Minnesota Department of Natural Resources

MNDNR

St. Louis County Meadowlands Garage

Biomass Energy System

Preliminary Feasibility Report

FINAL
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1.0 EXECUTIVE SUMMARY

The St. Louis County highway department operates a maintenance shop and truck garage in Meadowlands, MN. This garage is heated by propane and uses an average of 11,391 gallons of propane per year costing an average of approximately $16,972 per year for the past 5 years. A wood heating system utilizing pellets, cordwood, or potentially dry chips 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. Due to the variations in the potential fuels available in various locations, there are differing systems for each fuel type. Wood pellets and cordwood are the fuel types evaluated for this facility. Dry wood chips are a potential fuel which is not commercially available at this time, but could be in the future. Options evaluated in this report would require an estimated annual use of up to 64 tons of wood pellets, or 46-50 cords (74-80 tons) of cordwood. A wood chip option is not evaluated in detail, but if dry chips were available, 93 tons per year would be required. 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
Cordwood[1], cord	$220	22.0	65%	14.3	$15.38
Cordwood (self-sourced), cord	$150	22.0	65%	14.3	$10.49
Wood Pellet[2], ton	$194	16.4	80%	13.1	$14.79
Dry Wood Chip[3], ton	$80	12.0	75%	9.0	$8.89
Green Wood Chip[4], ton	$35	10.0	70%	7.0	$5.00
Propane, gal (5-yr avg)	$1.49	0.091	85%	0.078	$19.19

Note 1: Cost is for hardwood. $220 per cord equals $138 per ton assuming that wood has been seasoned to 20% moisture content wet basis.
Note 2: Wood pellets are 6-8% moisture content wet basis.
Note 3: Dry wood chips (25-30% moisture content wet basis) are not commercially available in Meadowlands. Cost for dry wood chips is estimated by WES as a fair market price.
Note 4: Green wood chips are not appropriate for this facility due to the relatively small size of the facility.
Note 5: Table 5 contains the assumptions used to develop the above values.

Three biomass boiler options are evaluated for this facility.

Option 1 – Indoor Cordwood Boiler System: Two indoor cordwood hot water boilers, each rated 170,000 Btu/hr (340,000 Btu/hr total), would be installed in a new boiler room located at the southeast corner of the building adjacent to the existing mechanical room. These boilers would offset approximately 75% of the facility's annual propane usage. A 1,000 gallon thermal storage tank(s) would be installed with the boilers. The cordwood boilers would tie into the facility's heating system in the existing mechanical room. A new zone of hydronic unit heaters would be plumbed in the garage area, to offset the use of propane by the overhead radiant system.

Option 2 – Outdoor Cordwood Boiler System: Two outdoor cordwood hot water boilers, each rated 170,000 Btu/hr (340,000 Btu/hr total), would be installed adjacent to the southeast corner of the building near the existing mechanical room. These boilers would offset approximately 75% of the facility's annual propane usage. A 1,000 gallon thermal storage tank(s) would be installed inside the building. The cordwood boilers would tie into the facility's heating system in the existing mechanical room. A new zone of hydronic unit heaters would be plumbed in the garage area, to offset the use of propane by the overhead radiant system.

Option 3 – Wood Pellet Boiler System: Two wood pellet hot water boilers, each rated 191,000 Btu/hr (382,000 Btu/hr total), would be installed in a new boiler room located at the southeast corner of the building adjacent to the existing mechanical room. These boilers would offset approximately 95% of the facility's annual propane usage. A 120 gallon thermal storage tank would be installed with the boilers. The pellet boilers would tie into the facility's heating system in the existing mechanical room. A new zone of hydronic unit heaters would be plumbed in the garage area, to offset the use of propane by the overhead radiant system.

Estimated capital costs for each option, including construction and installation, are listed in Table ES2.

Table ES2 – Capital Cost Estimate Summary

Option	Estimated Capital Cost
1 - Indoor Cordwood	$138,250
2 - Outdoor Cordwood	$95,500
3 - Pellet	$171,463

A proposed system fuel use profile is provided in Table ES3 showing the estimated annual fuel use compared to the existing propane system.

Table ES3 – Proposed System Fuel Use Profile

Option	Current Annual Fuel Use	Annual Fuel Use with Proposed Biomass System			
	Propane (gal)	Biomass Demand Coverage	Estimated Biomass Use (tons)[1]		Estimated Propane Use with Biomass System (gal)
			Oct-Mar	Apr-Sep	
1 - Indoor Cordwood	11,391	75%	65	9	2,848
2 - Outdoor Cordwood	11,391	75%	71	10	2,848
3 - Pellet	11,391	95%	56	8	570

Note 1: Fuel use in this table is in tons. Option 1 would require 46 cords, while Option 2 would require 50 cords.

Note 2: Table 5 contains the assumptions used to develop the above values.

Table ES4 provides a comparison of fuel costs and operating costs for the options.

Table ES4 – Fuel and Operating Cost Comparison

Option	Current Annual Fuel Use	Estimated Annual Costs with Proposed Biomass System			Estimated First Year Operational Savings	Thermal Production Incentive	Estimated Net Cash Flow
	Propane Cost	Biomass Cost	Propane Cost	O&M Increase			
1 - Indoor Cordwood	$16,972	$10,204	$4,243	$5,480	($2,954)	$2,916	($38)
2 - Outdoor Cordwood	$16,972	$11,054	$4,243	$5,480	($3,804)	$2,916	($888)
3 - Pellet	$16,972	$12,422	$849	$1,616	$2,085	$3,693	$5,779

Note: Table 5 contains the assumptions used to develop the above values.

A summary of the estimated capital costs and payback is provided in Table ES5. 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 ES5 – Cost and Payback Analysis

Option	Estimated Capital Cost	Assumed Grant Funding	Financed Amount	Simple Payback Period[1] (years)	Net Present Value (25 years)
1 - Indoor Cordwood[2]	$138,250	$0	$138,250	-	($137,888)
2 - Outdoor Cordwood[2]	$95,500	$0	$95,500	-	($114,981)
3 - Pellet	$171,463	$0	$171,463	65	($42,019)
1 - Indoor Cordwood w/ grant[2]	$138,250	$34,563	$103,688	-	($103,325)
2 - Outdoor Cordwood w/ grant[2]	$95,500	$23,875	$71,625	-	($91,106)
3 - Pellet w/ grant	$171,463	$42,866	$128,597	44	$846

Note 1: Simple payback is calculated taking into account the assumption that thermal production incentive payments end after 10 years. The payback periods of all options exceed the estimated useful life of the equipment.
Note 2: The cordwood options are evaluated using a market rate of $220/cord. There may be opportunities for the County to obtain cordwood at a substantially lower cost. Appendix C shows a sensitivity analysis which provides annual overall savings at varying cordwood and propane prices.

A modern biomass boiler system would allow the Meadowlands Garage to reduce fossil fuel usage while utilizing a local and renewable source of energy. The options evaluated in this report would provide benefits to St. Louis County as summarized:

- Option 1 is an indoor boiler system capable of utilizing split cordwood. This project would provide a first year net operating loss of $38, and would have a capital cost of $138,250. This assumes a market rate for cordwood of $220/cord.
- Option 2 is an outdoor boiler system capable of utilizing split cordwood. This project would provide a first year net operating loss of $888, and would have a capital cost of $95,500. This assumes a market rate for cordwood of $220/cord.
- Option 3 is a boiler system capable of utilizing wood pellets. This project would provide a first year net operating savings of $5,779, and would have a capital cost of $171,463.

