System: Two cordwood boilers would be installed in a new boiler building. The boilers would heat a 2,000 gallon thermal storage tank, and would connect to the mezzanine boiler room via underground supply and return piping.

Option 2 – Pellet Boiler System: One pellet boiler would be installed in a new boiler building. The boiler would heat a 500 gallon thermal storage tank, and would connect to the mezzanine boiler room via underground supply and return piping. Pellets would be stored in a 30 ton silo, and would be conveyed to the boiler automatically via a flexible auger.

Option 3 – Dry Chip Boiler System: One dry wood chip boiler would be installed in a new boiler building. A 500 gallon thermal storage tank would be installed with the boiler. Wood chip fuel would be produced on site from scraps sourced from Mann Lake Ltd., and would be stored in a below-grade day bin, or an above grade silo. The fuel storage would provide automatic fuel feed to the boiler. The boiler and storage system would also be able to utilize wood pellets. The boiler system would connect to the mezzanine boiler room via underground supply and return piping.

6.1 OPTION 1 – CORDWOOD BOILER SYSTEM

This option consists of two cordwood boilers, rated approximately 500,000 Btu/hr and 300,000 Btu/hr. These boilers will be connected to a 2,000 gallon thermal storage tank which will act as a buffer and will store heat in order to increase the cycle time between loading of the boilers, and to allow the boilers to run efficiently.

The 2,000 gallon thermal storage tank would be typically maintained above 160°F, and could get as hot as 195°F, depending on the capabilities of the wood boilers selected. Loading of wood into the boilers would be managed so that the boilers would deliver heat at full output, and this heat would either be utilized right away by the building, or stored in the thermal storage tank as a rise in temperature. The ability to deliver heat at full-fire from the boiler, either to the thermal storage tank, or to the building and the tank together is a key design feature, because operating at full-fire has the optimal efficiency and emissions characteristics. Even during the shoulder seasons, when demand is much less than the rated output of the boiler, the boilers can be operated at full fire this way, if the temperature in the thermal storage tank is first allowed to approach a low of 120-130°F.

Using a variable speed circulator pump, or a mixing valve, hot water from the thermal storage would be blended with cooler return water from the building heating distribution system to maintain a distribution supply water temperature based on an outside reset schedule. Storing water at temperatures that are higher than distributed allows maximization of the potential storage in the fixed tank volume and allows coverage of temporary peaks above wood boiler capacity.

The rated output of the cordwood boilers should be interpreted as a maximum hour output and not as an output that can be sustained over a long period of time, as would be expected with a fossil fuel or wood boiler with an automatic fuel feed. For example, a common 300,000 Btu/hr indoor wood boiler has a firebox which measures 26”x24”x32” (DxWxH), which is equivalent to 11.6 cubic feet. Assuming a 90% firebox fill ratio, this means that up to 260 pounds of wood can be loaded at a time (based on the cordwood density listed in Table 4). Using the HHV of cordwood and the cordwood boiler efficiency from Table 4, this gives a fuel input of 1,625,000 Btu, and a total heat output of 1,056,250 Btu. Assuming average output of 300,000 Btu/hr, this is a 3.5 hour burn time. Note that this example is for seasoned cordwood—use of wood scraps will degrade performance.

An important consideration for a cordwood system is the necessary reloading frequency. Thermal storage can increase the time between reloading the boilers, but the heating demand of the shelter during the winter exceeds that which can be effectively covered by thermal storage for more than a couple hours. For example, if the building can utilize water at 120°F, and the water in the thermal storage is 180°F, a 2,000 gallon tank is able to supply 972,000 Btu, which would supply heating to the building for approximately 1.5 hours during the winter, or 4-5 hours in the spring or fall.

Increasing the amount of thermal storage would improve overnight coverage of the wood boiler system, assuming that the boilers were fired at the end of the day with the thermal storage already mostly charged. This way, the building would be initially heated directly from the boiler output, and subsequently from the thermal storage. This scheme would not work well during the coldest parts of winter, however, because the building demand would be so great that the thermal storage could not be adequately recharged the following day, unless there was a break in the weather which resulted in a lower building load. To cover the overnight load in the cold parts of winter would likely require significantly increased thermal storage, as well as an additional cordwood boiler which would allow total boiler plant output greater than the building demand during the day, so that when night came and operators were not able to load the boilers, the thermal storage would be charged and would be able to cover the load.

Dry wood scraps available from Mann Lake are an alternative fuel to split and seasoned cordwood, at a much lower cost. There is the potential that the dry wood scraps could be mixed with seasoned cordwood to reduce overall fuel costs. Guidance from cordwood boiler manufacturers urges caution when utilizing kiln dried lumber or wood fuel with a high surface area to volume ratio. Cordwood boilers are intended for burning seasoned (air dried) cordwood which has a fair amount of moisture, and this moisture moderates the combustion process. Use of kiln dried wood in a cordwood boiler can result in rapid gasification, which carries the risk of high firebox temperatures, whuffing, and overfiring of the boiler. Placing even 1/2 load of dry wood scrap on the grate of a cordwood boiler has the potential to overfire the boiler, or produce dangerous whuffing conditions if the door is opened by an operator at the wrong time. Additionally, it will burn out pretty quickly, compared to a full load of seasoned cordwood, effectively de-rating the boiler capacity and efficiency. If dry wood scraps will be used as fuel, the following are recommended:

- Mix kiln dried wood scraps with cordwood in order to modulate the gasification rate. A mixture of 60% cordwood and 40% wood scraps in the winter, and the inverse in shoulder seasons is a good starting point.
- When mixing cordwood with kiln dried wood scraps, use cordwood that has only been seasoned for one summer, so that the moisture content is closer to 25% wet basis. This will help to balance out the dryness of the wood scraps.
- Store wood scraps uncovered, outdoors, for a short period of time, to allow them to gain moisture.
- Install electronic Btu meters and stack temperature sensors on the boilers to allow operators to monitor and understand the combustion characteristics of each load. This will build tribal knowledge of the wood system and ensure that loading procedures are reasonable and fact-based.

Appendix A includes a site plan, conceptual boiler plant layout, and schematics for the system.

Cordwood boilers operate most efficiently between 50% and 100% of their rated heating output. Therefore, this boiler installation would have an efficient operating range of 150,000 Btu/hr to 800,000 Btu/hr. However, with careful management of the load and proper use of the thermal storage tank, the small cordwood boiler could be used to cover the entire shoulder season load, as long as the burns were small and hot. Coverage for the boilers is evaluated using the estimated load duration curve which was shown in Figure 3. Figure 4 shows the cordwood boilers covering approximately 100% of the estimated load.

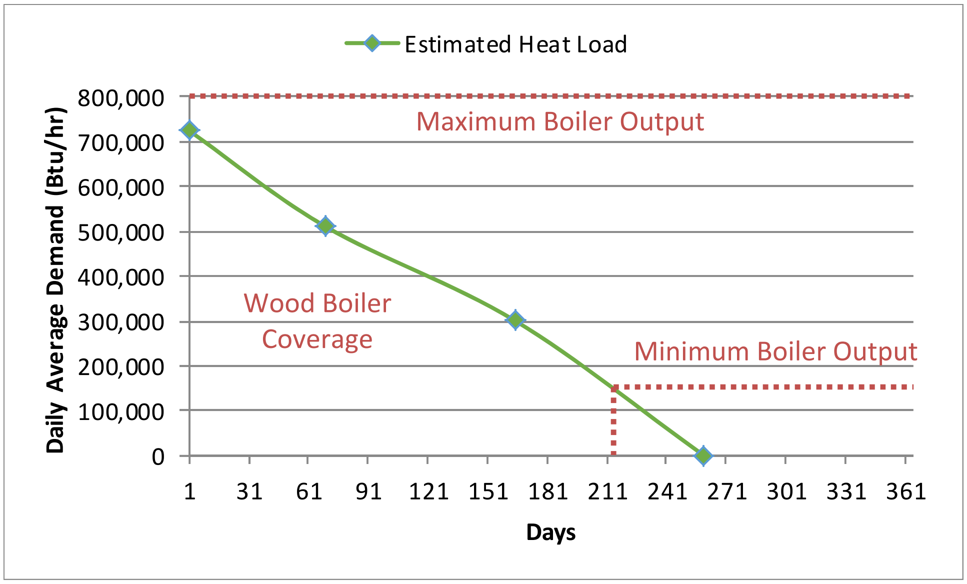

Figure 4 – Estimated LDC and Coverage of Cordwood Boilers

Note: Assumptions regarding system efficiencies are listed in Table 4. Values shown are daily average demands. During the course of a 24-hr period, it is anticipated that the hourly demand would fluctuate both above and below the values shown.

In a typical year, 75% coverage of the connected load by the wood boilers is estimated for the economic analysis when utilizing cordwood. The reason for this is that manual loading of the cordwood boilers may not always be possible at nights or on weekends. Exact sizing of the boiler(s) depends on the vendor selected, their product offerings, and the frequency that the owner is willing and able to load the firebox.

6.2 Option 2 – Pellet Boiler System

This option consists of a single pellet boiler, rated 700,000 Btu/hr, and a 500 gallon thermal storage tank. Pellets would be automatically supplied from a 30 ton pellet silo.

The 500 gallon thermal storage tank would be typically maintained around 195°F. Using a variable speed circulator pump, or a mixing valve, hot water from the thermal storage would be blended with cooler return water from the heating distribution system to maintain a distribution supply water temperature based on an outside reset schedule. Storing water at temperatures that are higher than distributed allows maximization of the potential storage in the fixed tank volume and allows coverage of temporary peaks above wood boiler capacity.

Appendix A includes a site plan, conceptual boiler plant layout, and schematics for the system.

Wood pellet fueled biomass boilers operate most efficiently between 20% and 100% of their rated heating output. Therefore, this boiler installation would have an efficient operating range of 140,000 Btu/hr to 700,000 Btu/hr. However, the pellet boiler would include an automatic ignition system to allow it to turn on and off during times of lighter load, and thus cover the shoulder season loads below 140,000 Btu/hr. Coverage for the boiler is evaluated using the estimated load duration curve which was shown in Figure 3. Figure 4 shows the cordwood/pellet boilers covering approximately 99% of the estimated load.

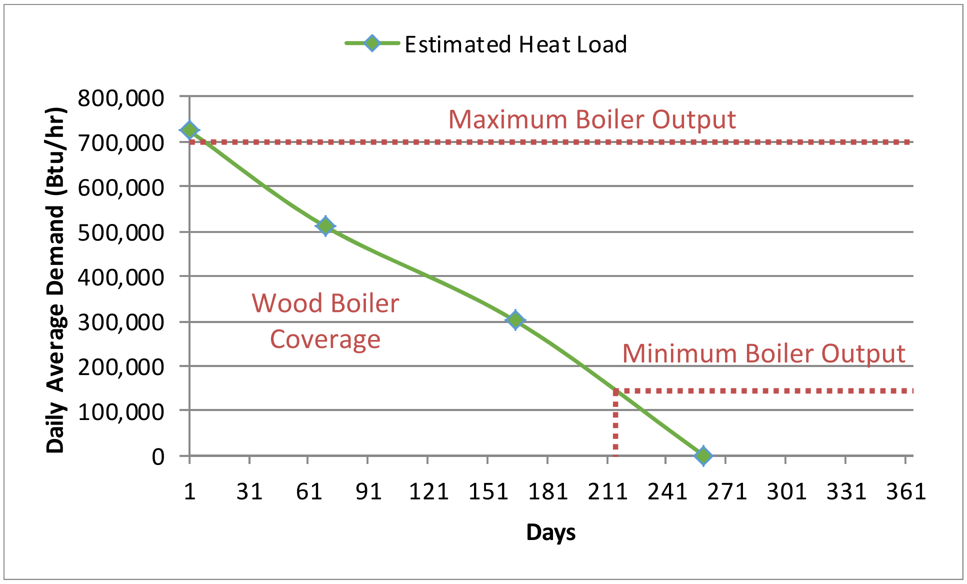

Figure 5 – Estimated LDC and Coverage of Pellet Boiler

Note: Assumptions regarding system efficiencies are listed in Table 4. Values shown are daily average demands. During the course of a 24-hr period, it is anticipated that the hourly demand would fluctuate both above and below the values shown.

In a typical year, 95% coverage of the connected load by the pellet boiler is estimated for the economic analysis. Exact sizing of the boiler(s) depends on the vendor selected, and their product offerings.

6.3 Option 3 – Dry Chip Boiler System

This option consists of a 512,000 Btu/hr wood chip boiler, a 500 gallon thermal storage tank, and a day bin with spring agitator for automatic fuel supply. The wood chip boiler would be capable of utilizing wood chips up to 30% moisture content wet basis, as well as wood pellets.

The 500 gallon thermal storage tank would be typically maintained around 195°F. Using a variable speed circulator pump, or a mixing valve, hot water from the thermal storage would be blended with cooler return water from the heating distribution system to maintain a distribution supply water temperature based on an outside reset schedule. Storing water at temperatures that are higher than distributed allows maximization of the potential storage in the fixed tank volume and allows coverage of temporary peaks above wood boiler capacity.

As previously mentioned, there are no viable suppliers of dry chips in the area. Dry chips would need to be produced by Paws and Claws staff using wood scraps from Mann Lake as the feedstock. The capital cost for this option includes the cost of purchasing a wood grinder, and the assumed cost per ton of dry wood chips includes operational costs of the wood grinder in addition to purchase costs for the wood scraps. Because the wood scraps are relatively small in dimension, a small wood grinder would be adequate, such as would be used for pallets or scrap wood. These grinders are known as horizontal grinders due to the orientation of the grinding drum, and often have a hopper where material can be accumulated prior to starting the grinding process. The hopper would have a hydraulic ram which would feed the material into the cutting wheel at a controlled rate. The outfeed of the grinder would be accomplished by a pneumatic blower unit which would blow the chips into the storage bin. Alternatively, a mobile grinder could be purchased, which would have an infeed table, and outfeed via a conveyor belt. The machine could be oriented so that the chips would be conveyed into the fuel storage bin.

The storage bin could be a silo similar to a pellet silo, but with a flat bottom (as opposed to a conical bottom). An alternative would be a below-grade storage pit, which is shown in the conceptual drawings for this option in Appendix A. At the bottom of the storage bin there would be a sweeper arm assembly which would rotate and push the chips into an auger, which would then feed the chips into the boiler at the prescribed rate.

The below-grade bin concept option was initially developed with the assumption that the chips would be delivered from Mann Lake by dump trailer, which is now known to be infeasible. If the chips will be produced on site, an above grade silo would be cheaper to construct and would likely have a higher capacity if a blower system was used to transport material to the top.

In addition to dry wood chips, this boiler and fuel handling system would be able to utilize wood pellets. However, the higher cost of wood pellets makes the use of dry chips much more attractive. Appendix A includes a site plan, conceptual boiler plant layout, and schematics for the system.

Wood chip fueled biomass boilers operate most efficiently between 25% and 100% of their rated heating output. At times of low load, they will typically turn down to approximately 25% of their rated load before they cycle to meet the heat demand. The chip boiler would therefore have an efficient operating range of 128,000 Btu/hr to 512,000 Btu/hr. However, the chip boiler would include an automatic ignition system to allow it to turn on and off during times of lighter load. Coverage for the boiler is evaluated using the estimated load duration curve which was shown in Figure 3. Figure 6 shows the chip boiler covering approximately 92% of the estimated load.

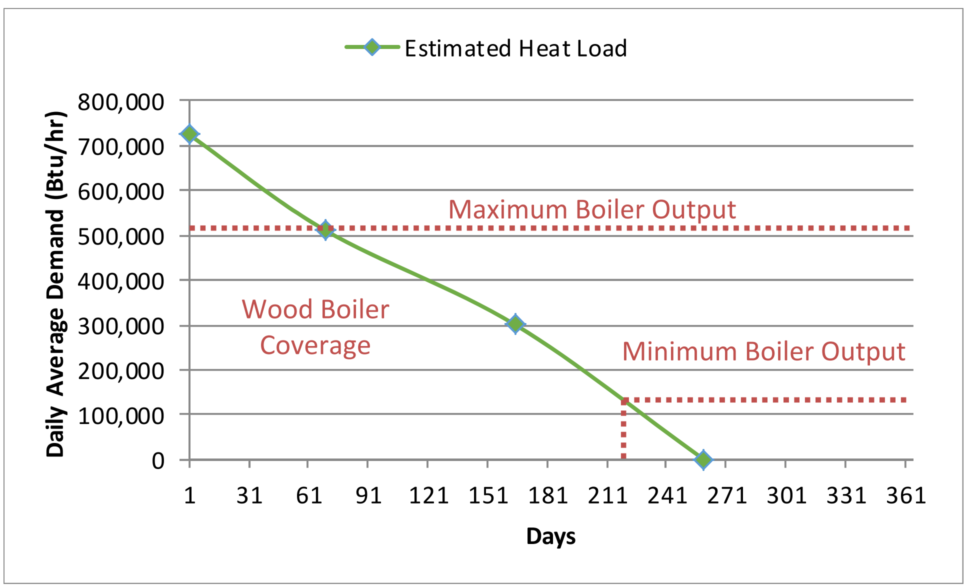

Figure 6 – Estimated LDC and Coverage of Chip Boiler

Note: Assumptions regarding system efficiencies are listed in Table 4. Values shown are daily average demands. During the course of a 24-hr period, it is anticipated that the hourly demand would fluctuate both above and below the values shown.