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. The cost of the purchased and delivered cordwood is a major driver of the economics for options 1 and 2. If St. Louis County has an internal lower cost source for cordwood, that would change economics for these options. On a delivered heat basis, wood pellets are cheaper than purchased cordwood, and require significantly less labor. As previously discussed, dry wood chips are a lower-cost fuel which is currently widely available in MN. Dry wood chips would be an ideal fuel for the Meadowlands Garage, based on expected market price, but only if there were one or more local, reliable suppliers of this fuel. If a dry wood chips supplier is identified in the region, WES strongly recommends investigating the feasibility of a dry chip boiler system. Wood pellet options can be designed to have the flexibility to use either pellets or screened, dry wood chips. The capital cost for a dry chip boiler system similar in scale to the options presented in this report is approximately $250,000.

Payments from the Minnesota Biomass Thermal Production Incentive are a major driver of savings. It is important to note that these payments only occur for 10 years following startup of the project. Without the incentive payments, the annual savings or loss in today's dollars becomes a loss of $2,954 for Option 1, a loss of $3,804 for Option 2, and a savings of $2,085 for Option 3.

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

- Net reduction of greenhouse gas emissions by 44 - 57 metric tonnes annually,
- Keeping ~$12,000/yr spent on energy within the region,
- Diversification of fuels used by the fleet of St. Louis County buildings,
- 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 St. Louis County be interested in pursuing a biomass option, WES recommends that county staff in both administration and operations visit 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 St. Louis County continues to pursue renewable biomass energy options, WES recommends that the next level of evaluation includes detailed consideration of the following items:

- Work with the MN SWET to identify alternative funding sources (low interest loans, grants, and incentives)
- Perform site investigations (utility, geotechnical) for the new boiler room and fuel storage building and further develop the biomass plant layout and capital cost based on investigation results.
- Explore lower cost options for cordwood fuel procurement, if this fuel is of interest to the facility managers.

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 MEADOWLANDS GARAGE OPPORTUNITY

The St. Louis County Meadowlands Garage is located in Meadowlands, MN and is used for storage and servicing of equipment and as a base for work crews. The building, shown in Figure 1, was built in 2009 and is heated by propane. Because of the abundance of wood resources in the area, St. Louis County is investigating whether it is feasible to install a wood energy system to supply heat. A wood heating system utilizing pellets, cordwood, or potentially dry chips has the potential to reduce fuel costs and greenhouse gas emissions for this facility, while utilizing a renewable, local fuel source.

Figure 1 – Meadowlands Garage

Note: Image source: Google Earth Pro. The taller part of the building, encompassing the front entrance and the first overhead door on the side, is the office and maintenance area. The four overhead doors towards the rear of the building are the garage area.

3.0 FACILITY OVERVIEW

WES personnel conducted a site visit on June 20, 2016 in order to evaluate the existing systems and become familiar with the physical plant layout. This facility consists of a maintenance shop, administrative offices, and a truck garage. The building is approximately 17,500 square feet and was constructed in 2009.

The heating in the maintenance shop and offices is done through an in-floor radiant system as well as an air handler with a hot water coil that feeds the offices. Figure 2 shows the maintenance shop, looking west. The area covered by these systems is 5,500 square feet.

Figure 2 – Maintenance Shop

Note: The office area is to the left in the photo under the mezzanine.

The hydronic system for the office and maintenance area is supplied by 2 Lochinvar Knight propane boilers (Figure 3), rated 150 MBH input, 136 MBH output (90.7% nominal efficiency). The boilers are plumbed in parallel, each with their own circulator (Grundfos UPS 26-99 set to HI), and they share a single set of closely spaced tees where they inject into the main loop. Flow in the main loop is due to operation of zone pumps.

Figure 3 – Propane Boilers

The radiant heating zones are as follows:

- Zone 1: Toilet/Locker Rooms

- Zone 2: Break Room
- Zone 3: Office
- Zone 4: Storage
- Zone 5: Mechanical Office
- Zone 6: Mechanical Room
- Zone 7: Repair Shop West
- Zone 8: Repair Shop East

The 5 heating zone pumps, shown in Figure 4, are Bell & Gossett PL 36, IBC001. They supply the hydronic loads in the following configuration:

- Zones 1-3 (pump is labeled “lunch room”)
- Zones 4-6 (pump is labeled “mechanic’s office”)
- Zone 7
- Zone 8
- Air Handler

Figure 4 – Zone Pumps

There is a 100 gallon propane domestic hot water (DHW) heater in the mechanical room which is rated 199.9 MBH input. There is a small circulator for DHW, but there is minimal DHW use in the facility.

The garage area, which is separate from the maintenance shop, is heated with an overhead radiant infrared propane system, shown in Figure 5. The area of the garage is 12,000 square feet. The system is manufactured by CoRayVac, with 4" tubes, and direct venting at the end of each run. There are 7 burners overall in the radiant system, set up on 3 different runs.

Figure 5 – Garage Area with Overhead Radiant System

The sizing and model numbers of the radiant heating units were not able to be recorded at the time of the site visit because the units were mounted out of reach near the ceiling. A printed set of mechanical plans for the building, which are kept in the mechanical room, were consulted; however, these plans showed the positioning and layout of the radiant units but did not indicate sizing or model numbers. Based on the mechanical plans and the CoRayVac design guide, WES was able to estimate the approximate sizing of the radiant system. Table 1 summarizes the design data and estimated building load.

Table 1 – Radiant Heater Design Data

Branch	Location	Heater Module	Radiant Run[2] (feet)	Assumed Burner Model	Burner Input (Btu/hr)	Burner Output (Btu/hr)	Derived Building Load[3] (Btu/hr)
1	Garage	IR-01	37	B-10	100,000	85,000	106,250
1	Garage	IR-02	43	B-10	100,000	85,000	106,250
1	Garage	IR-03	70	B-12	120,000	102,000	127,500
2	Garage	IR-04	42	B-10	100,000	85,000	106,250
2	Garage	IR-05	63	B-12	120,000	102,000	127,500
2	Garage	IR-06	63	B-12	120,000	102,000	127,500
3	Wash Bay[1]	IR-07	40	B-10	100,000	85,000	106,250
				Total	**760,000**	**646,000**	**807,500**

Note 1: The wash bay is part of the garage area, and is located at the northwest corner of the building.

Note 2: Radiant run length obtained from building mechanical plans.

Note 3: CoRayVac specifies a Building Load Adjustment Factor of 80% for sizing of the radiant units.

On the roof there are 3 air handlers which take in outside air, with direct fired propane burners. These heaters are only used when the exhaust system is running by manual operation or when called for by NO_X or CO sensors. The 1 unit above the maintenance shop is model V3-HOX, 4500 CFM, 0.75" wc, 3982 SCFM, 486 MBH input. The 2 units above the garage bays are model V5-HOX, 8750 CFM, 0.65" wc, 7666 SCFM, 945 MBH input. Staff estimates that these units use a limited amount of propane compared to the overall usage of the building.

Figure 6 – Rooftop Air Handler (V3-HOX)

The facility has (4) 990 gallon propane tanks, for a total storage capacity of 3,960 gallons. Usable capacity is approximately 3,200 gallons.

4.0 BUILDING HEAT DEMAND

St. Louis County staff provided WES with propane delivery and cost, and electric usage and cost history for the Meadowlands Garage, for heating seasons 2010-2011 through 2014-2015 (July-June). Table 2 lists the annual propane delivery amounts and costs. Weather data of daily mean temperatures from Range Regional Airport in Hibbing were obtained for the time period encompassed by the fuel usage data. Daily temperatures are used to calculate the heating degree days for each day of the year. These models use a HDD base temperature of 55°F.