In a typical year, 90% coverage of the load by the dry chip boiler is estimated for the economic analysis. Exact sizing of the boiler(s) depends on the vendor selected, and their product offerings. At this facility, a dry chip boiler sized within the range of 500,000 Btu/hr to 750,000 Btu/hr would be appropriate.

7.0 GRANTS AND INCENTIVES

7.1 BIOMASS THERMAL PRODUCTION INCENTIVE

Minnesota Statutes 2015, section 41A.18, and Minnesota Session Laws 2016, chapter 189, article 2, section 21 provide for a "biomass thermal production incentive" which pays eligible facilities $5 for each mmBtu of heat supplied to a building or process using biomass fuel. In order to be eligible, a facility must install a biomass boiler or other similar device after July 1, 2015, and this system must deliver no less than 250 mmBtu to the facility during one single calendar quarter. For a period of 10 years after qualification, the facility owner can receive $5 per mmBtu of thermal output for calendar quarters in which thermal production exceeds 250 mmBtu. Specific sustainable harvesting and sourcing requirements have to be met. Material must be sourced from within Minnesota. For wood pellets, the location of the pellet plant is not important, as long as the raw material for the pellets is sourced from a qualifying location (i.e. within Minnesota).

Based on assumptions in Table 4, 250 mmBtu of thermal output is approximately equivalent to using 3,220 gallons of propane, 19 tons of pellets, 22 tons of dry chips, or 19 cords of cordwood. It is likely that Paws and Claws could qualify for this incentive during the fall and winter quarters. There is a chance that the facility could also qualify during the spring quarter, but achieving this would require careful management of the load. During qualifying quarters, this incentive would effectively reduce the price of pellets by $66/ton, dry chips by $58/ton, and cordwood by $65/cord.

7.2 COMMUNITY FACILITIES DIRECT LOAN AND GRANT

The program, administered by the USDA, provides funding in the form of loans and grants to develop community facilities in rural communities. The program is open to public bodies, and community-based nonprofit corporations. The program is primarily geared towards loans, which can have terms of up to 40 years. Grant funding awards are determined with preference for smaller communities with lower household income relative to state medians.

7.3 RURAL ENERGY FOR AMERICA PROGRAM (REAP)

REAP is administered by the USDA and provides grant and/or loan funding to for-profit small businesses for energy projects in rural areas (Hackensack is a qualifying area). Grant funding of up to $500,000 per project can be used to cover up to 25% of total project costs. Additional loan funding is available on top of the grant funding to cover up to a total of 75% of project costs. Because Paws and Claws is a nonprofit corporation, it would not qualify directly for this grant. However, the potential exists for a creative ownership model for a biomass plant which could allow the project to qualify for this valuable program.

For example, Paws and Claws could enter into an agreement with a local wood products business such as Mann Lake Ltd., where Mann Lake would purchase, construct, and own a biomass boiler plant located at Paws and Claws, and Paws and Claws would purchase heat from this boiler plant at an agreed-upon rate. This arrangement would allow Paws and Claws to access renewable energy with very little upfront cost, and would allow Mann Lake to have a guaranteed outlet at a known price for a portion of their wood residuals.

WES discussed this hypothetical arrangement with Ron Omann, the USDA Rural Development Energy Coordinator for Minnesota. Mr. Omann indicated that this arrangement would most likely qualify for the REAP program, provided that the commercial entity purchasing and owning the equipment was provided with "site control," meaning that there had to be a lease in writing, which would allow the entity access to the equipment, for at least the life of the equipment. This lease would have to be executed prior to the grant application process. Additionally, the for-profit business developing the project would have to qualify as a small business, the requirements for which vary depending on the type of business.

For more information, contact:

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375 Jackson Street, Suite 410
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http://www.rd.usda.gov/mn

8.0 BIOMASS SYSTEM ANALYSIS

Table 4 lists the values and assumptions used in the analysis.

Table 4 – Values and Assumptions

Assumption	Value	Unit	Source
Propane HHV	0.091333	mmBtu/gal	WES Assumption
Propane Cost Estimate	$1.50	$/gal	PCRR
Propane Boiler Seasonal Efficiency	85%	percent	WES Assumption
Wood Pellet HHV	16.4	mmBtu/ton	WES Assumption
Wood Pellet Cost	$200	$/ton	WES Assumption
Wood Pellet Boiler Efficiency	80%	Percent	WES Assumption
Dry Wood Chip and Wood Scrap HHV	15.4	mmBtu/ton	WES Assumption
Dry Wood Chip Cost	$50	$/ton	WES Assumption
Dry Wood Scraps Cost	$30	$/ton	WES Assumption
Dry Wood Chip Boiler Efficiency	75%	Percent	WES Assumption
Cordwood Boiler Efficiency when fired on dry scraps	60%	Percent	WES Assumption
Cordwood HHV (cord basis)	20.0	mmBtu/cord	WES Assumption
Cord Wood Density	1.6	tons/cord	WES Assumption
Cordwood HHV (ton basis)	12.5	mmBtu/ton	WES Assumption
Cordwood Cost	$185	$/cord	PCRR
Cordwood Boiler Efficiency when fired on cordwood	65%	Percent	WES Assumption
HDD Base Temp	60	˚F	WES Assumption
Oct-Mar Heating Load (% of annual)	87%	Percent	Table 1
Electric Cost	$0.07	$/kWh	WES Assumption
Labor Cost (at Facility)	$20	$/hr	WES Assumption
CO_2 emitted during combustion of Propane	62.87	kg/mmBtu	EPA
CH_4 emitted during combustion of Propane	0.003	kg/mmBtu	EPA
N_2O emitted during combustion of Propane	0.0006	kg/mmBtu	EPA
CO_2 emitted due to use of Electricity (includes line losses)	3.32	kg/kWh	EPA
CH_4 emitted due to use of Electricity (includes line losses)	0.0000644	kg/kWh	EPA
N_2O emitted due to use of Electricity (includes line losses)	0.0000566	kg/kWh	EPA
CH_4 100-year Global Warming Potential	25	* CO2	IPCC
N_2O 100-year Global Warming Potential	298	* CO2	IPCC

8.1 Capital Cost Estimates and Operating Cost Savings

Estimated capital costs for each option are listed in Table 5.

Table 5 – Capital Cost Estimate Summary

Option	Estimated Capital Cost
1 - Cordwood	$174,819
2 - Pellet	$201,341
3 - Dry Chip	$302,268

Costs for the systems include the boilers, pumps, controls, thermal storage, piping, automatic fuel storage and handling, underground connection to the mezzanine boiler room, and installation. Detailed breakdowns of capital costs are provided in Appendix B.

Table 6 gives a breakdown of estimated operating and maintenance costs for each option. Option 1, using cordwood, is expected to require approximately 1 hour of staff time per day. Option 1, using a mixture of cordwood and wood scraps, is expected to require 1.5 hours of staff time per day. Option 2, using pellets, is expected to require 1 hour of staff time per week. Option 3, the dry wood chip boiler, is expected to require 15 minutes of staff time per day.

Table 6 – Estimated Operating and Maintenance Costs

Option	Electric Usage	Maintenance / Wear Parts	Staff Time	Total O&M Cost
1 - Cordwood	$262	$100	$5,200	**$5,562**
1 - Cordwood w/ 50% scraps	$262	$100	$7,800	**$8,162**
2 - Pellet	$393	$150	$743	**$1,286**
3 - Dry Chip	$393	$500	$1,300	**$2,193**

Note: No cost is included for ash disposal as this is a valuable soil amendment.

A proposed system fuel use profile is provided in Table 7 showing the estimated annual fuel use for each option compared to the existing fossil fuel system.

Table 7 – Proposed System Fuel Use Profile

Option	Estimated Annual Fuel Use	Estimated Annual Fuel Use with Proposed Biomass System		
	Propane (gal)	Biomass Demand Coverage	Estimated Biomass Use (tons)[1]	Estimated Propane Use with Biomass System (gal)
1 - Cordwood	29,492	75%	211	7,373
1 - Cordwood w/ 50% scraps	29,492	75%	199	7,373
2 - Pellet	29,492	95%	166	1,475
3 - Dry Chip	29,492	90%	178	2,949

Note 1: Fuel use in this table is in tons. Option 1 using cordwood only is equivalent to 132 cords.
Note: Table 4 contains the assumptions used to develop the above values.

Table 8 shows the expected daily fuel consumption of the biomass plant at two different output rates. Refer to Figure 3 for how these output rates figure in relation to the expected annual load.

Table 8 – Example Daily Fuel Consumption by Option

Option	Daily Consumption with Plant Output at 700,000 Btu/hr				Daily Consumption with Plant Output at 200,000 Btu/hr			
	Cordwood (cords)[1]	Scrap (tons)	Pellets (tons)	Dry Chips (tons)	Cordwood (cords)[1]	Scrap (tons)	Pellets (tons)	Dry Chips (tons)
1 - Cordwood	1.3	-	-	-	0.4	-	-	-
1 - Cordwood w/ 50% scraps	0.6	0.9	-	-	0.2	0.3	-	-
2 - Pellet	-	-	1.3	-	-	-	0.4	-
3 - Dry Chip	-	-	-	1.5	-	-	-	0.4

Note 1: Cordwood density is assumed to be 1.6 tons per cord in Table 4.
Note: Table 4 contains the assumptions used to develop the above values.

Table 9 provides a comparison of fuel costs and operating costs for the options.

Table 9 – Fuel and Operating Cost Comparison

Option	Estimated Annual Fuel Use	Estimated Annual Costs with Proposed Biomass System			Estimated First Year Operational Savings	Thermal Production Incentive[1]	Estimated Net Cash Flow
	Propane Cost	Biomass Cost	Propane Cost	O&M Increase			
1 - Cordwood	$44,239	$24,437	$11,060	$5,562	$3,180	$7,481	$10,661
1 - Cordwood w/ 50% scraps	$44,239	$15,006	$11,060	$8,162	$10,011	$7,481	$17,492
2 - Pellet	$44,239	$33,157	$2,212	$1,286	$7,584	$9,476	$17,059
3 - Dry Chip	$44,239	$8,920	$4,424	$2,193	$28,701	$8,977	$37,678

Note 1: Thermal Production Incentive payment assumes that 87% of heating takes place October-March (based on Table 1), and that heating outside these 2 quarters is insufficient to qualify for the incentive.
Note: Table 4 contains the assumptions used to develop the above values.

A summary of the estimated capital costs and payback is provided in Table 10. This table also evaluates the options with an assumed 25% grant. No specific grant funding opportunity has been identified.

Table 10 – Cost and Payback Analysis

Option	Estimated Capital Cost	Assumed Grant Funding	Financed Amount	Simple Payback Period[1] (years)	Net Present Value (25 years)
1 - Cordwood	$174,819	$0	$174,819	31	$67,540
1 - Cordwood w/ 50% scraps	$174,819	$0	$174,819	10	$230,361
2 - Pellet	$201,341	$0	$201,341	14	$181,060
3 - Dry Chip	$302,268	$0	$302,268	7	$563,408
1 - Cordwood w/ grant	$174,819	$43,705	$131,114	18	$111,245
1 - Cordwood w/ 50% scraps w/ grant	$174,819	$43,705	$131,114	6	$274,065
2 - Pellet w/ grant	$201,341	$50,335	$151,006	7	$231,395
3 - Dry Chip w/ grant	$302,268	$75,567	$226,701	5	$638,975

Note 1: Simple payback is calculated taking into account the assumption that thermal production incentive payments end after 10 years.

Detailed financial analyses were generated for all options and are included in Appendix C. Appendix C also includes fuel cost sensitivity analyses which show the annual savings for a range of wood fuel and fossil fuel prices.

9.0 EMISSIONS, PERMITTING, AND LICENSING

9.1 PARTICULATE MATTER EMISSIONS

All fuel combustion equipment emits some level of particulate matter from the combustion process. For all fossil fuels and renewable fuels, properly tuned systems are critical to ensure optimal conversion efficiencies and minimal emissions. Modern biomass boilers utilize oxygen sensors and variable speed drives to optimize the combustion process with the proper air/fuel mixture. This results in high combustion efficiencies and low emissions, and this section compares particulate matter emission rates for various fuels and equipment.

Note that in this section, the term lb/mmBtu refers to pounds of a certain pollutant emitted in the flue gas per million Btu of fuel (HHV) input. Based on the assumed efficiencies in Table 4, the cordwood boilers proposed in Option 1 would have a combined maximum fuel input rate of 1.2 mmBtu/hr, the pellet boiler proposed in Option 2 would have a maximum fuel input rate of 0.9 mmBtu/hr, and the dry wood chip boiler proposed in Option 3 would have a maximum fuel input rate of 0.7 mmBtu/hr.

Minnesota Administrative Rules section 7011.0550 Table II sets the maximum particulate emissions from a boiler at 0.4 lb/mmBtu. This emission requirement can be met by modern wood boilers. Visually, the flue gas of a modern wood boiler would exhibit no opacity.

The EPA publishes emissions factors for a wide range of fuel burning devices in its publication AP-42. Table 11 presents these emissions factors along with the expected emissions factors for wood boilers based on stack test data obtained by WES.

Table 11 – Emissions Factors for PM

Fuel and Source	PM Emissions	Unit
Residential Fireplace[1]	2.01	lb/mmBtu
Residential Wood Stove[2]	1.12	lb/mmBtu
Cordwood Boiler[3]	0.16 – 0.32	lb/mmBtu
Wood Chip Boiler[3]	0.08 – 0.15	lb/mmBtu
Wood Pellet Boiler[3]	0.05 – 0.15	lb/mmBtu
#2 Fuel Oil Boiler[4]	0.014	lb/mmBtu
Propane Boiler[5]	0.008	lb/mmBtu

Note 1: EPA AP-42, PM10 value is 34.6 lb/dry ton, conversion based on 17.2 mmBtu/dry ton
Note 2: EPA AP-42, EPA Phase II noncatalytic, PM10 value is 14.6 lb/ton, conversion based on 13.0 mmBtu/ton
Note 3: Values are representative of independent lab testing of boilers comparable to the ones in the proposed options
Note 4: EPA AP-42, boiler < 100 mmBtu/hr
Note 5: EPA AP-42

9.2 GASEOUS EMISSIONS

Besides PM, other pollutants from fuel combustion include VOC, NO_X (NO and NO_2), SO_X, and CO. Ozone (O_3) is a byproduct of NO_X and VOC emissions. Table 12 presents emissions factors for the gaseous pollutants mentioned.

Table 12 – Emissions Factors for Gaseous Pollutants

Fuel and Source	Emission Factors (lbs/mmBtu)			
	VOC	NOx	SOx	CO
Wood Pellet Boiler[1]	0.004	0.140	0.001	0.150
Wood Chip Boiler[1]	0.004	0.180	0.002	0.150
#2 Fuel Oil Boiler[2]	0.004	0.144	0.207	0.036
Propane Boiler[3]	0.005	0.142	0.0002	0.082
Natural Gas Boiler[4]	0.005	0.098	0.0001	0.082

Note 1: Wood chip and wood pellet values are obtained from stack test results. Emissions for cordwood boilers are comparable to chip and pellet emissions.
Note 2: Oil factors are taken from AP-42 for boilers <100 mmBtu/hr, using values of 0.2% sulfur and HHV of 0.139 mmBtu/gal
Note 3: Propane factors are taken from AP-42, S content of 0.2 g/100ft^3
Note 4: Natural gas values taken from AP-42 for boilers <100 mmBtu/hr, and EIA listed values from IPCC for Industry

Based on this table, a wood boiler would be comparable to a propane boiler in terms of VOC and NO_X. The elevated level of SO_X is due to naturally occurring sulfur in the wood, and can vary regionally. While SO_X emissions for a wood boiler are an order of magnitude larger than for propane, they are two orders of magnitude smaller than for #2 fuel oil.