Table 2 – Propane Fuel Deliveries and Weather Data

Heating Year	Propane Deliveries (gal)	Cost	Unit Cost	HDD	Deviation from Average HDD	gal/HDD
2010-2011	14,375	$24,430	$1.70	7,066	0%	2.0
2011-2012	9,765	$13,842	$1.42	5,791	-18%	1.7
2012-2013	7,911	$11,634	$1.47	7,286	3%	1.1
2013-2014	17,253	$35,612	$2.06	8,260	17%	2.1
2014-2015	7,651	$5,954	$0.78	6,942	-2%	1.1
Average	**11,391**	**$18,294**	**$1.49**	**7,069**		**1.6**

Table 2 shows that the delivered propane on an annual basis varies beyond what would be expected due to changes in weather and operations. It is probable that this variation is a result of when purchases are made versus when the fuel is used. Heating seasons 2010-2011, 2012-2013, and 2014-2015 had similar weather profiles, yet the propane usage in 2010-2011 was significantly greater. Heating year 2011-2012 was warmer than any other year, yet it used a disproportionate amount of propane. Due to this variation, the average annual value is used as the basis for the economics in this report.

Each year is modeled based on the total deliveries and weather data for that year. The heating degree days for each day are used to proportionally distribute the annual fuel usage totals. Figure 7 shows modeled daily average heat demand for heating seasons 2010-2011 through 2014-2015.

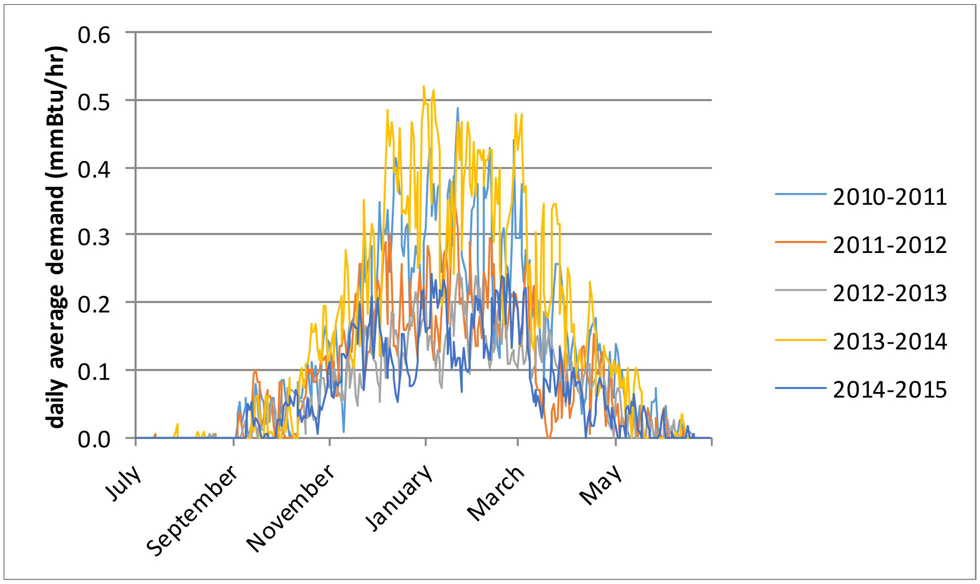

Figure 7 – Daily Average Demand for 5 Heating Seasons

Note: Assumptions regarding system efficiencies are listed in Table 5. 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.

Note that the daily average loads in Figure 7 exceed the combined output of the 2 propane boilers in many cases. This is because the propane usage data includes the combined usage of both the boilers and the radiant overhead heaters.

Figure 8 presents load duration curves (LDC) for the same 5 year period. 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 8 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.

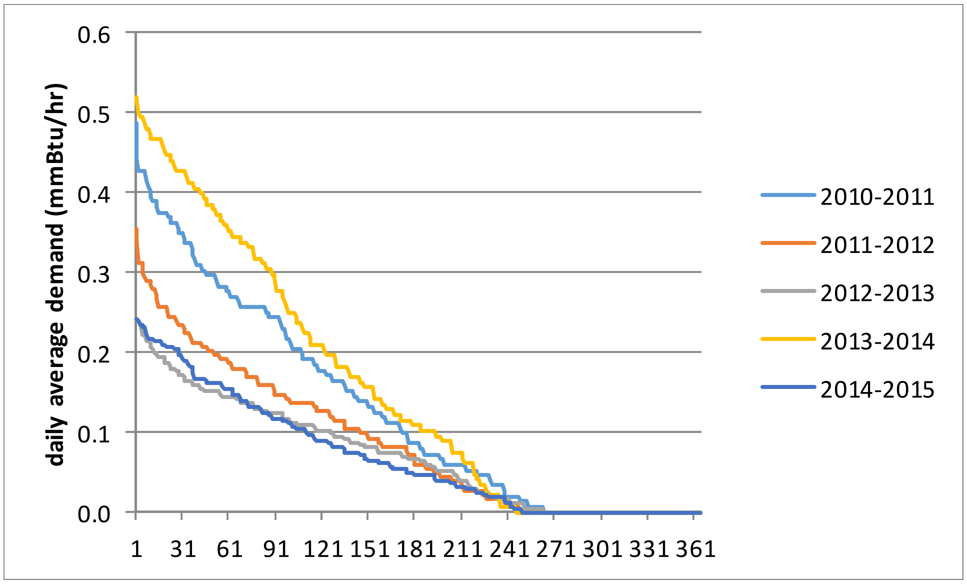

Figure 8 – Load Duration Curves

Note: Assumptions regarding system efficiencies are listed in Table 5. 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.

The heating year 2011-2012 is used as the basis of further analysis, because its propane usage is the closest to the average in Table 2. From Figure 8, it is apparent that the coldest day's average heat demand in 2011-2012 is approximately 0.35 mmBtu/hr. Using the models and values previously discussed, WES estimates that the peak hourly demand for the facility is approximately 0.65 mmBtu/hr. It is important to remember that peak demands are only seen for an hour or two in a specific 24-hr period, on the coldest days of the year.

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. Due to the variations in the potential fuels available in various locations, there are differing systems for each fuel type. 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 what can be achieved by air drying. Some cordwood systems are able to also use wood pellets following a manual adjustment of the grates.

Options evaluated in this report would require an estimated annual use of up to 64 tons of wood pellets, or 46-50 cords (74-80 tons) of cordwood. A wood chip option is not evaluated in detail, but if dry chips were available, 93 tons per year would be required.

Table 3 compares the cost of delivered heat for wood and fossil fuels.

Table 3 – Fuel Pricing and Cost per mmBtu

Technology, Unit	Cost/Unit	Input mmBtu /Unit	Assumed Efficiency	Output mmBtu /Unit	Output Cost /mmBtu
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Dry Wood Chip[3], ton	$80	12.0	75%	9.0	$8.89
Green Wood Chip[4], ton	$35	10.0	70%	7.0	$5.00
Propane, gal (5-yr average)	$1.49	0.091	85%	0.078	$19.19

Note 1: Cost is for hardwood. $220 per cord equals $138 per ton assuming that wood has been seasoned to 20% moisture content wet basis.
Note 2: Wood pellets are 6-8% moisture content wet basis.
Note 3: Dry wood chips (25-30% moisture content wet basis) are not commercially available in Meadowlands. Cost for dry wood chips is estimated by WES as a fair market price.
Note 4: Green wood chips are not appropriate for this facility due to the relatively small size of the facility.
Note 5: Table 5 contains the assumptions used to develop the above values.

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 Meadowlands 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 nearest wood pellet plant, Great Lakes Renewable Energy (GLRE), 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 slightly farther away 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 unchanged, and overall delivered price of pellets would reflect a savings of approximately $15/ton compared to GLRE. However, this is a relatively new pellet plant and therefore long term pricing and supply 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 reflects GLRE prices, which is conservative. Significant savings could be realized if pellets can be obtained from Propellet at prices below GLRE's.

5.2 CORDWOOD

Several firewood suppliers were identified, located in Duluth, Grand Rapids, and Hibbing. Pricing at the producer is in the range of $205-$225 per cord for hardwood. Delivered cost is estimated to be in the range of $220-$230 per cord. Unlike pellets, cordwood is relatively easy to produce with low cost equipment. For the purposes of this study, an estimated delivered cost of $220 per cord for cut and split hardwood is assumed.