9.3 GREENHOUSE GAS EMISSIONS BENEFITS

By displacing fossil fuel used for heating (propane), installation of a biomass boiler system would result in reduction of Paws and Claws' annual net CO_2 equivalent greenhouse gas emissions by up to 143 metric tonnes, as shown in Table 13. Although combustion of wood releases CO_2, the use of wood fuel provides net carbon benefit as long as the fuel is sourced in a sustainable manner. CO_2 equivalent values presented in this report include CO_2, as well as CH_4 and N_2O adjusted for their 100-year global warming potential relative to CO_2. These values are listed in Table 4.

Table 13 – Greenhouse Gas Emission (CO_2 equivalent) Reductions

Option	Estimated Fossil Fuel Only System	With Proposed Biomass System			Reduction in CO_2 Equivalent Emissions (tonnes)
	Propane CO_2 Equivalent Emissions (tonnes)	Biomass CO_2 Equivalent Emissions (tonnes)	Biomass Boiler Electric CO_2 Equivalent Emissions[1] (tonnes)	Propane CO_2 Equivalent Emissions (tonnes)	
1 - Cordwood	170	0	13	43	115
2 - Pellet	170	0	19	9	143
3 - Dry Chip	170	0	19	17	134

Note 1: Biomass boilers use more electricity than comparable gas boilers due to fuel handling equipment, larger blowers, etc. Table 4 contains the assumptions used to develop the above values.

9.4 AIR PERMITTING

Boilers in Minnesota can be subject to both state and federal emissions and permitting requirements. Using EPA AP-42 factors for wood and propane boilers, the PTE (potential to emit) of Paws and Claws, with either wood boiler option implemented, would not exceed the state or federal emissions thresholds for air pollutants. The PTE of a facility also includes non-combustion emissions sources such as VOCs and dust. WES estimates that there are no significant emissions sources at this facility that would affect the permitting status other than the boilers. Additionally, the facility would not be subject to any NSPS (New Source Performance Standards). Based on these calculations and assumptions, the addition of a wood boiler system as described in the options would not trigger any state or federal permitting requirements.

9.5 USE OF WOOD RESIDUALS AS FUEL

Wood pellets are a manufactured product and would not be considered by the Minnesota Pollution Control Agency (MPCA) to be a solid waste.

The MPCA has issued a Standing Beneficial Use Determination (SBUD) codified in Minn. R. 7035.2860, subpart 4(a), that allows for the use of "unadulterated wood, wood chips, bark, and sawdust" as a fuel, as long as the material is stored and managed appropriately. Unadulterated wood means wood that is not contaminated with paints, stains, glues, preservatives, or other chemicals. This SBUD allows facilities to use cord wood or clean wood chips, regardless of their source, as a fuel without any further action from MPCA's solid waste program.

9.6 ASH

Cordwood and wood chips generally contain about 1% ash by weight, while wood pellets contain 0.5-1.0% ash by weight. Modern pellet boilers have automated ash handling systems which deposit ashes in a portable metal container, an example of which is shown in Figure 7. Cordwood boilers generally have an ash cleanout location which must be manually raked every few days.

Figure 7 – Automated Ash Collection from Pellet Boiler

Options described in this report have the potential to generate up to 2 tons of ash per year.

Wood ash is a valuable soil amendment which has properties similar to lime. Studies have shown that land application of wood ash can improve forest health[1]. Wood ash is classified and regulated as a solid waste in Minnesota. However, the MPCA has a process whereby it will make a case-specific beneficial

[1] https://www.forestry.umn.edu/sites/forestry.umn.edu/files/Staffpaper153.PDF

use determination (CSBUD) to decide whether a specific management option for the solid waste is a beneficial use. Because wood ash is known to have valuable properties when used as a soil amendment, the MPCA has made determinations for several other facilities with biomass boilers that ashes can be spread on land, and therefore it is likely that permission will be granted in future cases. Prior to implementation of a biomass project, a proposal should be submitted to the MPCA in order to gain permission for this use of the wood ash.

Beneficial use of the ash is anticipated to be significantly cheaper than landfilling, and for the purposes of this study, it is assumed that the ash can be used beneficially at no cost to the facility. In the Hackensack area, use of ash would most likely be on timber harvest sites. The Carlton County Extension Office can assist with finding beneficial use sites, and applying for a CSBUD. Additional information on ash use from UMN Extension is provided in Appendix D.

9.7 Boiler Operator Requirements

Minnesota Administrative Rules section 5225.1110 requires all boilers be operated, maintained, and attended by a licensed operating engineer, unless specifically exempted. Minnesota Statutes section 326B.988 exempts hot water heating boilers that do not exceed a combined heat input capacity of 750,000 Btu per hour.

Minnesota Statutes section 326B.978 sets the classifications and qualifications for operating engineers. Engineers are divided into four classes based on individual boiler size allowed to be operated: chief, first class, second class, and special engineers. The maximum boiler size allowed to be operated by license class is presented in Table 14. Licenses classes are also divided into Grade A, B, C licenses. Grade C licenses allow for the operation of low pressure boilers (steam less than 15 psig, or hot water less than 160 psig or 250°F). Grade B licenses allow for the operation of low or high pressure boilers. Grade A licenses allow for the operation of low or high pressure boilers with engines, turbines or other appurtenances.

Table 14 – Maximum Boiler Size by License Class

Class	Maximum Boiler Size
Chief Engineer	Unlimited
First Class Engineer	500 HP (16.7 mmBtu/hr)
Second Class Engineer	100 HP (3.35 mmBtu/hr)
Special Engineer	50 HP (1.67 mmBtu/hr)

Attendance requirements for low pressure boilers are set by the chief boiler inspector. A boiler attendance policy issued on July 29, 2014 requires a licensed operating engineer check the boiler(s) at least once each day during normal workdays. For weekends and holidays, boiler attendance policy requires a licensed operating engineer check the boiler(s) if: outside air temperature is forecasted to reach 10°F or below, a situation occurs that impacts the safety of the boiler or equipment, or the building will be occupied by employees or the public. No boiler should be left unattended for more than two consecutive days. A check of the boiler includes visual examination of all associated equipment and a logbook entry of the conditions observed.

The designed aggregate input rate for the Paws and Claws mezzanine propane boiler room is approximately 1.6 mmBtu/hr. Addition of a wood boiler system would increase the input capacity by up to 1.2 mmBtu/hr, to a total of 2.8 mmBtu/hr. Because the design of the propane boiler plant already exceeds the 750,000 Btu/hr threshold, no change in attendance requirements would be required, but the license class requirement would increase to Second Class Engineer, according to the class designations in Table 14.

10.0 CONCLUSIONS AND RECOMMENDATIONS

A modern biomass boiler system would allow Paws and Claws to avoid fossil fuel usage while utilizing a local and renewable source of energy. The options evaluated in this report would provide benefits to the organization as summarized:

- Option 1 is a boiler system capable of utilizing cordwood or a percentage of dry wood scraps. This project would provide a first year net operating savings of $3,180 when utilizing cordwood only, or $10,011 when utilizing a mixture of cordwood and dry wood scraps, and would have a capital cost of $174,819.
- Option 2 is a boiler system capable of utilizing wood pellets. This project would provide a first year net operating savings of $7,584, and would have a capital cost of $201,341.
- Option 3 is a boiler system capable of utilizing dry wood chips or wood pellets. This project would provide a first year net operating savings of $28,701, and would have a capital cost of $302,268.

Financial performance of the evaluated options is heavily dependent on the cost of fossil fuels and wood fuels, as shown by the sensitivity analyses in Appendix C. If the cost of propane rises, then the savings will increase fairly dramatically.

Payments from the Minnesota Biomass Thermal Production Incentive are a major driver of savings for this project. It is important to note that these payments only occur for 10 years following startup of the project. Payments from this incentive increase the annual savings in today's dollars by $7,481 for Option 1, $9,476 for Option 2, and $8,977 for Option 3. The amount of the incentive is proportional to the quantity of fossil fuel offset, and this is expected to vary depending on the biomass technology installed, as explained in Section 6.

The economics of Option 1, the cordwood option, vary considerably depending on whether the cordwood will be purchased as cut-and-split cordwood from a commercial cordwood processor, or whether scrap wood from Mann Lake will be used to offset some of the cordwood needs. However, use of dry scrap wood may degrade the performance of the cordwood boilers and may result in unsafe operation if too much dry wood is loaded at a time. In addition, Option 1 requires the greatest investment in ongoing staff time compared to the other 2 options. The savings projected for Option 1 will not be fully realized if facility staff are unable or unwilling to service and load the cordwood boilers several times per day.

Additional benefits which would be provided through the use of local biomass at the facility include:

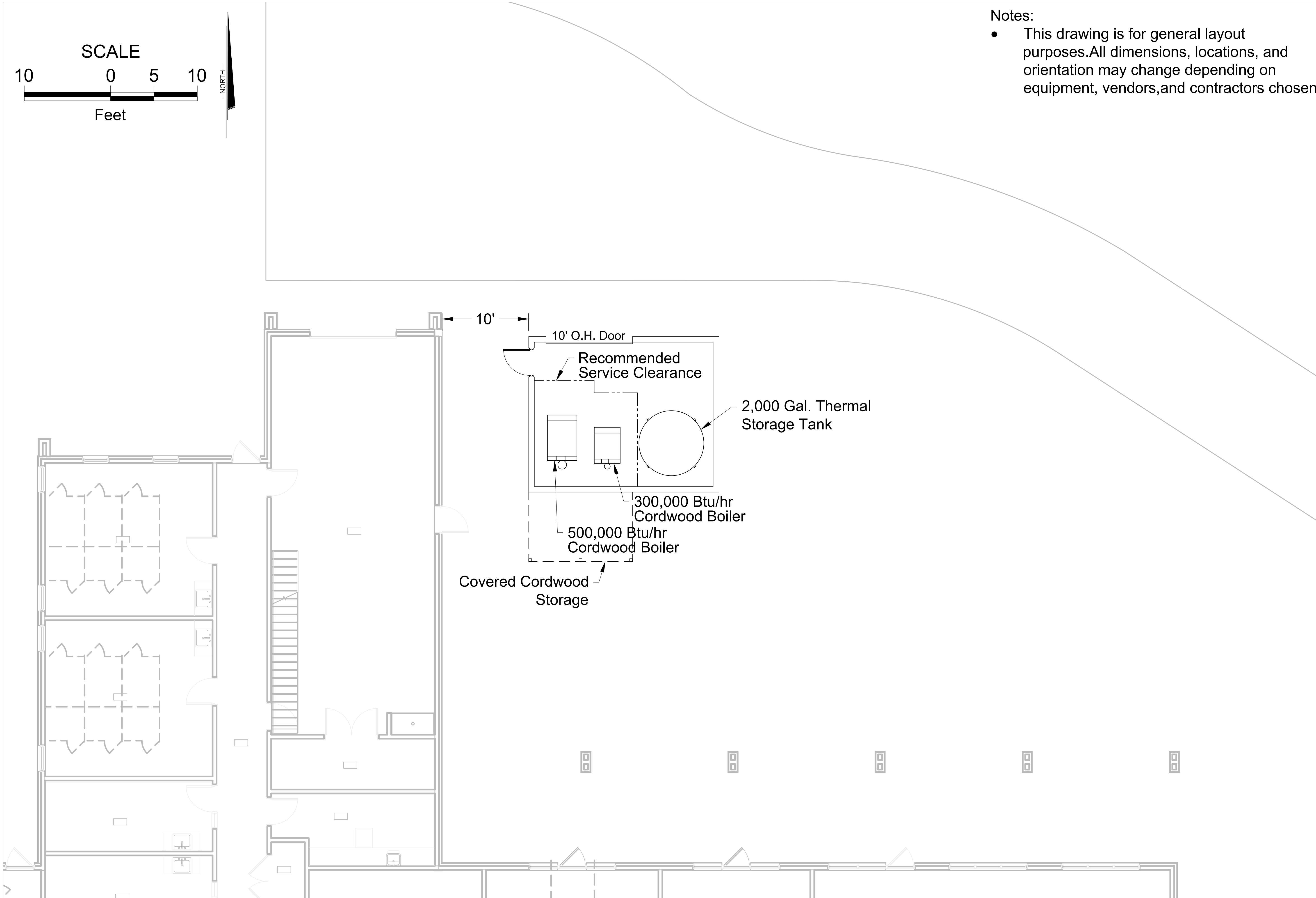
- Net reduction of greenhouse gas emissions by approximately 115-143 metric tonnes annually,
- Keeping $9,000-$33,000/yr spent on energy within the region,
- Diversification of fuels used by the facility,
- Reduction in operating budget volatility due to wide fluctuations in fossil energy pricing,
- Creating markets for low-value woody biomass to enhance opportunities for forest management activities to reduce pests and disease, prevent fires, and manage for ecological diversity, soil health, and water quality.

Should Paws and Claws be interested in pursuing a biomass option, WES recommends that staff visit several types of modern biomass boiler installations to develop a detailed understanding of the equipment and its capabilities. The MN SWET is available to assist in arranging tours of existing facilities. As Paws and Claws continues to pursue renewable biomass energy options, WES recommends that the next level of evaluation includes detailed consideration of the following items:

- Evaluate domestic hot water loads for the facility and determine whether an indirect DHW tank heated by the propane boiler system could replace one of the two specified propane DHW heaters, to reduce capital and operating costs and provide seamless coverage of the DHW using the wood boiler system
- Work with the MN SWET to identify alternative funding sources (low interest loans, grants, and incentives)
- Discuss possible plant ownership or fuel sourcing agreements with local wood products manufacturers in order to leverage available grant programs.
- If biomass installation is delayed, carefully monitor building performance and fuel usage to inform sizing of biomass boilers.

Appendix A – Drawings

- A.1 Option 1 (Cordwood) Layout
- A.2 Option 2 (Pellet) Layout
- A.3 Option 3 (Dry Chip) Layout
- A.4 Option 3 (Dry Chip) Section
- A.5 Option 1 (Cordwood) Schematic
- A.6 Option 2 (Pellet) Schematic
- A.7 Option 3 (Dry Chip) Schematic



Notes:

- This drawing is for general layout purposes.All dimensions, locations, and orientation may change depending on equipment, vendors,and contractors chosen.