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. WES recommends purchasing wood fuel in the 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.

An alternative to purchasing cut and split cordwood would be for St. Louis County to obtain suitable logs from county property or from clearing roadsides, and stage them at the Meadowlands Garage. There are several mobile firewood processing operations in the area which can bring a grapple skidsteer and a firewood processor to the facility, and cut and split the wood on site, for a cost of approximately $65 per cord. Depending on the cost to St. Louis County of procuring the logs, this method could provide significant savings compared to delivery of processed cordwood.

Like any wood product, the cost of cordwood consists of stumpage, harvest, intermediate transportation, processing, and final delivery. Estimated costs for each of these activities are shown in Table 4. St. Louis County has the potential to reduce or eliminate any of these factors in order to reduce the cost of cordwood at the Meadowlands Garage.

Table 4 – Estimated Components of Cordwood Pricing

Item	Cost per Cord
Stumpage	$30
Harvest	$70
Transportation	$25
Processing	$65
Delivery	$30
TOTAL	**$220**

The estimate for self-sourced cordwood from county land is $150 per cord. This scenario assumes that a cordwood processor is hired for $65/cord to process logs at the landing. Harvest of the wood is performed for $70/cord by the logger working the tract (who presumably is harvesting other timber per the timber contract). Delivery to Meadowlands is done on a backhaul basis using St. Louis County equipment, for an estimated cost of $15/cord.

5.3 WOOD CHIPS

Although a wood chip system is not evaluated for the Meadowlands Garage, this fuel has a strong regional presence and is worth discussing. Sources of wood chips could be local loggers, regional wood products manufacturers, MN DNR, or the US Forest Service. Wood chip CHP (combined heat and power) plants in Virginia and Hibbing are the primary outlets for low value residuals. WES spoke with several local loggers and learned that there are a significant number of logging operations which are doing in-woods chipping. The in-woods chipping is done in conjunction with harvesting of saw timber or pulpwood. The general unofficial chip spec in the woods is a 2" whole tree chip, and these are for the most part delivered to the power plants in Virginia and Hibbing for a delivered cost of $30 to $40 per ton.

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 a higher ash content than debarked roundwood. Paper and OSB mills use debarked roundwood chips as their primary feedstocks, and therefore these materials will command a higher price.

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. Compared to the 2" whole tree chips being produced by in-woods chippers, these chips must be sized less than 1.5" and oversize pieces must be removed. These chips can be commercially produced by screening chips and then drying chips using a rotary dryer heated by a wood chip furnace. In some cases, facility owners themselves produce dry chips from dry residuals and use them in their own boilers. Rather than using a dryer, 30% moisture or less can be achieved if logs are air dried for a year prior to being chipped. There is the potential that a local logging or tree service company could be willing to stage logs and chip them, however, no potential suppliers have been identified at this time.

Another reason why a green chip or dry chip system is not evaluated for the Meadowlands Garage is that 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 storage areas with automated reclaim equipment, or stored under cover and then loaded into a daybin 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.

6.0 EVALUATED BIOMASS SYSTEMS

Three biomass fueled hot water boiler systems are evaluated for the Meadowlands Garage. These biomass system options were sized and evaluated using the analysis in Section 4. The options include the following equipment:

> **Option 1 – Indoor Cordwood Boiler System:** Two indoor cordwood hot water boilers, each rated 170,000 Btu/hr (340,000 Btu/hr total), would be installed in a new boiler room located at the southeast corner of the building adjacent to the existing mechanical room. A 1,000 gallon thermal storage tank(s) would be installed with the boilers. The cordwood boilers would tie into the facility's heating system in the existing mechanical room. A new zone of hydronic unit heaters would be plumbed in the garage area, to offset the use of propane by the radiant system.
>
> **Option 2 – Outdoor Cordwood Boiler System:** Two outdoor cordwood hot water boilers, each rated 170,000 Btu/hr (340,000 Btu/hr total), would be installed adjacent to the southeast corner of the building near the existing mechanical room. A 1,000 gallon thermal storage tank(s) would

be installed inside the building. The cordwood boilers would tie into the facility's heating system in the existing mechanical room. A new zone of hydronic unit heaters would be plumbed in the garage area, to offset the use of propane by the radiant system.

Option 3 – Wood Pellet Boiler System: Two wood pellet hot water boilers, each rated 191,000 Btu/hr (382,000 Btu/hr total), would be installed in a new boiler room located at the southeast corner of the building adjacent to the existing mechanical room. A 120 gallon thermal storage tank would be installed with the boilers. The pellet boilers would tie into the facility's heating system in the existing mechanical room. A new zone of hydronic unit heaters would be plumbed in the garage area, to offset the use of propane by the radiant system.

The proposed location for the new biomass equipment is shown in Figure 9. Note that there is a utility transformer, electric meter, and A/C condenser already located in this area. At least 10' of clear working space must be maintained in front of the doors of the transformer to allow for safe access by utility workers. The drawings in Appendix A provide specific equipment positions for the various options.

Figure 9 – General Location for Wood Boilers

6.1 OPTION 1 – INDOOR CORD WOOD BOILER SYSTEM

This option includes two cordwood gasification boilers, each rated 170,000 Btu/hr. The boilers would heat a 1,000 gallon thermal storage tank(s). A new boiler room would be built adjacent to the mechanical room to house the boilers and thermal storage tank. The cordwood would be stored nearby in the area near the propane and motor fuel tanks.

The 1,000 gallons of thermal storage would be typically maintained around 200°F. Using 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. Using the mixing valve and 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.

In the case of a cordwood boiler the thermal storage has another important role. Cordwood boilers can be expected to have a 4-8 hour burn time with efficient operation. Cordwood boilers should be paired with thermal storage in order to increase the time between loading wood and to allow all the wood in the firebox to be consumed while firing at or above 50% of the boiler's rated capacity. A cordwood boiler is used to "charge" the thermal storage to a high temperature in a highly efficient burn cycle.

Then the heat demand can be met from the hot water in the thermal storage, and the boiler does not have to be stoked again until the thermal storage temperature goes below what is needed for satisfying the heat transfer requirements of the hydronic system.

Modern cordwood gasification boilers are clean and efficient. Use of refractory, combustion air control based on oxygen sensors, and efficient heat exchanger tube designs make modern cordwood boilers highly efficient if they are fired correctly. Unlike pellet and chip boilers, cordwood boilers do not have automatic fuel feed, and therefore the boiler operator must stoke the boiler by hand, taking into consideration the building load.

Burn time for a cordwood boiler is a function of the firebox size and configuration, and the demand on the system. For efficient operation, the size of the firebox should be proportional to the demand, rather than proportional to the desired burn time. If the wood loaded into the firebox cannot be used at approximately 50% of the boiler's nominal firing rate or greater, lower firebox temperatures can occur, resulting in reduced fuel efficiency and undesirable smoke. Oversizing of a cordwood boiler will result in increased emissions and increased fuel usage.

A pair of cordwood boilers are indicated for this option, rather than one larger one, in order to allow for efficient operation in the shoulder seasons, when demand is lower.

The boilers and thermal storage tank(s) would be supplied from the boiler vendor in two 20' shipping containers, pre-wired and pre-plumbed. The containerized system would include all plumbing from the boilers to the thermal storage, expansion tanks, the boiler circulators, the boiler controls, and an electrical breaker panel with circuits for the boilers and circulation pumps. Work on site would involve setting the containers on suitable footings, and making plumbing and electrical connections from the building to the containers.

Heat from cordwood stored in the thermal storage would cover the demand as possible based on heat stored and staffing schedules for system loading. The existing boilers and radiant heaters will remain in place as automated backup.