Designed	dHb	11/20/16
Drawn	dHb	11/20/16
Checked	THW	12/5/16

Approved ____ Date ____

Title ____ Job Class ____

Paws & Claws

Hackensack, MN

Option 1 Cordwood Boiler

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Wilson Engineering Services, PC
www.wilsonengineeringservices.com
902 Market St. Meadville, PA 16335

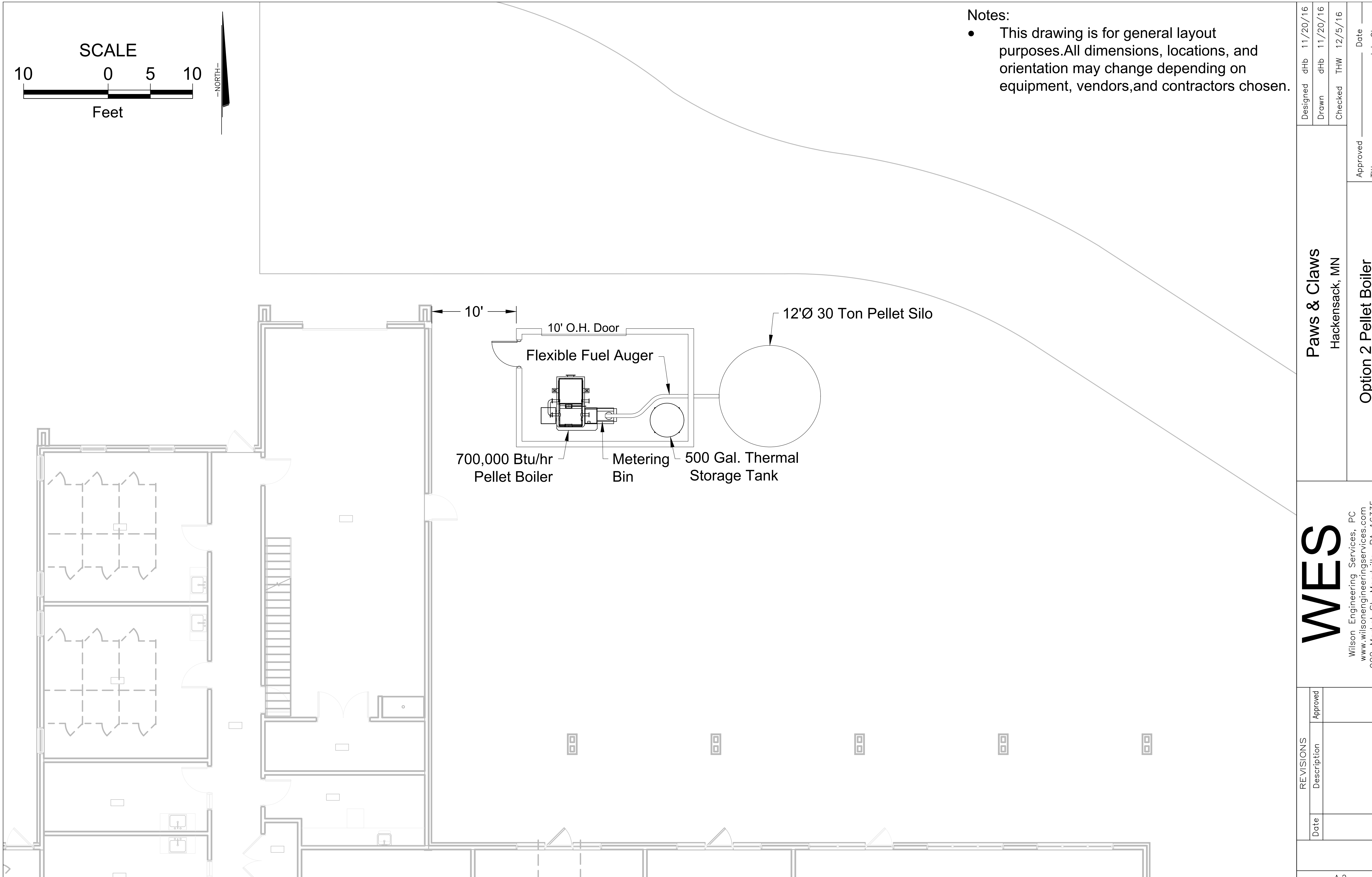
REVISIONS

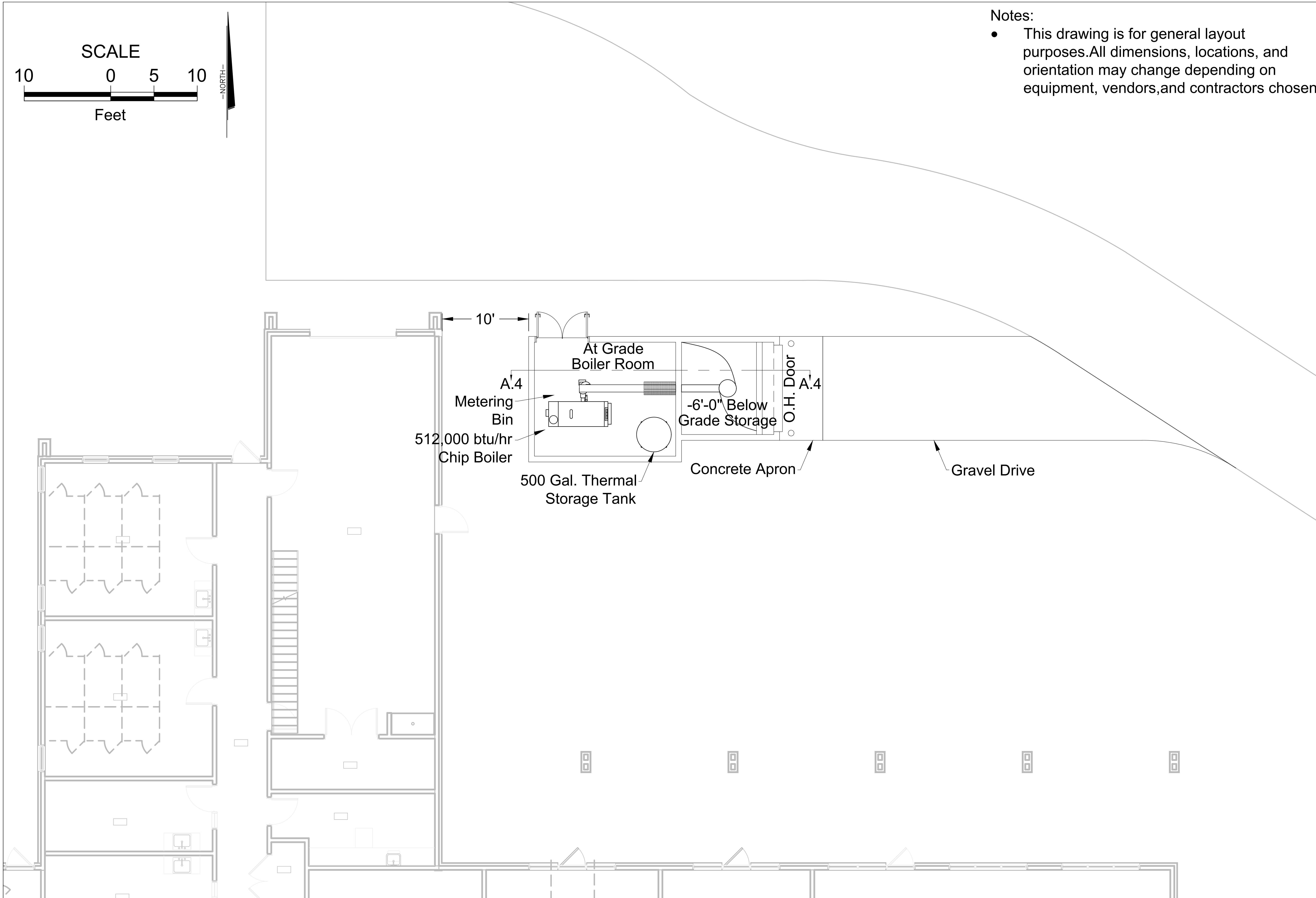
Date	Description	Approved

A.1

Notes:

- This drawing is for general layout purposes.All dimensions, locations, and orientation may change depending on equipment, vendors,and contractors chosen.





Notes:

- This drawing is for general layout purposes.All dimensions, locations, and orientation may change depending on equipment, vendors,and contractors chosen.

Designed	dHb	11/20/16
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Checked	THW	12/5/16

Approved ______ Date ______

Title ______ Job Class ______

Paws & Claws

Hackensack, MN

Option 3 Chip Boiler

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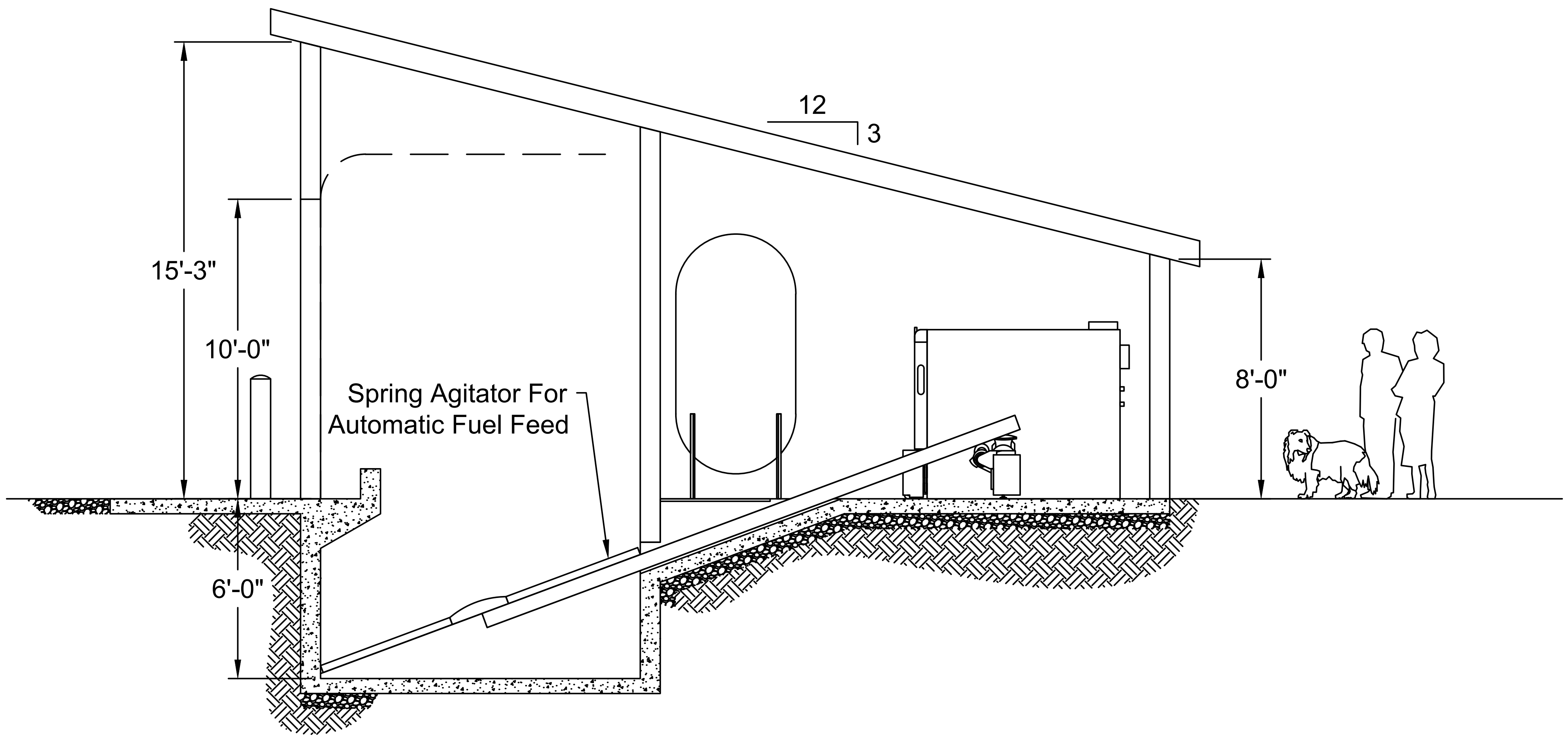
Date	Description	Approved

Notes:

- This drawing is for general layout purposes.All dimensions, locations, and orientation may change depending on equipment, vendors,and contractors chosen.



SCALE

5' 0' 2.5' 5'

Designed	dHb	11/20/16
Drawn	dHb	11/20/16
Checked	THW	12/5/16

Approved ____ Date ____

Title ____ Job Class ____

Paws & Claws

Hackensack, MN

Option 3 Section

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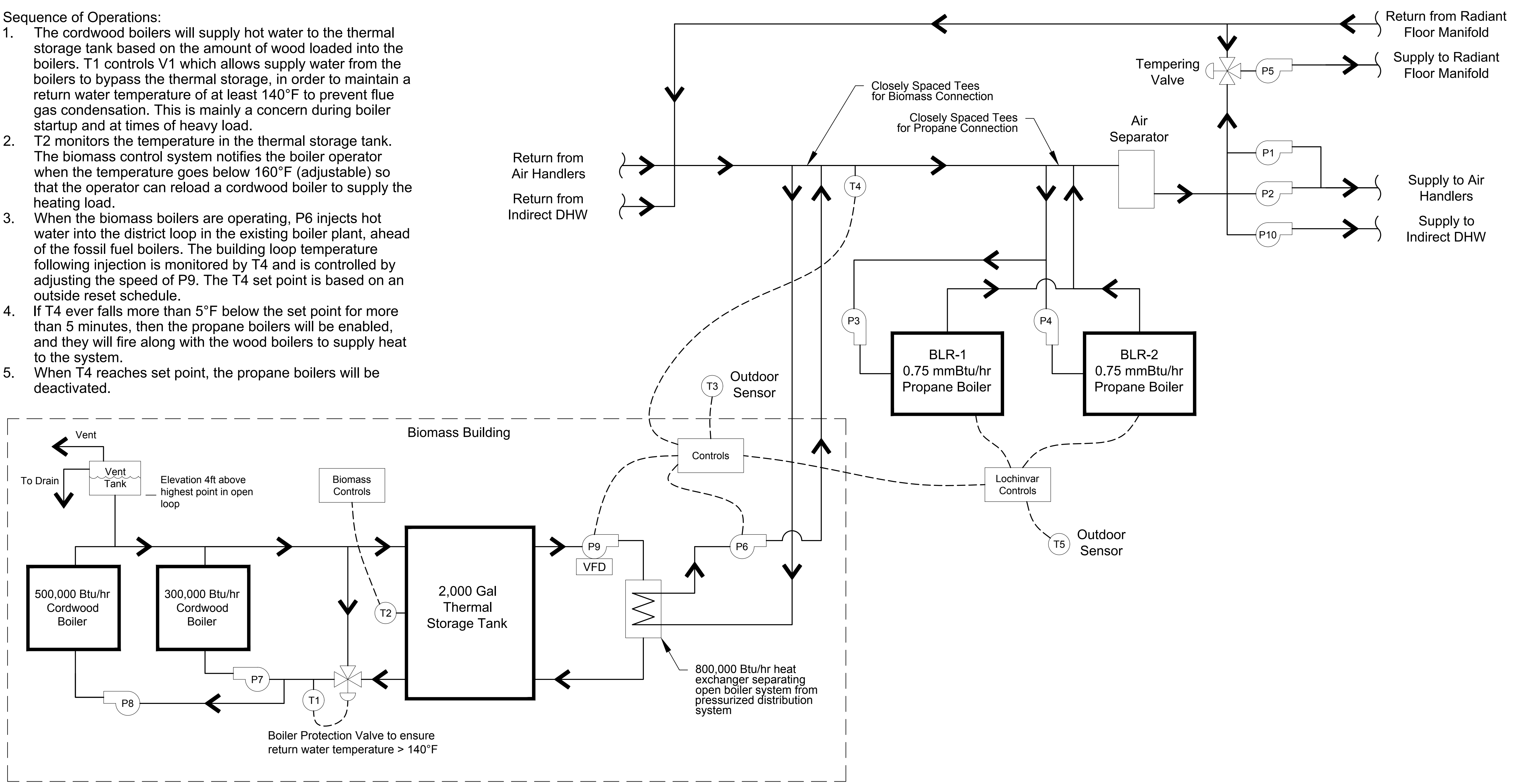
Sequence of Operations:

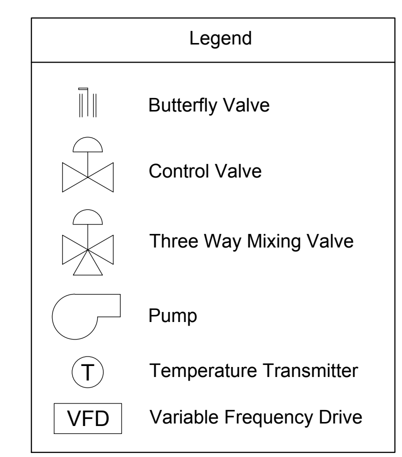
1. The cordwood boilers will supply hot water to the thermal storage tank based on the amount of wood loaded into the boilers. T1 controls V1 which allows supply water from the boilers to bypass the thermal storage, in order to maintain a return water temperature of at least 140°F to prevent flue gas condensation. This is mainly a concern during boiler startup and at times of heavy load.
2. T2 monitors the temperature in the thermal storage tank. The biomass control system notifies the boiler operator when the temperature goes below 160°F (adjustable) so that the operator can reload a cordwood boiler to supply the heating load.
3. When the biomass boilers are operating, P6 injects hot water into the district loop in the existing boiler plant, ahead of the fossil fuel boilers. The building loop temperature following injection is monitored by T4 and is controlled by adjusting the speed of P9. The T4 set point is based on an outside reset schedule.
4. If T4 ever falls more than 5°F below the set point for more than 5 minutes, then the propane boilers will be enabled, and they will fire along with the wood boilers to supply heat to the system.
5. When T4 reaches set point, the propane boilers will be deactivated.



Notes:

1. The propane boilers and pumps P1 through P5 have been specified by Design Learned Inc.
2. Indirect DHW is a proposed modification to the building mechanical plans. Current plans prepared by Design Learned Inc. specify propane DHW heaters.
3. This drawing is a conceptual layout for the purposes of showing biomass system options.
4. Final design and layout will change based on equipment selected, designer, and site conditions.

Hydronic System Schematic Including Cordwood Boilers



Designed PFO 10/20/16
Drawn PFO 10/20/16
Checked THW 12/5/16
Approved
Date
Title
Job Class

Paws & Claws
Hackensack, MN
Option 1 Hydronic System Schematic

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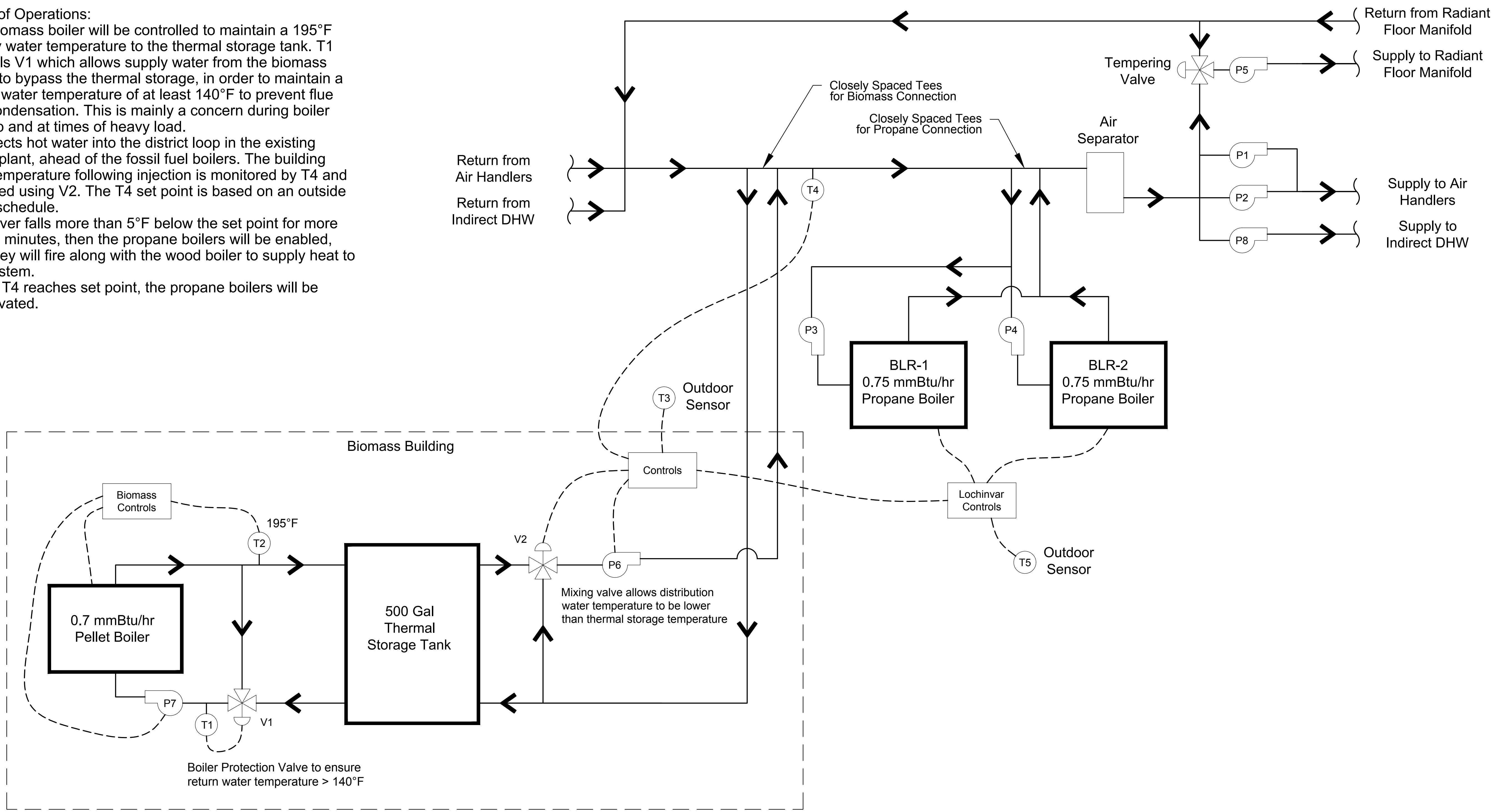
REVISIONS
Date | Description | Approved

A.5

Sequence of Operations:

1. The biomass boiler will be controlled to maintain a 195°F supply water temperature to the thermal storage tank. T1 controls V1 which allows supply water from the biomass boiler to bypass the thermal storage, in order to maintain a return water temperature of at least 140°F to prevent flue gas condensation. This is mainly a concern during boiler startup and at times of heavy load.
2. P6 injects hot water into the district loop in the existing boiler plant, ahead of the fossil fuel boilers. The building loop temperature following injection is monitored by T4 and adjusted using V2. The T4 set point is based on an outside reset schedule.
3. If T4 ever falls more than 5°F below the set point for more than 5 minutes, then the propane boilers will be enabled, and they will fire along with the wood boiler to supply heat to the system.
4. When T4 reaches set point, the propane boilers will be deactivated.



Notes:

1. The propane boilers and pumps P1 through P5 have been specified by Design Learned Inc.
2. Indirect DHW is a proposed modification to the building mechanical plans. Current plans prepared by Design Learned Inc. specify propane DHW heaters.
3. This drawing is a conceptual layout for the purposes of showing biomass system options.
4. Final design and layout will change based on equipment selected, designer, and site conditions.

Hydronic System Schematic Including Pellet Boiler

Legend

- Butterfly Valve
- Control Valve
- Three Way Mixing Valve
- Pump
- T Temperature Transmitter
- VFD Variable Frequency Drive

Designed	PFO	10/20/16
Drawn	PFO	10/20/16
Checked	THW	12/5/16

Approved ____ Date ____

Title ____ Job Class ____

Paws & Claws
Hackensack, MN

Option 2 Hydronic System Schematic

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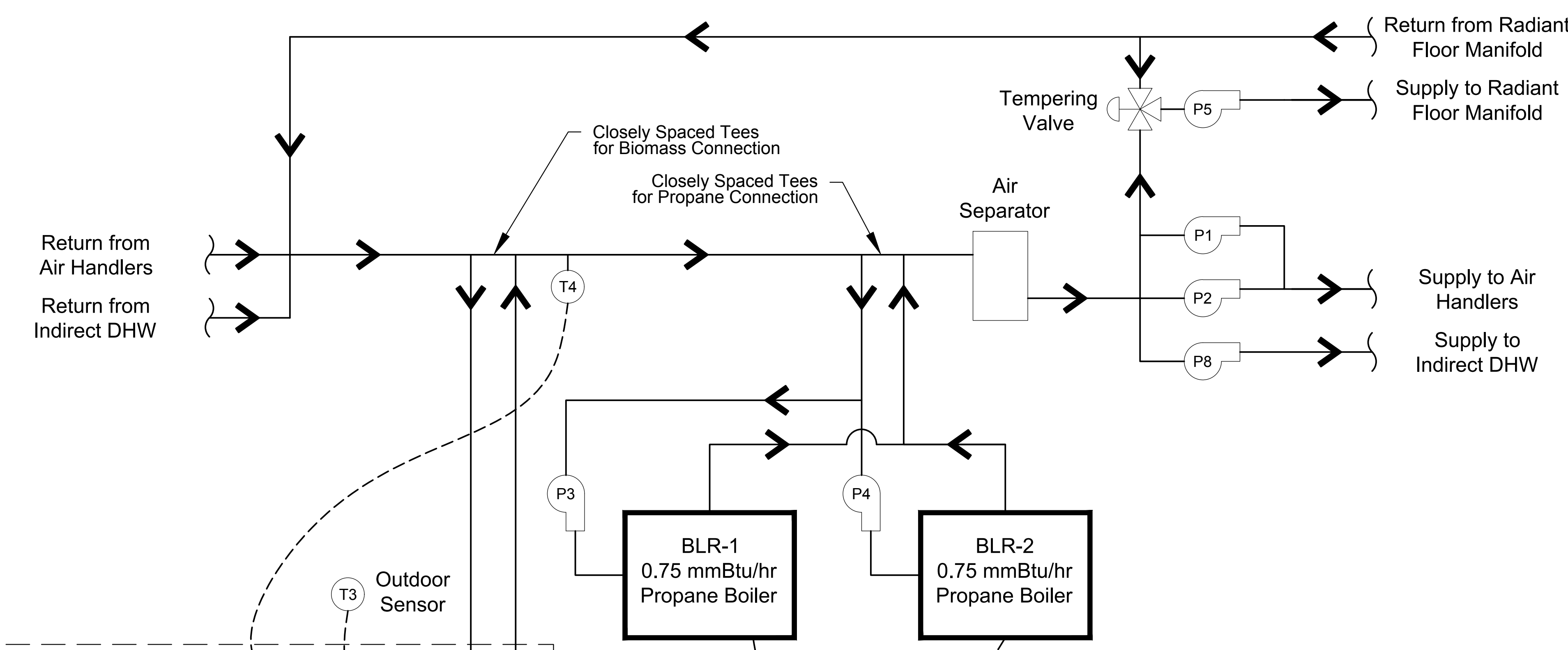
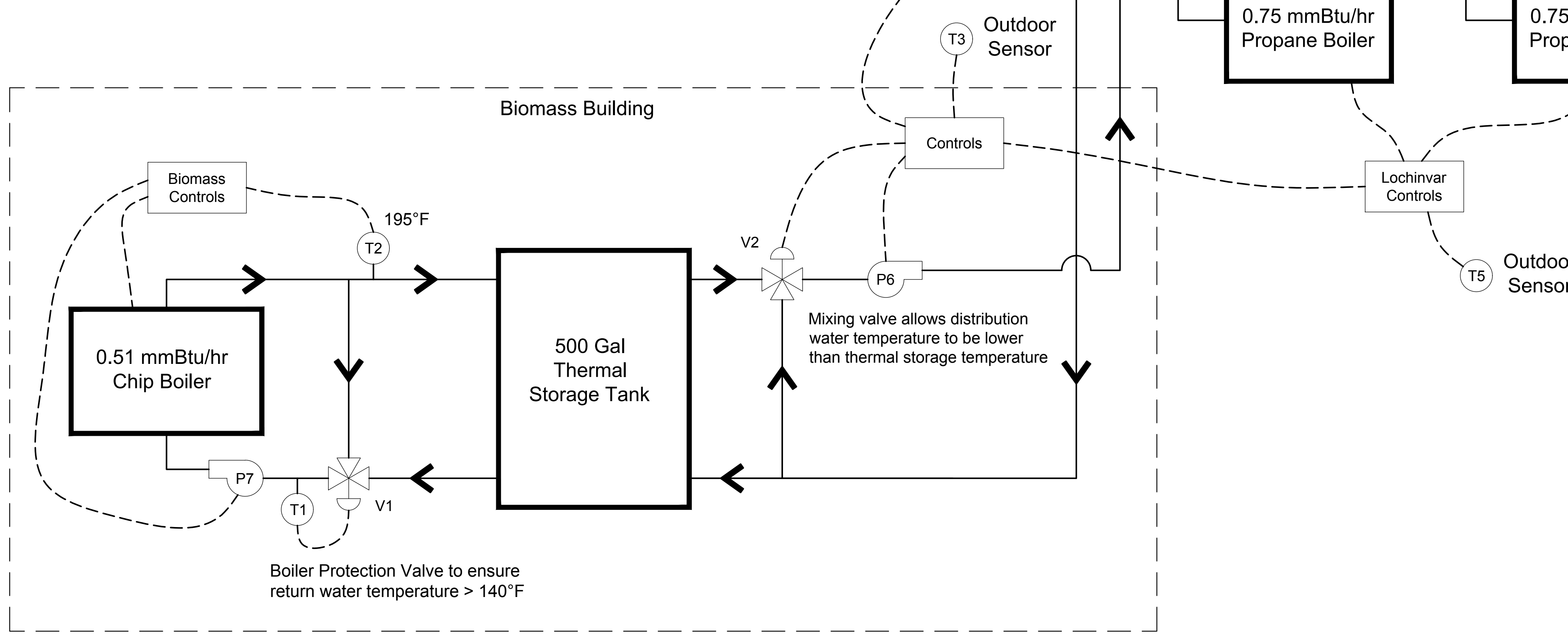
REVISIONS

Date	Description	Approved

Sequence of Operations:

1. The biomass boiler will be controlled to maintain a 195°F supply water temperature to the thermal storage tank. T1 controls V1 which allows supply water from the biomass boiler to bypass the thermal storage, in order to maintain a return water temperature of at least 140°F to prevent flue gas condensation. This is mainly a concern during boiler startup and at times of heavy load.
2. P6 injects hot water into the district loop in the existing boiler plant, ahead of the fossil fuel boilers. The building loop temperature following injection is monitored by T4 and adjusted using V2. The T4 set point is based on an outside reset schedule.
3. If T4 ever falls more than 5°F below the set point for more than 5 minutes, then the propane boilers will be enabled, and they will fire along with the wood boiler to supply heat to the system.
4. When T4 reaches set point, the propane boilers will be deactivated.





Legend

- Butterfly Valve
- Control Valve
- Three Way Mixing Valve
- Pump
- T — Temperature Transmitter
- VFD — Variable Frequency Drive

Notes:

1. The propane boilers and pumps P1 through P5 have been specified by Design Learned Inc.
2. Indirect DHW is a proposed modification to the building mechanical plans. Current plans prepared by Design Learned Inc. specify propane DHW heaters.
3. This drawing is a conceptual layout for the purposes of showing biomass system options.
4. Final design and layout will change based on equipment selected, designer, and site conditions.

Hydronic System Schematic Including Chip Boiler

Designed	PFO	10/20/16
Drawn	PFO	10/20/16
Checked	THW	12/5/16

Approved ____ Date ____

Title ____ Job Class ____

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Hackensack, MN

Option 3 Hydronic System Schematic

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Date	Description	Approved

Appendix B – Capital Cost Estimates

- B.1 Option 1 – Cordwood Boiler System
- B.2 Option 2 – Pellet Boiler System
- B.3 Option 3 – Dry Chip Boiler System

Option 1 - Cordwood Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item		Cost
300,000 Btu/hr cordwood boiler	$	15,000
500,000 Btu/hr cordwood boiler	$	25,000
Shipping	$	1,000
Total Boiler Manufacturer Contract	**$**	**41,000**

General Contract

Line Item			Cost
Sitework for building		$	10,000
22'x18' boiler building ($70/sf)		$	27,720
2,000 gallon non-ASME thermal storage tank		$	5,000
Heat exchanger to interface open unpressurized system to closed system		$	5,000
Pumps, expansion tanks, hydronic specialties		$	5,000
Underground supply and return pipes to mezzanine boiler room		$	5,000
Boiler stacks		$	7,500
Boiler installation, piping, and controls		$	20,000
Sub-Total		$	85,220
Contractor profit, overhead, and insurance	*16%*	*$*	*13,635*
Total General Contract Building and Site[2]		**$**	**98,855**

Total Project Cost

Line Item			Cost
Project Sub-Total (Boiler, General Contract, Additional Items)		$	139,855
Professional Services [3]	*10%*	*$*	*13,986*
Contingency	*15%*	*$*	*20,978*
Total Project Cost		**$**	**174,819**

Notes:
1 - Assumes that biomass boiler and general contract are bid separately.
2 - Costs are approximate. Estimate is based on competitive bidding.
3 - Professional Services includes engineering, permitting, legal, and project management.

Option 2 - Pellet Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item		Cost
700,000 Btu/hr pellet boiler and controls	$	50,000
Flexible auger pellet handling system	$	5,000
Shipping	$	1,000
Total Boiler Manufacturer Contract	**$**	**56,000**

General Contract

Line Item			Cost
Sitework for silo and building		$	15,000
21'x14' boiler building ($70/sf)		$	20,580
30 ton pellet silo and installation		$	10,000
500 gallon ASME thermal storage tank		$	5,000
Heat exchanger to interface boilers and thermal storage to closed system		$	5,000
Pumps, expansion tanks, hydronic specialties		$	5,000
Underground supply and return pipes to mezzanine boiler room		$	5,000
Boiler stack		$	5,000
Boiler installation, piping, and controls		$	20,000
Sub-Total		$	90,580
Contractor profit, overhead, and insurance	*16%*	*$*	*14,493*
Total General Contract Building and Site[2]		**$**	**105,073**

Total Project Cost

Line Item			Cost
Project Sub-Total (Boiler, General Contract, Additional Items)		$	161,073
Professional Services[3]	*10%*	*$*	*16,107*
Contingency	*15%*	*$*	*24,161*
Total Project Cost		**$**	**201,341**

Notes:
1 - Assumes that biomass boiler and general contract are bid separately.
2 - Costs are approximate. Estimate is based on competitive bidding.
3 - Professional Services includes engineering, permitting, legal, and project management.