In order to maximize coverage of the load by the wood boilers, a new hydronic zone would be plumbed to heat the garage area which is currently heated by propane radiant heaters. This zone would include 6 hydronic unit heaters mounted near the ceiling. The unit heaters would be vertical style units which would direct hot air downwards as shown in Figure 10.

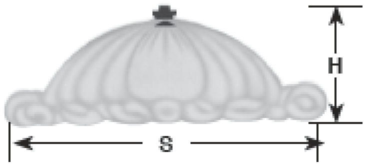

Figure 10 – Vertical Hydronic Unit Heater Air Distribution

Note: Image source: Modine catalog.

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

Cordwood fueled biomass boilers operate most efficiently between 50% and 100% of their rated heating output. The two cordwood boilers would have an efficient operating range of 85,000 to 340,000 Btu/hr. Coverage for the cordwood boilers is evaluated using data from the 2011-2012 heating season. Figure 11 shows the boilers covering 100% of the load. Coverage of loads below 85,000 Btu/hr is made possible by the thermal storage tank, which stores excess heat if the boiler produces more heat than the distribution system is calling for. After the fire in the boiler goes out, the heat in the thermal storage tank is supplied to the system.

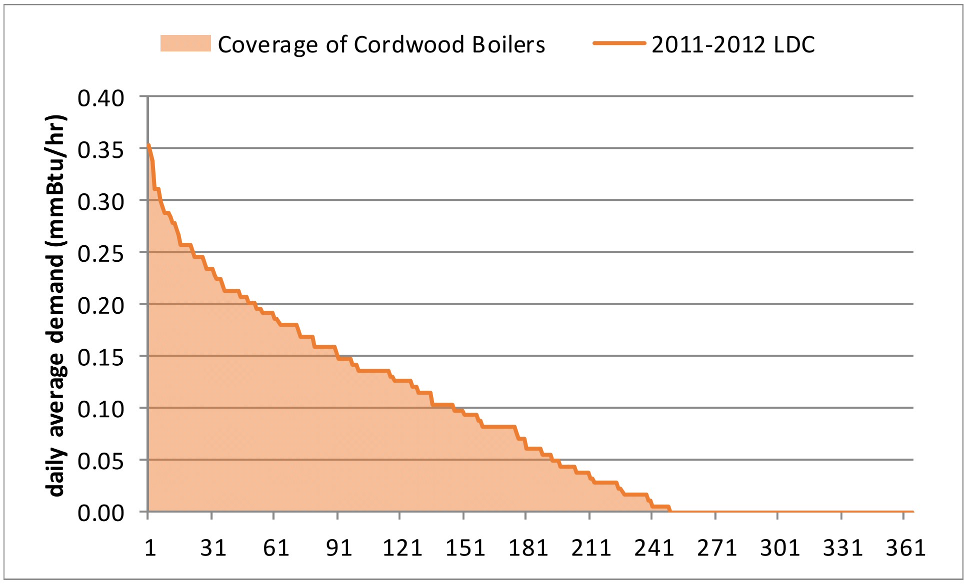

Figure 11 – 2011-2012 LDC and Coverage of Cordwood Boilers

Note: Assumptions regarding system efficiencies are listed in Table 5. 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.

A value of 75% coverage of the load by the cordwood boilers is estimated for the economic analysis because it is likely that the boilers will not be stoked at all times, especially during the weekends when the garage is not staffed except during snow events. Exact sizing of the boilers depends on the vendor selected, and their product offerings.

6.2 OPTION 2 – OUTDOOR CORD WOOD BOILER SYSTEM

This option includes two outdoor cordwood gasification boilers, each rated 170,000 Btu/hr. The boilers would be installed outside the mechanical room. One or more thermal storage tanks totaling 1,000 gallons would be installed inside the building, either in the mechanical room, or a nearby storage area. In other respects, this option is essentially the same as Option 1. A value of 75% coverage of the load is estimated for the economic analysis.

Appendix A includes a conceptual layout and schematic for the boiler system.

6.3 OPTION 3 – WOOD PELLET BOILER SYSTEM

This option consists of a containerized wood pellet boiler system with (2) 191,000 Btu/hr pellet boilers, a 120 gallon thermal storage tank, and a 30 ton silo. Pellets would be automatically conveyed to the boilers as needed via a flexible auger or vacuum system.

Wood pellet boilers will typically turn down to approximately 20% of their rated load before they cycle to meet the heat demand. To maximize the load coverage, two wood pellet boilers were chosen to provide a larger operating range than could be provided by one larger boiler. If the facility would desire to accommodate the potential future use of dry chips, the type of pellet boilers specified here would not accommodate dry chips, whereas, one larger pellet boiler may be able to accommodate a dry chip fuel.

The containerized system would be a turnkey pre-wired and pre-plumbed "heat cabin" supplied by the boiler vendor, similar to a standard 20' shipping container. Work on site would involve setting the container on suitable footings, and making plumbing and electrical connections from the building to the container.

The boilers would be used to heat a 120 gallon hot water thermal storage tank. The thermal storage tank would be typically maintained around 200°F. Using 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. Using the mixing valve and 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.

In order to maximize coverage of the load by the wood boilers, a new hydronic zone would be plumbed to heat the garage area which is currently heated by propane radiant heaters. This zone would include 6 hydronic unit heaters mounted near the ceiling. The unit heaters would be vertical style units which would direct hot air downwards as shown in Figure 10.

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. The pellet boilers would have an efficient operating range of 38,000 Btu/hr to 382,000 Btu/hr. Coverage for the pellet boilers is evaluated using data from the 2011-2012 heating season. Figure 12 shows the pellet boilers covering approximately 96% of the 2011-2012 load.

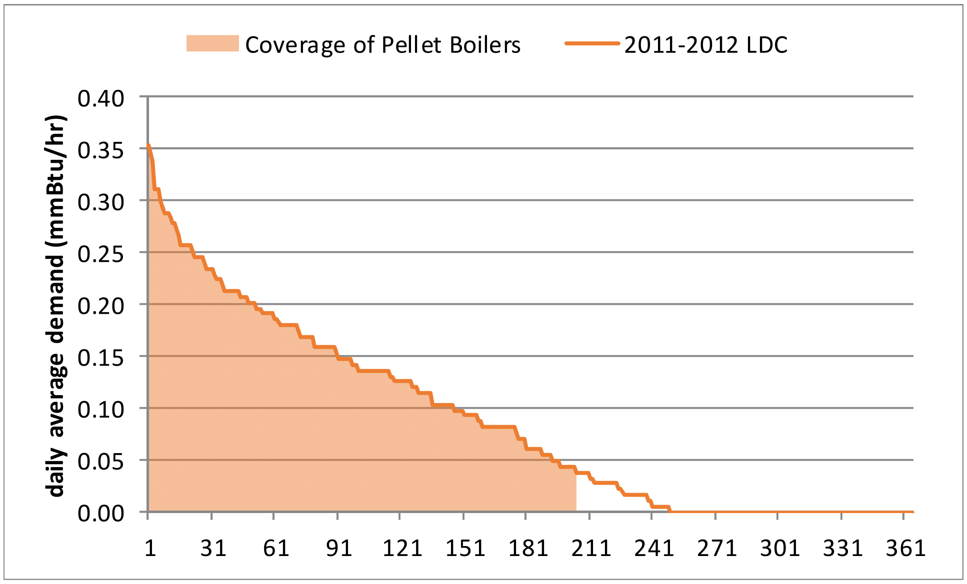

Figure 12 – 2011-2012 LDC and Coverage of Pellet Boilers

Note: Assumptions regarding system efficiencies are listed in Table 5. 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 load by the pellet boilers is estimated for the economic analysis. Exact sizing of the boiler(s) depends on the vendor selected, and their product offerings.