Option 3 - Dry Chip Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item		Cost
512,000 Btu/hr dry wood chip boiler and controls	$	65,000
Spring agitator fuel reclaim equipment and augers	$	15,000
Shipping	$	1,000
Total Boiler Manufacturer Contract	**$**	**81,000**

General Contract

Line Item			Cost
Sitework for building		$	25,000
29'x15' boiler and fuel storage building ($90/sf)		$	39,150
500 gallon ASME thermal storage tank		$	5,000
Pumps, expansion tanks, hydronic specialties		$	5,000
Underground supply and return pipes to mezzanine boiler room		$	5,000
Boiler stack		$	5,000
Boiler installation, piping, and controls		$	20,000
Sub-Total		$	104,150
Contractor profit, overhead, and insurance	*16%*	*$*	*16,664*
Total General Contract Building and Site[2]		**$**	**120,814**

Other Items

Line Item		Cost
Wood grinder for processing wood scraps into chips	$	40,000
Total	**$**	**40,000**

Total Project Cost

Line Item			Cost
Project Sub-Total (Boiler, General Contract, Other Items)		$	241,814
Professional Services[3]	*10%*	*$*	*24,181*
Contingency	*15%*	*$*	*36,272*
Total Project Cost		**$**	**302,268**

Notes:
1 - Assumes that biomass boiler and general contract are bid separately.
2 - Costs are approximate. Estimate is based on competitive bidding.
3 - Professional Services includes engineering, permitting, legal, and project management.

Appendix C – Financial and Fuel Cost Analyses

- C.1 Option 1 (Cordwood) Financial Analysis
- C.2 Option 1 (Cordwood) Financial Analysis with 25% Grant
- C.3 Option 1 (Cordwood) Fuel Cost Sensitivity Analysis
- C.4 Option 1 (Cordwood using 50% scraps) Financial Analysis
- C.5 Option 1 (Cordwood using 50% scraps) Financial Analysis with 25% Grant
- C.6 Option 1 (Cordwood using 50% scraps) Fuel Cost Sensitivity Analysis
- C.7 Option 2 (Pellet) Financial Analysis
- C.8 Option 2 (Pellet) Financial Analysis with 25% Grant
- C.9 Option 2 (Pellet) Fuel Cost Sensitivity Analysis
- C.10 Option 3 (Dry Chip) Financial Analysis
- C.11 Option 3 (Dry Chip) Financial Analysis with 25% Grant
- C.12 Option 3 (Dry Chip) Fuel Cost Sensitivity Analysis

Appendix C

Option 1 - Cordwood Boiler System
25-year Cash Flow Analysis

Input Variables	Value	Units
Project Costs Financed	$174,819	$
Grant Amount	$0	$
Project Costs Financed	$174,819	$
Annual Propane Usage	29,492	gal
Average Propane Price	$1.50	$/gal
Cordwood Usage	132	cords/yr
Year 1 Cordwood Price	$185	$/cord
Annual Propane Usage w/ Wood System	7,373	gal
Fossil Fuel Escalation Rate (apr)	1.5%	Percent
Wood Fuel Escalation Rate (apr)	0.5%	Percent
Real Discount Rate (apr)	1.0%	Percent
Inflation Rate (apr)	2.7%	Percent
Added Annual O&M Costs for Biomass Plant	$5,562	$/year
Thermal Production Incentive	$7,481	$/year

Year	Total Fossil Fuel Cost, Current System	Wood Fuel Cost	Fossil Fuel Cost w/ Wood System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (174,819)	$ (174,819)
1	$ 44,239	$ (24,437)	$ (11,060)	$ (5,562)	$ 3,180	$ 7,481	$ 10,661	$ 10,555
2	$ 44,902	$ (24,559)	$ (11,226)	$ (5,562)	$ 3,555	$ 7,284	$ 10,840	$ 10,626
3	$ 45,576	$ (24,682)	$ (11,394)	$ (5,562)	$ 3,938	$ 7,093	$ 11,030	$ 10,706
4	$ 46,259	$ (24,805)	$ (11,565)	$ (5,562)	$ 4,327	$ 6,906	$ 11,233	$ 10,795
5	$ 46,953	$ (24,929)	$ (11,738)	$ (5,562)	$ 4,724	$ 6,725	$ 11,448	$ 10,893
6	$ 47,658	$ (25,054)	$ (11,914)	$ (5,562)	$ 5,127	$ 6,548	$ 11,675	$ 10,998
7	$ 48,372	$ (25,179)	$ (12,093)	$ (5,562)	$ 5,538	$ 6,376	$ 11,914	$ 11,112
8	$ 49,098	$ (25,305)	$ (12,274)	$ (5,562)	$ 5,956	$ 6,208	$ 12,164	$ 11,234
9	$ 49,834	$ (25,432)	$ (12,459)	$ (5,562)	$ 6,382	$ 6,045	$ 12,427	$ 11,362
10	$ 50,582	$ (25,559)	$ (12,645)	$ (5,562)	$ 6,816	$ 5,886	$ 12,702	$ 11,499
11	$ 51,341	$ (25,687)	$ (12,835)	$ (5,562)	$ 7,257		$ 7,257	$ 6,504
12	$ 52,111	$ (25,815)	$ (13,028)	$ (5,562)	$ 7,706		$ 7,706	$ 6,839
13	$ 52,892	$ (25,944)	$ (13,223)	$ (5,562)	$ 8,163		$ 8,163	$ 7,173
14	$ 53,686	$ (26,074)	$ (13,421)	$ (5,562)	$ 8,628		$ 8,628	$ 7,506
15	$ 54,491	$ (26,204)	$ (13,623)	$ (5,562)	$ 9,102		$ 9,102	$ 7,840
16	$ 55,308	$ (26,335)	$ (13,827)	$ (5,562)	$ 9,584		$ 9,584	$ 8,173
17	$ 56,138	$ (26,467)	$ (14,035)	$ (5,562)	$ 10,075		$ 10,075	$ 8,507
18	$ 56,980	$ (26,599)	$ (14,245)	$ (5,562)	$ 10,574		$ 10,574	$ 8,840
19	$ 57,835	$ (26,732)	$ (14,459)	$ (5,562)	$ 11,082		$ 11,082	$ 9,173
20	$ 58,702	$ (26,866)	$ (14,676)	$ (5,562)	$ 11,599		$ 11,599	$ 9,506
21	$ 59,583	$ (27,000)	$ (14,896)	$ (5,562)	$ 12,125		$ 12,125	$ 9,839
22	$ 60,477	$ (27,135)	$ (15,119)	$ (5,562)	$ 12,660		$ 12,660	$ 10,171
23	$ 61,384	$ (27,271)	$ (15,346)	$ (5,562)	$ 13,205		$ 13,205	$ 10,504
24	$ 62,305	$ (27,407)	$ (15,576)	$ (5,562)	$ 13,759		$ 13,759	$ 10,836
25	$ 63,239	$ (27,544)	$ (15,810)	$ (5,562)	$ 14,323		$ 14,323	$ 11,169
							25-year Net Present Value	**$ 67,540**

Note: All values are in real dollars.

Option 1 - Cordwood Boiler System
25-year Cash Flow Analysis w/ 25% Grant

Input Variables	Value	Units
Project Costs Financed	$174,819	$
Grant Amount	$43,705	$
Project Costs Financed	$131,114	$
Annual Propane Usage	29,492	gal
Average Propane Price	$1.50	$/gal
Cordwood Usage	132	cords/yr
Year 1 Cordwood Price	$185	$/cord
Annual Propane Usage w/ Wood System	7,373	gal
Fossil Fuel Escalation Rate (apr)	1.5%	Percent
Wood Fuel Escalation Rate (apr)	0.5%	Percent
Real Discount Rate (apr)	1.0%	Percent
Inflation Rate (apr)	2.7%	Percent
Added Annual O&M Costs for Biomass Plant	$5,562	$/year
Thermal Production Incentive	$7,481	$/year

Year	Total Fossil Fuel Cost, Current System	Wood Fuel Cost	Fossil Fuel Cost w/ Wood System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (131,114)	$ (131,114)
1	$ 44,239	$ (24,437)	$ (11,060)	$ (5,562)	$ 3,180	$ 7,481	$ 10,661	$ 10,555
2	$ 44,902	$ (24,559)	$ (11,226)	$ (5,562)	$ 3,555	$ 7,284	$ 10,840	$ 10,626
3	$ 45,576	$ (24,682)	$ (11,394)	$ (5,562)	$ 3,938	$ 7,093	$ 11,030	$ 10,706
4	$ 46,259	$ (24,805)	$ (11,565)	$ (5,562)	$ 4,327	$ 6,906	$ 11,233	$ 10,795
5	$ 46,953	$ (24,929)	$ (11,738)	$ (5,562)	$ 4,724	$ 6,725	$ 11,448	$ 10,893
6	$ 47,658	$ (25,054)	$ (11,914)	$ (5,562)	$ 5,127	$ 6,548	$ 11,675	$ 10,998
7	$ 48,372	$ (25,179)	$ (12,093)	$ (5,562)	$ 5,538	$ 6,376	$ 11,914	$ 11,112
8	$ 49,098	$ (25,305)	$ (12,274)	$ (5,562)	$ 5,956	$ 6,208	$ 12,164	$ 11,234
9	$ 49,834	$ (25,432)	$ (12,459)	$ (5,562)	$ 6,382	$ 6,045	$ 12,427	$ 11,362
10	$ 50,582	$ (25,559)	$ (12,645)	$ (5,562)	$ 6,816	$ 5,886	$ 12,702	$ 11,499
11	$ 51,341	$ (25,687)	$ (12,835)	$ (5,562)	$ 7,257		$ 7,257	$ 6,504
12	$ 52,111	$ (25,815)	$ (13,028)	$ (5,562)	$ 7,706		$ 7,706	$ 6,839
13	$ 52,892	$ (25,944)	$ (13,223)	$ (5,562)	$ 8,163		$ 8,163	$ 7,173
14	$ 53,686	$ (26,074)	$ (13,421)	$ (5,562)	$ 8,628		$ 8,628	$ 7,506
15	$ 54,491	$ (26,204)	$ (13,623)	$ (5,562)	$ 9,102		$ 9,102	$ 7,840
16	$ 55,308	$ (26,335)	$ (13,827)	$ (5,562)	$ 9,584		$ 9,584	$ 8,173
17	$ 56,138	$ (26,467)	$ (14,035)	$ (5,562)	$ 10,075		$ 10,075	$ 8,507
18	$ 56,980	$ (26,599)	$ (14,245)	$ (5,562)	$ 10,574		$ 10,574	$ 8,840
19	$ 57,835	$ (26,732)	$ (14,459)	$ (5,562)	$ 11,082		$ 11,082	$ 9,173
20	$ 58,702	$ (26,866)	$ (14,676)	$ (5,562)	$ 11,599		$ 11,599	$ 9,506
21	$ 59,583	$ (27,000)	$ (14,896)	$ (5,562)	$ 12,125		$ 12,125	$ 9,839
22	$ 60,477	$ (27,135)	$ (15,119)	$ (5,562)	$ 12,660		$ 12,660	$ 10,171
23	$ 61,384	$ (27,271)	$ (15,346)	$ (5,562)	$ 13,205		$ 13,205	$ 10,504
24	$ 62,305	$ (27,407)	$ (15,576)	$ (5,562)	$ 13,759		$ 13,759	$ 10,836
25	$ 63,239	$ (27,544)	$ (15,810)	$ (5,562)	$ 14,323		$ 14,323	$ 11,169
							25-year Net Present Value	**$ 111,245**

Note: All values are in real dollars.

Option 1 - Cordwood Boiler System
Fuel Cost Sensitivity Analysis

Table Shows Sensitivity of Annual Operating Savings to Changes in Fossil Fuel and Wood Fuel Prices*

Fossil Fuel Price, $/gal

Price of Cordwood - $/ton	$1.00	$1.25	$1.50	$1.75	$2.00	$2.50	$3.00
$100	$3,348	$8,878	$14,408	$19,938	$25,467	$36,527	$47,587
$110	$2,027	$7,557	$13,087	$18,617	$24,146	$35,206	$46,266
$120	$706	$6,236	$11,766	$17,296	$22,826	$33,885	$44,945
$130	($615)	$4,915	$10,445	$15,975	$21,505	$32,564	$43,624
$140	($1,936)	$3,594	$9,124	$14,654	$20,184	$31,243	$42,303
$150	($3,256)	$2,273	$7,803	$13,333	$18,863	$29,922	$40,982
$160	($4,577)	$952	$6,482	$12,012	$17,542	$28,602	$39,661
$170	($5,898)	($369)	$5,161	$10,691	$16,221	$27,281	$38,340
$180	($7,219)	($1,689)	$3,840	$9,370	$14,900	$25,960	$37,019
$185	($7,880)	($2,350)	$3,180	$8,710	$14,240	$25,299	$36,359
$195	($9,201)	($3,671)	$1,859	$7,389	$12,919	$23,978	$35,038
$200	($9,861)	($4,331)	$1,199	$6,728	$12,258	$23,318	$34,378
$210	($11,182)	($5,652)	($122)	$5,407	$10,937	$21,997	$33,057
$220	($12,503)	($6,973)	($1,443)	$4,087	$9,616	$20,676	$31,736

**Notes: All other costs fixed. Excludes financing costs. Excludes thermal production incentive.*

Option 1 - Cordwood Boiler System using 50% scraps
25-year Cash Flow Analysis

Input Variables	Value	Units
Project Costs Financed	$174,819	$
Grant Amount	$0	$
Project Costs Financed	$174,819	$
Annual Propane Usage	29,492	gal
Average Propane Price	$1.50	$/gal
Cordwood and Scrap Usage	199	tons/yr
Year 1 Cordwood and Scrap Price (blended)	$76	$/ton
Annual Propane Usage w/ Wood System	7,373	gal
Fossil Fuel Escalation Rate (apr)	1.5%	Percent
Wood Fuel Escalation Rate (apr)	0.5%	Percent
Real Discount Rate (apr)	1.0%	Percent
Inflation Rate (apr)	2.7%	Percent
Added Annual O&M Costs for Biomass Plant	$8,162	$/year
Thermal Production Incentive	$7,481	$/year

Year	Total Fossil Fuel Cost, Current System	Wood Fuel Cost	Fossil Fuel Cost w/ Wood System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (174,819)	$ (174,819)
1	$ 44,239	$ (15,006)	$ (11,060)	$ (8,162)	$ 10,011	$ 7,481	$ 17,492	$ 17,318
2	$ 44,902	$ (15,081)	$ (11,226)	$ (8,162)	$ 10,433	$ 7,284	$ 17,718	$ 17,368
3	$ 45,576	$ (15,157)	$ (11,394)	$ (8,162)	$ 10,863	$ 7,093	$ 17,956	$ 17,428
4	$ 46,259	$ (15,232)	$ (11,565)	$ (8,162)	$ 11,300	$ 6,906	$ 18,206	$ 17,496
5	$ 46,953	$ (15,308)	$ (11,738)	$ (8,162)	$ 11,744	$ 6,725	$ 18,469	$ 17,573
6	$ 47,658	$ (15,385)	$ (11,914)	$ (8,162)	$ 12,196	$ 6,548	$ 18,744	$ 17,658
7	$ 48,372	$ (15,462)	$ (12,093)	$ (8,162)	$ 12,655	$ 6,376	$ 19,031	$ 17,751
8	$ 49,098	$ (15,539)	$ (12,274)	$ (8,162)	$ 13,122	$ 6,208	$ 19,330	$ 17,851
9	$ 49,834	$ (15,617)	$ (12,459)	$ (8,162)	$ 13,597	$ 6,045	$ 19,642	$ 17,959
10	$ 50,582	$ (15,695)	$ (12,645)	$ (8,162)	$ 14,079	$ 5,886	$ 19,965	$ 18,074
11	$ 51,341	$ (15,774)	$ (12,835)	$ (8,162)	$ 14,570		$ 14,570	$ 13,059
12	$ 52,111	$ (15,852)	$ (13,028)	$ (8,162)	$ 15,069		$ 15,069	$ 13,373
13	$ 52,892	$ (15,932)	$ (13,223)	$ (8,162)	$ 15,576		$ 15,576	$ 13,686
14	$ 53,686	$ (16,011)	$ (13,421)	$ (8,162)	$ 16,091		$ 16,091	$ 13,999
15	$ 54,491	$ (16,091)	$ (13,623)	$ (8,162)	$ 16,615		$ 16,615	$ 14,311
16	$ 55,308	$ (16,172)	$ (13,827)	$ (8,162)	$ 17,147		$ 17,147	$ 14,624
17	$ 56,138	$ (16,253)	$ (14,035)	$ (8,162)	$ 17,689		$ 17,689	$ 14,936
18	$ 56,980	$ (16,334)	$ (14,245)	$ (8,162)	$ 18,239		$ 18,239	$ 15,248
19	$ 57,835	$ (16,416)	$ (14,459)	$ (8,162)	$ 18,798		$ 18,798	$ 15,560
20	$ 58,702	$ (16,498)	$ (14,676)	$ (8,162)	$ 19,367		$ 19,367	$ 15,872
21	$ 59,583	$ (16,580)	$ (14,896)	$ (8,162)	$ 19,945		$ 19,945	$ 16,184
22	$ 60,477	$ (16,663)	$ (15,119)	$ (8,162)	$ 20,532		$ 20,532	$ 16,496
23	$ 61,384	$ (16,746)	$ (15,346)	$ (8,162)	$ 21,129		$ 21,129	$ 16,807
24	$ 62,305	$ (16,830)	$ (15,576)	$ (8,162)	$ 21,736		$ 21,736	$ 17,119
25	$ 63,239	$ (16,914)	$ (15,810)	$ (8,162)	$ 22,353		$ 22,353	$ 17,430
							25-year Net Present Value	**$ 230,361**

Note: All values are in real dollars.

Option 1 - Cordwood Boiler System using 50% scraps
25-year Cash Flow Analysis w/ 25% Grant

Input Variables	Value	Units
Project Costs Financed	$174,819	$
Grant Amount	$43,705	$
Project Costs Financed	$131,114	$
Annual Propane Usage	29,492	gal
Average Propane Price	$1.50	$/gal
Cordwood and Scrap Usage	199	tons/yr
Year 1 Cordwood and Scrap Price (blended)	$76	$/ton
Annual Propane Usage w/ Wood System	7,373	gal
Fossil Fuel Escalation Rate (apr)	1.5%	Percent
Wood Fuel Escalation Rate (apr)	0.5%	Percent
Real Discount Rate (apr)	1.0%	Percent
Inflation Rate (apr)	2.7%	Percent
Added Annual O&M Costs for Biomass Plant	$8,162	$/year
Thermal Production Incentive	$7,481	$/year

Year	Total Fossil Fuel Cost, Current System	Wood Fuel Cost	Fossil Fuel Cost w/ Wood System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (131,114)	$ (131,114)
1	$ 44,239	$ (15,006)	$ (11,060)	$ (8,162)	$ 10,011	$ 7,481	$ 17,492	$ 17,318
2	$ 44,902	$ (15,081)	$ (11,226)	$ (8,162)	$ 10,433	$ 7,284	$ 17,718	$ 17,368
3	$ 45,576	$ (15,157)	$ (11,394)	$ (8,162)	$ 10,863	$ 7,093	$ 17,956	$ 17,428
4	$ 46,259	$ (15,232)	$ (11,565)	$ (8,162)	$ 11,300	$ 6,906	$ 18,206	$ 17,496
5	$ 46,953	$ (15,308)	$ (11,738)	$ (8,162)	$ 11,744	$ 6,725	$ 18,469	$ 17,573
6	$ 47,658	$ (15,385)	$ (11,914)	$ (8,162)	$ 12,196	$ 6,548	$ 18,744	$ 17,658
7	$ 48,372	$ (15,462)	$ (12,093)	$ (8,162)	$ 12,655	$ 6,376	$ 19,031	$ 17,751
8	$ 49,098	$ (15,539)	$ (12,274)	$ (8,162)	$ 13,122	$ 6,208	$ 19,330	$ 17,851
9	$ 49,834	$ (15,617)	$ (12,459)	$ (8,162)	$ 13,597	$ 6,045	$ 19,642	$ 17,959
10	$ 50,582	$ (15,695)	$ (12,645)	$ (8,162)	$ 14,079	$ 5,886	$ 19,965	$ 18,074
11	$ 51,341	$ (15,774)	$ (12,835)	$ (8,162)	$ 14,570		$ 14,570	$ 13,059
12	$ 52,111	$ (15,852)	$ (13,028)	$ (8,162)	$ 15,069		$ 15,069	$ 13,373
13	$ 52,892	$ (15,932)	$ (13,223)	$ (8,162)	$ 15,576		$ 15,576	$ 13,686
14	$ 53,686	$ (16,011)	$ (13,421)	$ (8,162)	$ 16,091		$ 16,091	$ 13,999
15	$ 54,491	$ (16,091)	$ (13,623)	$ (8,162)	$ 16,615		$ 16,615	$ 14,311
16	$ 55,308	$ (16,172)	$ (13,827)	$ (8,162)	$ 17,147		$ 17,147	$ 14,624
17	$ 56,138	$ (16,253)	$ (14,035)	$ (8,162)	$ 17,689		$ 17,689	$ 14,936
18	$ 56,980	$ (16,334)	$ (14,245)	$ (8,162)	$ 18,239		$ 18,239	$ 15,248
19	$ 57,835	$ (16,416)	$ (14,459)	$ (8,162)	$ 18,798		$ 18,798	$ 15,560
20	$ 58,702	$ (16,498)	$ (14,676)	$ (8,162)	$ 19,367		$ 19,367	$ 15,872
21	$ 59,583	$ (16,580)	$ (14,896)	$ (8,162)	$ 19,945		$ 19,945	$ 16,184
22	$ 60,477	$ (16,663)	$ (15,119)	$ (8,162)	$ 20,532		$ 20,532	$ 16,496
23	$ 61,384	$ (16,746)	$ (15,346)	$ (8,162)	$ 21,129		$ 21,129	$ 16,807
24	$ 62,305	$ (16,830)	$ (15,576)	$ (8,162)	$ 21,736		$ 21,736	$ 17,119
25	$ 63,239	$ (16,914)	$ (15,810)	$ (8,162)	$ 22,353		$ 22,353	$ 17,430
						25-year Net Present Value		**$ 274,065**

Note: All values are in real dollars.

Option 1 - Cordwood Boiler System using 50% scraps
Fuel Cost Sensitivity Analysis

Table Shows Sensitivity of Annual Operating Savings to Changes in Fossil Fuel and Wood Fuel Prices*

Fossil Fuel Price, $/gal

Blended Price of Cordwood - $/ton	$1.00	$1.25	$1.50	$1.75	$2.00	$2.50	$3.00
$45	$5,020	$10,550	$16,080	$21,610	$27,140	$38,199	$49,259
$50	$4,027	$9,557	$15,087	$20,617	$26,147	$37,206	$48,266
$55	$3,035	$8,564	$14,094	$19,624	$25,154	$36,213	$47,273
$60	$2,042	$7,571	$13,101	$18,631	$24,161	$35,220	$46,280
$65	$1,049	$6,578	$12,108	$17,638	$23,168	$34,227	$45,287
$70	$56	$5,585	$11,115	$16,645	$22,175	$33,235	$44,294
$76	($1,049)	$4,481	$10,011	$15,541	$21,070	$32,130	$43,190
$80	($1,930)	$3,599	$9,129	$14,659	$20,189	$31,249	$42,308
$85	($2,923)	$2,606	$8,136	$13,666	$19,196	$30,256	$41,315
$90	($3,916)	$1,614	$7,143	$12,673	$18,203	$29,263	$40,322
$95	($4,909)	$621	$6,150	$11,680	$17,210	$28,270	$39,329
$100	($5,902)	($372)	$5,157	$10,687	$16,217	$27,277	$38,336
$105	($6,895)	($1,365)	$4,164	$9,694	$15,224	$26,284	$37,343
$110	($7,888)	($2,358)	$3,171	$8,701	$14,231	$25,291	$36,350

**Notes: All other costs fixed. Excludes financing costs. Excludes thermal production incentive.*

Option 2 - Pellet Boiler System
25-year Cash Flow Analysis

Paws and Claws Rescue and Resort
Hackensack, MN

Input Variables	Value	Units
Project Costs Financed	$201,341	$
Grant Amount	$0	$
Project Costs Financed	$201,341	$
Annual Propane Usage	29,492	gal
Average Propane Price	$1.50	$/gal
Pellet Usage	166	tons/yr
Year 1 Pellet Price	$200	$/ton
Annual Propane Usage w/ Wood System	1,475	gal
Fossil Fuel Escalation Rate (apr)	1.5%	Percent
Wood Fuel Escalation Rate (apr)	0.5%	Percent
Real Discount Rate (apr)	1.0%	Percent
Inflation Rate (apr)	2.7%	Percent
Added Annual O&M Costs for Biomass Plant	$1,286	$/year
Thermal Production Incentive	$9,476	$/year

Year	Total Fossil Fuel Cost, Current System	Wood Fuel Cost	Fossil Fuel Cost w/ Wood System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (201,341)	$ (201,341)
1	$ 44,239	$ (33,157)	$ (2,212)	$ (1,286)	$ 7,584	$ 9,476	$ 17,059	$ 16,890
2	$ 44,902	$ (33,323)	$ (2,245)	$ (1,286)	$ 8,048	$ 9,227	$ 17,275	$ 16,934
3	$ 45,576	$ (33,489)	$ (2,279)	$ (1,286)	$ 8,521	$ 8,984	$ 17,505	$ 16,991
4	$ 46,259	$ (33,657)	$ (2,313)	$ (1,286)	$ 9,003	$ 8,748	$ 17,751	$ 17,059
5	$ 46,953	$ (33,825)	$ (2,348)	$ (1,286)	$ 9,494	$ 8,518	$ 18,012	$ 17,138
6	$ 47,658	$ (33,994)	$ (2,383)	$ (1,286)	$ 9,994	$ 8,294	$ 18,288	$ 17,228
7	$ 48,372	$ (34,164)	$ (2,419)	$ (1,286)	$ 10,503	$ 8,076	$ 18,579	$ 17,329
8	$ 49,098	$ (34,335)	$ (2,455)	$ (1,286)	$ 11,022	$ 7,864	$ 18,886	$ 17,440
9	$ 49,834	$ (34,507)	$ (2,492)	$ (1,286)	$ 11,550	$ 7,657	$ 19,207	$ 17,561
10	$ 50,582	$ (34,679)	$ (2,529)	$ (1,286)	$ 12,088	$ 7,456	$ 19,543	$ 17,692
11	$ 51,341	$ (34,853)	$ (2,567)	$ (1,286)	$ 12,635		$ 12,635	$ 11,325
12	$ 52,111	$ (35,027)	$ (2,606)	$ (1,286)	$ 13,192		$ 13,192	$ 11,707
13	$ 52,892	$ (35,202)	$ (2,645)	$ (1,286)	$ 13,760		$ 13,760	$ 12,090
14	$ 53,686	$ (35,378)	$ (2,684)	$ (1,286)	$ 14,337		$ 14,337	$ 12,473
15	$ 54,491	$ (35,555)	$ (2,725)	$ (1,286)	$ 14,926		$ 14,926	$ 12,856
16	$ 55,308	$ (35,733)	$ (2,765)	$ (1,286)	$ 15,524		$ 15,524	$ 13,239
17	$ 56,138	$ (35,911)	$ (2,807)	$ (1,286)	$ 16,134		$ 16,134	$ 13,623
18	$ 56,980	$ (36,091)	$ (2,849)	$ (1,286)	$ 16,754		$ 16,754	$ 14,007
19	$ 57,835	$ (36,271)	$ (2,892)	$ (1,286)	$ 17,386		$ 17,386	$ 14,391
20	$ 58,702	$ (36,453)	$ (2,935)	$ (1,286)	$ 18,028		$ 18,028	$ 14,775
21	$ 59,583	$ (36,635)	$ (2,979)	$ (1,286)	$ 18,683		$ 18,683	$ 15,160
22	$ 60,477	$ (36,818)	$ (3,024)	$ (1,286)	$ 19,349		$ 19,349	$ 15,545
23	$ 61,384	$ (37,002)	$ (3,069)	$ (1,286)	$ 20,026		$ 20,026	$ 15,930
24	$ 62,305	$ (37,187)	$ (3,115)	$ (1,286)	$ 20,716		$ 20,716	$ 16,315
25	$ 63,239	$ (37,373)	$ (3,162)	$ (1,286)	$ 21,418		$ 21,418	$ 16,701
							25-year Net Present Value	**$ 181,060**

Note: All values are in real dollars.

Option 2 - Pellet Boiler System
25-year Cash Flow Analysis w/ 25% Grant

Input Variables	Value	Units
Project Costs Financed	$201,341	$
Grant Amount	$50,335	$
Project Costs Financed	$151,006	$
Annual Propane Usage	29,492	gal
Average Propane Price	$1.50	$/gal
Pellet Usage	166	tons/yr
Year 1 Pellet Price	$200	$/ton
Annual Propane Usage w/ Wood System	1,475	gal
Fossil Fuel Escalation Rate (apr)	1.5%	Percent
Wood Fuel Escalation Rate (apr)	0.5%	Percent
Real Discount Rate (apr)	1.0%	Percent
Inflation Rate (apr)	2.7%	Percent
Added Annual O&M Costs for Biomass Plant	$1,286	$/year
Thermal Production Incentive	$9,476	$/year

Year	Total Fossil Fuel Cost, Current System	Wood Fuel Cost	Fossil Fuel Cost w/ Wood System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (151,006)	$ (151,006)
1	$ 44,239	$ (33,157)	$ (2,212)	$ (1,286)	$ 7,584	$ 9,476	$ 17,059	$ 16,890
2	$ 44,902	$ (33,323)	$ (2,245)	$ (1,286)	$ 8,048	$ 9,227	$ 17,275	$ 16,934
3	$ 45,576	$ (33,489)	$ (2,279)	$ (1,286)	$ 8,521	$ 8,984	$ 17,505	$ 16,991
4	$ 46,259	$ (33,657)	$ (2,313)	$ (1,286)	$ 9,003	$ 8,748	$ 17,751	$ 17,059
5	$ 46,953	$ (33,825)	$ (2,348)	$ (1,286)	$ 9,494	$ 8,518	$ 18,012	$ 17,138
6	$ 47,658	$ (33,994)	$ (2,383)	$ (1,286)	$ 9,994	$ 8,294	$ 18,288	$ 17,228
7	$ 48,372	$ (34,164)	$ (2,419)	$ (1,286)	$ 10,503	$ 8,076	$ 18,579	$ 17,329
8	$ 49,098	$ (34,335)	$ (2,455)	$ (1,286)	$ 11,022	$ 7,864	$ 18,886	$ 17,440
9	$ 49,834	$ (34,507)	$ (2,492)	$ (1,286)	$ 11,550	$ 7,657	$ 19,207	$ 17,561
10	$ 50,582	$ (34,679)	$ (2,529)	$ (1,286)	$ 12,088	$ 7,456	$ 19,543	$ 17,692
11	$ 51,341	$ (34,853)	$ (2,567)	$ (1,286)	$ 12,635		$ 12,635	$ 11,325
12	$ 52,111	$ (35,027)	$ (2,606)	$ (1,286)	$ 13,192		$ 13,192	$ 11,707
13	$ 52,892	$ (35,202)	$ (2,645)	$ (1,286)	$ 13,760		$ 13,760	$ 12,090
14	$ 53,686	$ (35,378)	$ (2,684)	$ (1,286)	$ 14,337		$ 14,337	$ 12,473
15	$ 54,491	$ (35,555)	$ (2,725)	$ (1,286)	$ 14,926		$ 14,926	$ 12,856
16	$ 55,308	$ (35,733)	$ (2,765)	$ (1,286)	$ 15,524		$ 15,524	$ 13,239
17	$ 56,138	$ (35,911)	$ (2,807)	$ (1,286)	$ 16,134		$ 16,134	$ 13,623
18	$ 56,980	$ (36,091)	$ (2,849)	$ (1,286)	$ 16,754		$ 16,754	$ 14,007
19	$ 57,835	$ (36,271)	$ (2,892)	$ (1,286)	$ 17,386		$ 17,386	$ 14,391
20	$ 58,702	$ (36,453)	$ (2,935)	$ (1,286)	$ 18,028		$ 18,028	$ 14,775
21	$ 59,583	$ (36,635)	$ (2,979)	$ (1,286)	$ 18,683		$ 18,683	$ 15,160
22	$ 60,477	$ (36,818)	$ (3,024)	$ (1,286)	$ 19,349		$ 19,349	$ 15,545
23	$ 61,384	$ (37,002)	$ (3,069)	$ (1,286)	$ 20,026		$ 20,026	$ 15,930
24	$ 62,305	$ (37,187)	$ (3,115)	$ (1,286)	$ 20,716		$ 20,716	$ 16,315
25	$ 63,239	$ (37,373)	$ (3,162)	$ (1,286)	$ 21,418		$ 21,418	$ 16,701
							25-year Net Present Value	**$ 231,395**

Note: All values are in real dollars.