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.

Based on assumptions in Table 5, 250 mmBtu of thermal output is approximately equal to 3,220 gallons of propane, 19 tons of pellets, or 17 cords of cordwood (assuming 65% cordwood seasonal efficiency). It is likely that the Meadowlands Garage could qualify for this incentive during the quarters Oct-Dec and Jan-Mar. During qualifying quarters, this incentive would effectively reduce the price of pellets by $66/ton, and the price of cordwood by $72/cord.

Specific sustainable harvesting and sourcing requirements have to be met. For facilities within 50 miles of the state border (this includes the Meadowlands Garage), the material must be sourced from within Minnesota, or within a 100 mile radius including areas outside Minnesota.

8.0 BIOMASS SYSTEM ANALYSIS

Table 5 lists the values and assumptions used in the analysis.

Table 5 – Values and Assumptions

Assumption	Value	Unit	Source
Propane HHV	0.091333	mmBtu/gal	WES Assumption
Propane Cost (5-yr average)	$1.49	$/gal	St. Louis County
Propane Boiler Seasonal Efficiency	85%	percent	WES Assumption
Propane Radiant Heater Seasonal Efficiency	85%	percent	WES Assumption
Propane Rooftop Air Handler Seasonal Efficiency	80%	percent	WES Assumption
Cord Wood HHV (seasoned hardwood)	22	mmBtu/cord	WES Assumption
Cord Wood Cost	$220	$/cord	WES Assumption
Indoor Cordwood Boiler Seasonal Efficiency	65%	Percent	WES Assumption
Advanced Outdoor Cordwood Boiler Seasonal Efficiency	60%	Percent	WES Assumption
Cord Wood Density	1.6	tons/cord	WES Assumption
Wood Pellet HHV	16.4	mmBtu/ton	WES Assumption
Wood Pellet Cost	$194	$/ton	WES Assumption
Wood Pellet Boiler Seasonal Efficiency	80%	Percent	WES Assumption
HDD Base Temp	55	˚F	WES Assumption
Electric Cost	$0.11	$/kWh	St. Louis County
Heat Usage Oct-Mar	88%	% of annual	WES Model
Labor Cost (at Facility)	$30	$/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 6.

Table 6 – Capital Cost Estimate Summary

Option	Estimated Capital Cost
1 - Indoor Cordwood	$138,250
2 - Outdoor Cordwood	$95,500
3 - Pellet	$171,463

Costs for the systems include the boilers, pumps, controls, thermal storage, piping, automatic fuel storage and handling (Option 3), turnkey containerized boiler rooms (Options 1 and 3), addition of a hydronic zone to heat the garage area, and installation. Detailed breakdowns of capital costs are provided in Appendix B.

Table 7 gives a breakdown of estimated operating and maintenance costs for each option. The cordwood options are estimated to require an operator for 1 hour per day, while the pellet option is estimated to require 10 minutes per day.

Table 7 – Estimated Operating and Maintenance Costs

Option	Electric Usage	Maintenance / Wear Parts	Staff Time	Total O&M Cost
1 - Indoor Cordwood	$180	$200	$5,100	**$5,480**
2 - Outdoor Cordwood	$180	$200	$5,100	**$5,480**
3 - Pellet	$166	$400	$1,050	**$1,616**

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 8 showing the estimated annual fuel use for each option compared to the existing fossil fuel system.

Table 8 – Proposed System Fuel Use Profile

Option	Current Annual Fuel Use	Annual Fuel Use with Proposed Biomass System			
			Estimated Biomass Use (tons)[1]		Estimated Propane Use with Biomass System (gal)
	Propane (gal)	Biomass Demand Coverage	Oct-Mar	Apr-Sep	
1 - Indoor Cordwood	11,391	75%	65	9	2,848
2 - Outdoor Cordwood	11,391	75%	71	10	2,848
3 - Pellet	11,391	95%	56	8	570

Note 1: Fuel use in this table is in tons. Option 1 would require 46 cords, while Option 2 would require 50 cords.

Note 2: Table 5 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	Current Annual Fuel Use	Estimated Annual Costs with Proposed Biomass System			Estimated First Year Operational Savings	Thermal Production Incentive	Estimated Net Cash Flow
	Propane Cost	Biomass Cost	Propane Cost	O&M Increase			
1 - Indoor Cordwood	$16,972	$10,204	$4,243	$5,480	($2,954)	$2,916	($38)
2 - Outdoor Cordwood	$16,972	$11,054	$4,243	$5,480	($3,804)	$2,916	($888)
3 - Pellet	$16,972	$12,422	$849	$1,616	$2,085	$3,693	$5,779

Note: Table 5 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 - Indoor Cordwood[2]	$138,250	$0	$138,250	-	($137,888)
2 - Outdoor Cordwood[2]	$95,500	$0	$95,500	-	($114,981)
3 - Pellet	$171,463	$0	$171,463	65	($42,019)
1 - Indoor Cordwood w/ grant[2]	$138,250	$34,563	$103,688	-	($103,325)
2 - Outdoor Cordwood w/ grant[2]	$95,500	$23,875	$71,625	-	($91,106)
3 - Pellet w/ grant	$171,463	$42,866	$128,597	44	$846

Note 1: Simple payback is calculated taking into account the assumption that thermal production incentive payments end after 10 years. The payback periods of all options exceed the estimated useful life of the equipment.
Note 2: The cordwood options are evaluated using a market rate of $220/cord. There may be opportunities for the County to obtain cordwood at a substantially lower cost. Appendix C shows a sensitivity analysis which provides annual overall savings at varying cordwood and propane prices.

Detailed financial analyses were generated for all options and are included in Appendix C.

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 5, the pair of cordwood boilers proposed in Options 1 or 2 would have a combined maximum fuel input rate of 0.57 mmBtu/hr, and the pair of pellet boilers proposed in Option 2 would have a maximum fuel input rate of 0.48 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 St. Louis County's annual net CO_2 equivalent greenhouse gas emissions by up to 54 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 5.

Table 13 – Greenhouse Gas Emission (CO_2 equivalent) Reductions

Option	Current 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 - Indoor Cordwood	66	0	5	16	44
2 - Outdoor Cordwood	66	0	5	16	44
3 - Pellet	66	0	5	3	57

Note 1: Biomass boilers use more electricity than comparable gas boilers due to fuel handling equipment, larger blowers, etc. Table 5 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 the Meadowlands Garage, with any 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 Meadowlands Garage 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 regardless of its source as a fuel without any further action from MPCA's solid waste program.

9.6 ASH

Whole tree wood chips generally contain about 1% ash by weight, while wood pellets contain 0.5-1.0% ash by weight. Modern chip and pellet boilers have automated or semi-automated ash handling systems which deposit ashes in a portable metal container such as a 55-gallon drum, an example of which is shown in Figure 13. Cordwood boilers generally have an ash cleanout location which must be manually raked every few days.

Figure 13 – Automated Ash Collection from Pellet/Chip Boiler

Options described in this report have the potential to generate 1 ton 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 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. In the case of the Meadowlands Garage, additional potential uses, subject to approval by MPCA, could be as a snow melter, traction enhancer, or flowable fill/CLSM additive.

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 Meadowlands area, use of ash could be on timber harvest sites or on agricultural land. 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

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

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 aggregate input rate for the existing boiler room is below the 750,000 Btu/hr threshold. Addition of a wood boiler system would increase the input capacity by up to 0.57 mmBtu/hr, to a total of 0.87 mmBtu/hr. With the addition of the wood system, the garage would become subject to the attendance requirements just described. If St. Louis County would find this attendance requirement burdensome, minor changes in sizing could be made to the pellet or cordwood options which would allow the facility to come in just under the 0.75 mmBtu/hr threshold, while maintaining good coverage of the load by the wood boilers.