Option 2 - Pellet Boiler System
Fuel Cost Sensitivity Analysis

Table Shows Sensitivity of Annual Operating Savings to Changes in Fossil Fuel and Wood Fuel Prices*

Fossil Fuel Price, $/gal

Price of Pellets - $/ton	$1.00	$1.25	$1.50	$1.75	$2.00	$2.50	$3.00
$185	($3,939)	$3,066	$10,070	$17,075	$24,079	$38,088	$52,097
$190	($4,767)	$2,237	$9,241	$16,246	$23,250	$37,259	$51,268
$195	($5,596)	$1,408	$8,413	$15,417	$22,421	$36,430	$50,439
$200	($6,425)	$579	$7,584	$14,588	$21,592	$35,601	$49,610
$205	($7,254)	($250)	$6,755	$13,759	$20,764	$34,772	$48,781
$210	($8,083)	($1,079)	$5,926	$12,930	$19,935	$33,943	$47,952
$213	($8,581)	($1,576)	$5,428	$12,433	$19,437	$33,446	$47,455
$215	($8,912)	($1,908)	$5,097	$12,101	$19,106	$33,115	$47,123
$220	($9,741)	($2,737)	$4,268	$11,272	$18,277	$32,286	$46,295
$225	($10,570)	($3,565)	$3,439	$10,443	$17,448	$31,457	$45,466
$230	($11,399)	($4,394)	$2,610	$9,614	$16,619	$30,628	$44,637
$235	($12,228)	($5,223)	$1,781	$8,786	$15,790	$29,799	$43,808
$240	($13,057)	($6,052)	$952	$7,957	$14,961	$28,970	$42,979
$245	($13,886)	($6,881)	$123	$7,128	$14,132	$28,141	$42,150

**Notes: All other costs fixed. Excludes financing costs. Excludes thermal production incentive.*

Option 3 - Dry Wood Chip Boiler System
25-year Cash Flow Analysis

Input Variables	Value	Units
Project Costs Financed	$302,268	$
Grant Amount	$0	$
Project Costs Financed	$302,268	$
Annual Propane Usage	29,492	gal
Average Propane Price	$1.50	$/gal
Wood Chip Usage	178	tons/yr
Year 1 Wood Chip Price	$50	$/ton
Annual Propane Usage w/ Wood System	2,949	gal
Fossil Fuel Escalation Rate (apr)	1.5%	Percent
Wood Fuel Escalation Rate (apr)	0.5%	Percent
Real Discount Rate (apr)	1.0%	Percent
Inflation Rate (apr)	2.7%	Percent
Added Annual O&M Costs for Biomass Plant	$2,193	$/year
Thermal Production Incentive	$8,977	$/year

Year	Total Fossil Fuel Cost, Current System	Wood Fuel Cost	Fossil Fuel Cost w/ Wood System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (302,268)	$ (302,268)
1	$ 44,239	$ (8,920)	$ (4,424)	$ (2,193)	$ 28,701	$ 8,977	$ 37,678	$ 37,305
2	$ 44,902	$ (8,965)	$ (4,490)	$ (2,193)	$ 29,254	$ 8,741	$ 37,995	$ 37,246
3	$ 45,576	$ (9,010)	$ (4,558)	$ (2,193)	$ 29,815	$ 8,511	$ 38,326	$ 37,199
4	$ 46,259	$ (9,055)	$ (4,626)	$ (2,193)	$ 30,385	$ 8,287	$ 38,673	$ 37,164
5	$ 46,953	$ (9,100)	$ (4,695)	$ (2,193)	$ 30,965	$ 8,070	$ 39,034	$ 37,140
6	$ 47,658	$ (9,146)	$ (4,766)	$ (2,193)	$ 31,553	$ 7,857	$ 39,410	$ 37,126
7	$ 48,372	$ (9,191)	$ (4,837)	$ (2,193)	$ 32,151	$ 7,651	$ 39,801	$ 37,123
8	$ 49,098	$ (9,237)	$ (4,910)	$ (2,193)	$ 32,758	$ 7,450	$ 40,207	$ 37,131
9	$ 49,834	$ (9,284)	$ (4,983)	$ (2,193)	$ 33,374	$ 7,254	$ 40,628	$ 37,148
10	$ 50,582	$ (9,330)	$ (5,058)	$ (2,193)	$ 34,001	$ 7,063	$ 41,064	$ 37,174
11	$ 51,341	$ (9,377)	$ (5,134)	$ (2,193)	$ 34,637		$ 34,637	$ 31,046
12	$ 52,111	$ (9,424)	$ (5,211)	$ (2,193)	$ 35,283		$ 35,283	$ 31,312
13	$ 52,892	$ (9,471)	$ (5,289)	$ (2,193)	$ 35,939		$ 35,939	$ 31,579
14	$ 53,686	$ (9,518)	$ (5,369)	$ (2,193)	$ 36,606		$ 36,606	$ 31,846
15	$ 54,491	$ (9,566)	$ (5,449)	$ (2,193)	$ 37,283		$ 37,283	$ 32,114
16	$ 55,308	$ (9,613)	$ (5,531)	$ (2,193)	$ 37,971		$ 37,971	$ 32,383
17	$ 56,138	$ (9,661)	$ (5,614)	$ (2,193)	$ 38,670		$ 38,670	$ 32,652
18	$ 56,980	$ (9,710)	$ (5,698)	$ (2,193)	$ 39,379		$ 39,379	$ 32,922
19	$ 57,835	$ (9,758)	$ (5,783)	$ (2,193)	$ 40,100		$ 40,100	$ 33,192
20	$ 58,702	$ (9,807)	$ (5,870)	$ (2,193)	$ 40,832		$ 40,832	$ 33,464
21	$ 59,583	$ (9,856)	$ (5,958)	$ (2,193)	$ 41,575		$ 41,575	$ 33,736
22	$ 60,477	$ (9,905)	$ (6,048)	$ (2,193)	$ 42,330		$ 42,330	$ 34,008
23	$ 61,384	$ (9,955)	$ (6,138)	$ (2,193)	$ 43,097		$ 43,097	$ 34,281
24	$ 62,305	$ (10,005)	$ (6,230)	$ (2,193)	$ 43,876		$ 43,876	$ 34,555
25	$ 63,239	$ (10,055)	$ (6,324)	$ (2,193)	$ 44,667		$ 44,667	$ 34,830
							25-year Net Present Value	**$ 563,408**

Note: All values are in real dollars.

Option 3 - Dry Wood Chip Boiler System
25-year Cash Flow Analysis w/ 25% Grant

Input Variables	Value	Units
Project Costs Financed	$302,268	$
Grant Amount	$75,567	$
Project Costs Financed	$226,701	$
Annual Propane Usage	29,492	gal
Average Propane Price	$1.50	$/gal
Wood Chip Usage	178	tons/yr
Year 1 Wood Chip Price	$50	$/ton
Annual Propane Usage w/ Wood System	2,949	gal
Fossil Fuel Escalation Rate (apr)	1.5%	Percent
Wood Fuel Escalation Rate (apr)	0.5%	Percent
Real Discount Rate (apr)	1.0%	Percent
Inflation Rate (apr)	2.7%	Percent
Added Annual O&M Costs for Biomass Plant	$2,193	$/year
Thermal Production Incentive	$8,977	$/year

Year	Total Fossil Fuel Cost, Current System	Wood Fuel Cost	Fossil Fuel Cost w/ Wood System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (226,701)	$ (226,701)
1	$ 44,239	$ (8,920)	$ (4,424)	$ (2,193)	$ 28,701	$ 8,977	$ 37,678	$ 37,305
2	$ 44,902	$ (8,965)	$ (4,490)	$ (2,193)	$ 29,254	$ 8,741	$ 37,995	$ 37,246
3	$ 45,576	$ (9,010)	$ (4,558)	$ (2,193)	$ 29,815	$ 8,511	$ 38,326	$ 37,199
4	$ 46,259	$ (9,055)	$ (4,626)	$ (2,193)	$ 30,385	$ 8,287	$ 38,673	$ 37,164
5	$ 46,953	$ (9,100)	$ (4,695)	$ (2,193)	$ 30,965	$ 8,070	$ 39,034	$ 37,140
6	$ 47,658	$ (9,146)	$ (4,766)	$ (2,193)	$ 31,553	$ 7,857	$ 39,410	$ 37,126
7	$ 48,372	$ (9,191)	$ (4,837)	$ (2,193)	$ 32,151	$ 7,651	$ 39,801	$ 37,123
8	$ 49,098	$ (9,237)	$ (4,910)	$ (2,193)	$ 32,758	$ 7,450	$ 40,207	$ 37,131
9	$ 49,834	$ (9,284)	$ (4,983)	$ (2,193)	$ 33,374	$ 7,254	$ 40,628	$ 37,148
10	$ 50,582	$ (9,330)	$ (5,058)	$ (2,193)	$ 34,001	$ 7,063	$ 41,064	$ 37,174
11	$ 51,341	$ (9,377)	$ (5,134)	$ (2,193)	$ 34,637		$ 34,637	$ 31,046
12	$ 52,111	$ (9,424)	$ (5,211)	$ (2,193)	$ 35,283		$ 35,283	$ 31,312
13	$ 52,892	$ (9,471)	$ (5,289)	$ (2,193)	$ 35,939		$ 35,939	$ 31,579
14	$ 53,686	$ (9,518)	$ (5,369)	$ (2,193)	$ 36,606		$ 36,606	$ 31,846
15	$ 54,491	$ (9,566)	$ (5,449)	$ (2,193)	$ 37,283		$ 37,283	$ 32,114
16	$ 55,308	$ (9,613)	$ (5,531)	$ (2,193)	$ 37,971		$ 37,971	$ 32,383
17	$ 56,138	$ (9,661)	$ (5,614)	$ (2,193)	$ 38,670		$ 38,670	$ 32,652
18	$ 56,980	$ (9,710)	$ (5,698)	$ (2,193)	$ 39,379		$ 39,379	$ 32,922
19	$ 57,835	$ (9,758)	$ (5,783)	$ (2,193)	$ 40,100		$ 40,100	$ 33,192
20	$ 58,702	$ (9,807)	$ (5,870)	$ (2,193)	$ 40,832		$ 40,832	$ 33,464
21	$ 59,583	$ (9,856)	$ (5,958)	$ (2,193)	$ 41,575		$ 41,575	$ 33,736
22	$ 60,477	$ (9,905)	$ (6,048)	$ (2,193)	$ 42,330		$ 42,330	$ 34,008
23	$ 61,384	$ (9,955)	$ (6,138)	$ (2,193)	$ 43,097		$ 43,097	$ 34,281
24	$ 62,305	$ (10,005)	$ (6,230)	$ (2,193)	$ 43,876		$ 43,876	$ 34,555
25	$ 63,239	$ (10,055)	$ (6,324)	$ (2,193)	$ 44,667		$ 44,667	$ 34,830
						25-year Net Present Value		**$ 638,975**

Note: All values are in real dollars.

Option 3 - Dry Wood Chip Boiler System
Fuel Cost Sensitivity Analysis

Table Shows Sensitivity of Annual Operating Savings to Changes in Fossil Fuel and Wood Fuel Prices*

Price of Dry Wood Chips - $/ton	Fossil Fuel Price, $/gal: $1.00	$1.25	$1.50	$1.75	$2.00	$2.50	$3.00
$0	$24,350	$30,986	$37,622	$44,257	$50,893	$64,165	$77,436
$10	$22,566	$29,202	$35,838	$42,473	$49,109	$62,381	$75,652
$20	$20,782	$27,418	$34,053	$40,689	$47,325	$60,597	$73,868
$30	$18,998	$25,634	$32,269	$38,905	$45,541	$58,812	$72,084
$40	$17,214	$23,849	$30,485	$37,121	$43,757	$57,028	$70,300
$50	$15,430	$22,065	$28,701	$35,337	$41,973	$55,244	$68,516
$58	$14,002	$20,638	$27,274	$33,910	$40,545	$53,817	$67,089
$60	$13,645	$20,281	$26,917	$33,553	$40,189	$53,460	$66,732
$70	$11,861	$18,497	$25,133	$31,769	$38,405	$51,676	$64,948
$80	$10,077	$16,713	$23,349	$29,985	$36,620	$49,892	$63,164
$90	$8,293	$14,929	$21,565	$28,201	$34,836	$48,108	$61,379
$100	$6,509	$13,145	$19,781	$26,416	$33,052	$46,324	$59,595
$110	$4,725	$11,361	$17,997	$24,632	$31,268	$44,540	$57,811
$120	$2,941	$9,577	$16,213	$22,848	$29,484	$42,756	$56,027

**Notes: All other costs fixed. Excludes financing costs. Excludes thermal production incentive.*

Appendix D –
UMN Extension By-Products Program Brochure

Why Recycle?

- Provide a beneficial use for products that were previously discarded in landfills
- Reduce landfill costs to government and industry and improve environmental quality by removing large volumes of by-products from concentrated landfill disposal
- Improve farm profitability by reducing fertilizer and lime costs
- Contribute to environmental quality and soil conservation by improving the economics of perennial forage crops as an alternative to row crops on more sensitive sites

Before any by-products are delivered to a field, the following requirements must be met:

1. Farmer must sign and follow Best Management Practices (BMP's)
2. Develop a farm plan, which includes crop rotation
3. Mapping and soil sampling of fields
4. Lease agreement signed if field is rented
5. Notification to township officers prior to hauling to site

If interested in receiving any of these by-products, contact the University of Minnesota Extension Service: Carlton County, P.O. Box 307, Carlton, MN (218) 384-3511 or 1-800-862-3760, ext. 223.

University of Minnesota
Extension
SERVICE

Carlton County

By-products Program

By-products Program

Wood Ash
Bio-Solids
Lime

By-product Program Resources

Troy Salzer
Extension Educator, Agriculture

Dr. Carl Rosen
Soil Scientist – Fertility

Dr. Tom Halbach
Water quality & Waste Mgmt

Russ Mathison
Forage Specialist

Bob Olen
Extension Educator, Horticulture

Dr. George Rehm
U of M Soil Scientist

Paul Peterson
Forage Specialist

MPCA
University Testing Labs
Forestry Specialists
Animal Science Specialists
University Dept on GIS/ Global Positioning

Wood Ash

Recycling wood ash saves valuable landfill space and provides farmers with an excellent liming source, as well as many of the nutrients needed to increase soil fertility. Wood ash increases soil pH and adds elements to the soil, which includes potassium, phosphorus, boron, and sulfur. Wood ash is delivered at no cost, but the farmer is responsible for spreading and incorporation.

There are eight local companies supplying wood ash. Listed below are the companies and the approximate amount of wood ash delivered annually.

	Tons	Acres
Minnesota Power	10,000	800
Georgia-Pacific, Duluth	400	50
Ainsworth, Bemidji	10,400	1,340
Trus Joist	1,300	220
Jardon Home Brands	125	15
Sappi Cloquet LLC	20,000	2,800
Potlatch, Bemidji	400	40
DNR Fisheries	30	10
TOTALS	42,280	5,285

Bio-Solids

Bio-solids are rich in organic matter and will provide nitrogen, along with small amounts of phosphorus, potassium, and lime. Additional commercial fertilizer may be needed to meet soil test recommendations. Each site for bio-solids must be approved by the Minnesota Pollution Control Agency.

However, not all fields qualify for bio-solids application due to soil pH, water table level, or slope. Records are kept to ensure that Best Management Practices are followed. Crops that would respond to the nitrogen in bio-solids are corn, grasses, legumes, and small grains.

Bio-solids are provided by the Western Lake Superior Sanitary District in Duluth, and are hauled, spread, and incorporated at no charge to the farmer.

Lime

We currently have three sources for by-product ag lime. The largest source is from Sappi Fine Paper of North America who delivers and spreads their lime at no cost to the farmers. This lime is made available as they produce it. The product is only produced during scheduled and unscheduled maintenance of the reclaiming kiln. The Effective Neutralizing Power (ENP) of this lime is 1300.

Cutler-Magner in Superior, WI has been the first source of by-product ag lime. The ENP of this lime is 1840. Loads are delivered with a semi-end dump with loads averaging 23 tons per load. The lime is free and the price farmers pay is based on distance from the plant.

Another source of by-product lime in Northeast Minnesota is from Specialty Minerals, Inc. in Cloquet. The ENP of this lime is 1600. This lime is a wet product that's good for certain applications. The lime and trucking are free to the farmer.

Benefits to participating in the By-products Program:

- Proven track record with over a decade of beneficial reuse of by-products
- University research used for application recommendations
- Education programs and field days for both industries and producers to share current research data and cropping improvement technologies
- Unbiased 3rd party involvement
- Provide educational programming to local decision makers/residents describing the research on the re-use benefits of these products.
- Assisting producers in developing environmentally sound crop management systems including the use of industrial by-products as soil amendments.
- Develop packets for individual fields including information about land ownership, soil types, soil analysis, and determine application rates based on crop type and soil analysis.
- Develop, research and secure funding for new potential uses for by-products.