10.0 CONCLUSIONS AND RECOMMENDATIONS

A modern biomass boiler system would allow the Meadowlands Garage to reduce fossil fuel usage while utilizing a local and renewable source of energy. The options evaluated in this report would provide benefits to St. Louis County as summarized:

- Option 1 is an indoor boiler system capable of utilizing split cordwood. This project would provide a first year net operating loss of $38, and would have a capital cost of $138,250. This assumes a market rate for cordwood of $220/cord.
- Option 2 is an outdoor boiler system capable of utilizing split cordwood. This project would provide a first year net operating loss of $888, and would have a capital cost of $95,500. This assumes a market rate for cordwood of $220/cord.
- Option 3 is a boiler system capable of utilizing wood pellets. This project would provide a first year net operating savings of $5,779, and would have a capital cost of $171,463.

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. The cost of the purchased and delivered cordwood is a major driver of the economics for options 1 and 2. If St. Louis County has an internal lower cost source for cordwood, that would change economics for these options. On a delivered heat basis, wood pellets are cheaper than purchased cordwood, and require significantly less labor. As previously discussed, dry wood chips are a lower-cost fuel which is currently widely available in MN. Dry wood chips would be an ideal fuel for the Meadowlands Garage, based on expected market price, but only if there were one or more local, reliable suppliers of this fuel. If a dry wood chips supplier is identified in the region, WES strongly recommends investigating the feasibility of a dry chip boiler system. Wood pellet options can be designed to have the flexibility to use either pellets or screened, dry wood chips. The capital cost for a dry chip boiler system similar in scale to the options presented in this report is approximately $250,000.

Payments from the Minnesota Biomass Thermal Production Incentive are a major driver of savings. It is important to note that these payments only occur for 10 years following startup of the project. Without the incentive payments, the annual savings or loss in today's dollars becomes a loss of $2,954 for Option 1, a loss of $3,804 for Option 2, and a savings of $2,085 for Option 3.

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

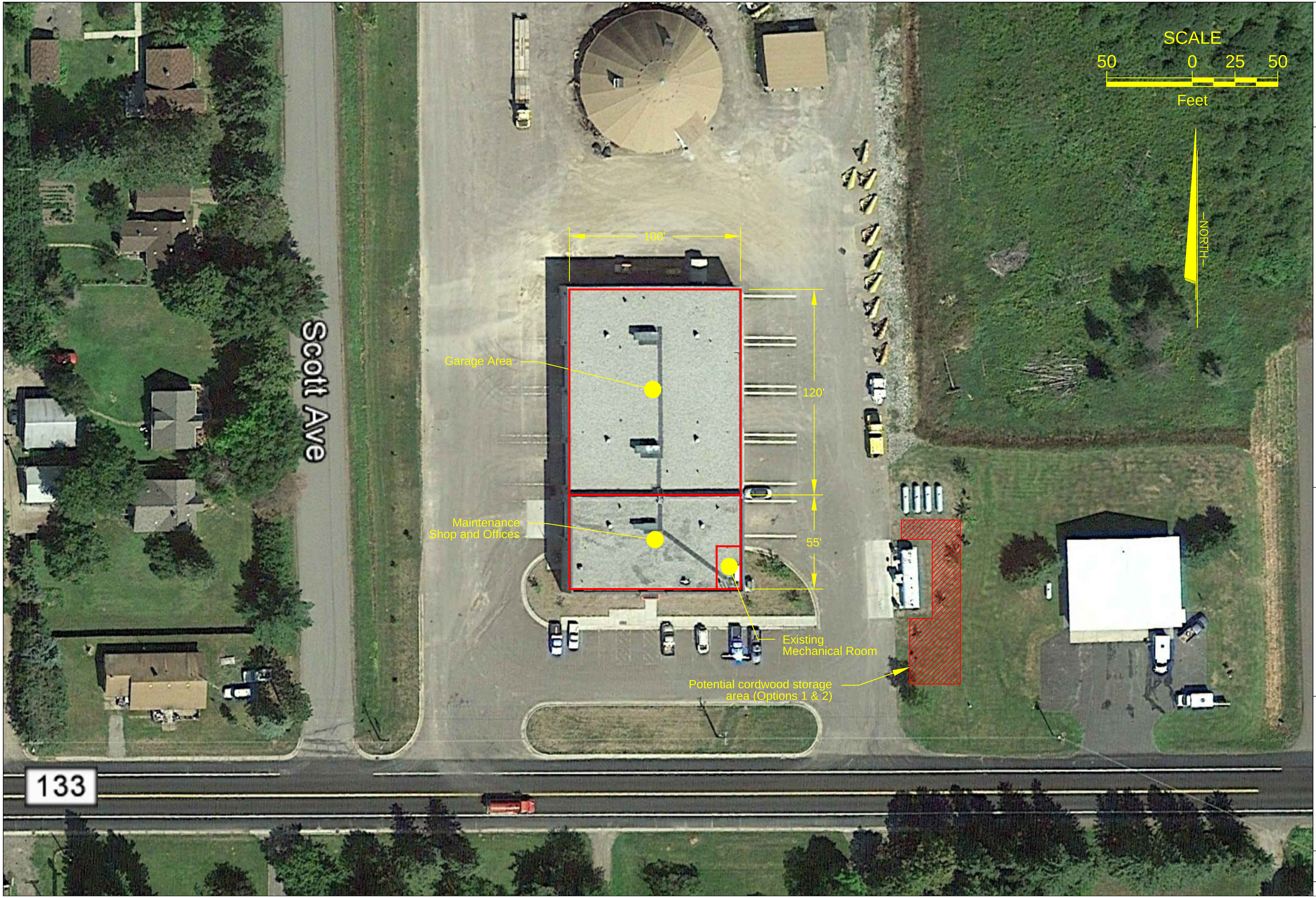
- Net reduction of greenhouse gas emissions by 44 - 57 metric tonnes annually,
- Keeping ~$12,000/yr spent on energy within the region,
- Diversification of fuels used by the fleet of St. Louis County buildings,
- Reduction in operating budget volatility due to wide fluctuations in fossil energy pricing,
- 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 St. Louis County be interested in pursuing a biomass option, WES recommends that county staff in both administration and operations visit 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 St. Louis County continues to pursue renewable biomass energy options, WES recommends that the next level of evaluation includes detailed consideration of the following items:

- Work with the MN SWET to identify alternative funding sources (low interest loans, grants, and incentives)
- Perform site investigations (utility, geotechnical) for the new boiler room and fuel storage building and further develop the biomass plant layout and capital cost based on investigation results.
- Explore lower cost options for cordwood fuel procurement, if this fuel is of interest to the facility managers.

Appendix A – Drawings

- A.1 Facility Site Plan
- A.2 Option 1 (Indoor Cordwood) Plan View
- A.3 Option 2 (Outdoor Cordwood) Plan View
- A.4 Options 1 & 2 (Indoor/Outdoor Cordwood) Schematic
- A.5 Option 3 (Pellet) Plan View
- A.6 Option 3 (Pellet) Schematic



St. Louis County Meadowlands Garage

Meadowlands, MN

Aerial Site Plan

Designed	PFO	8/18/16
Drawn	PFO	8/18/16
Checked	DAW	9/2/16

Approved ______ Date ______

Title ______ Job Class ______

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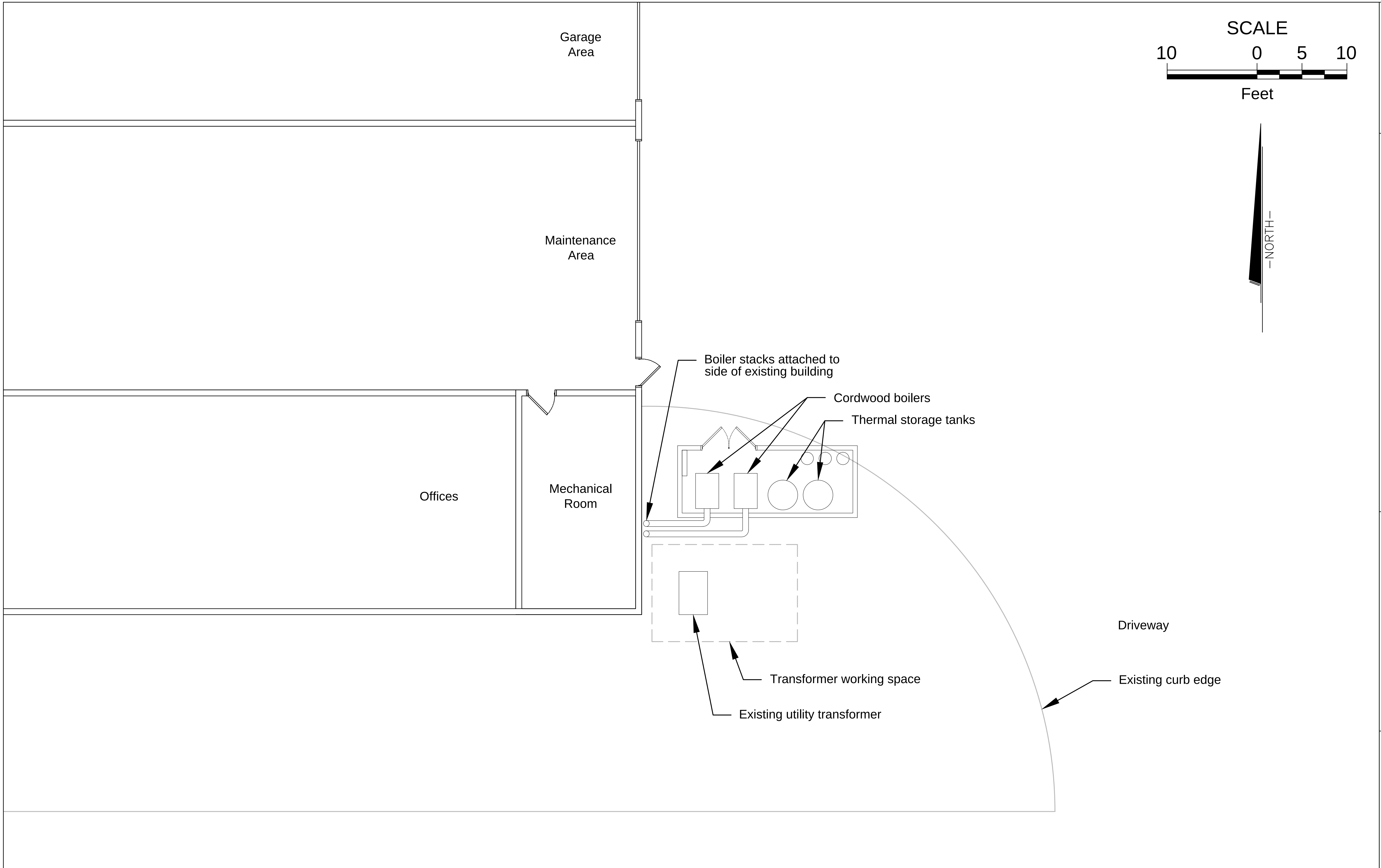
Date	Description	Approved

A.1



Option 1 - Indoor Cordwood Boiler Plan View

Designed	PFO	8/18/16
Drawn	PFO	8/18/16
Checked	DAW	9/2/16

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Job Class
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Indoor Cordwood Boiler Plan View

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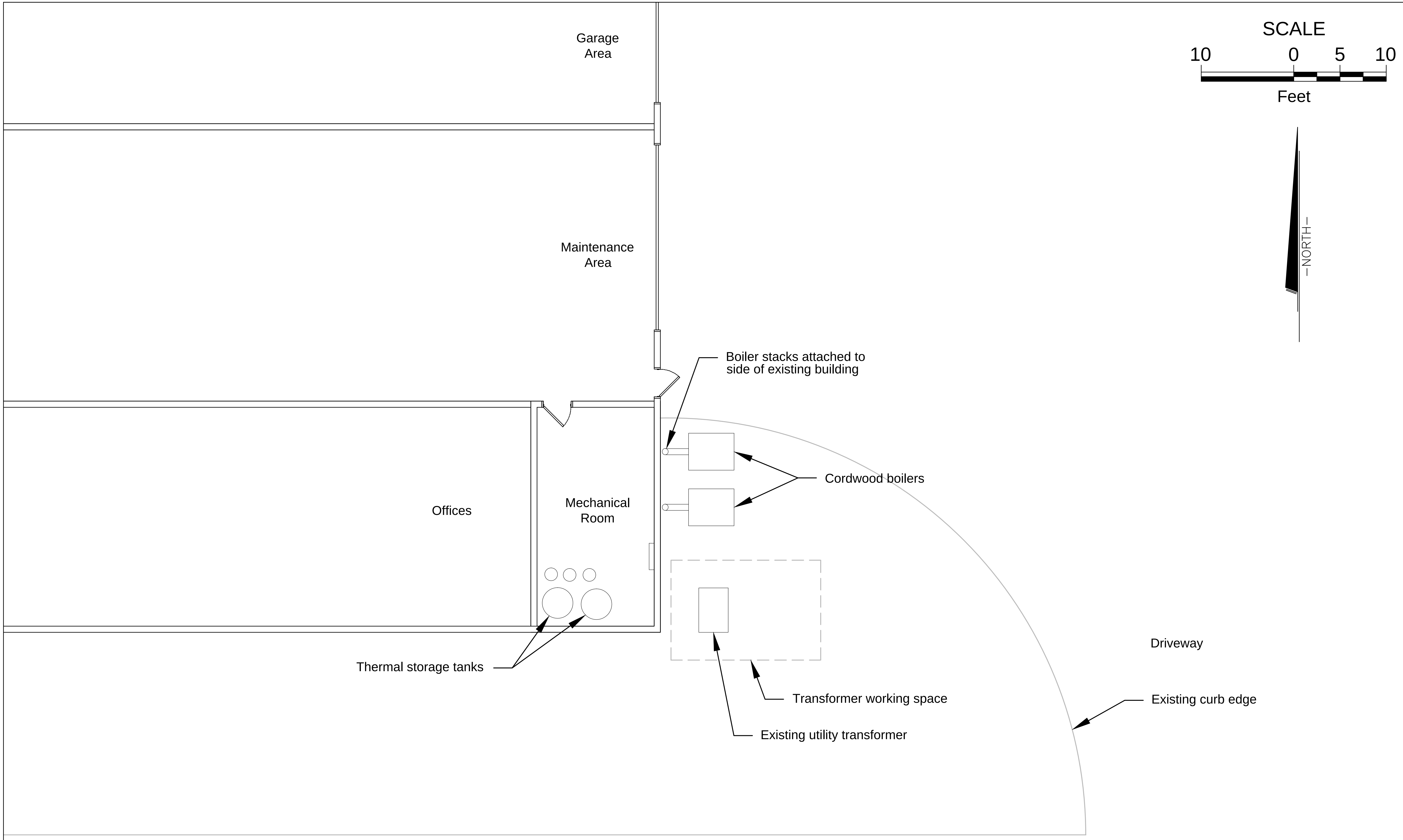
A.2



Option 2 - Outdoor Cordwood Boiler Plan View

Designed	PFO	8/22/16
Drawn	PFO	8/22/16
Checked	DAW	9/2/16

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Title ______ Job Class ______

St. Louis County Meadowlands Garage
Meadowlands, MN

Outdoor Cordwood Boiler Plan View

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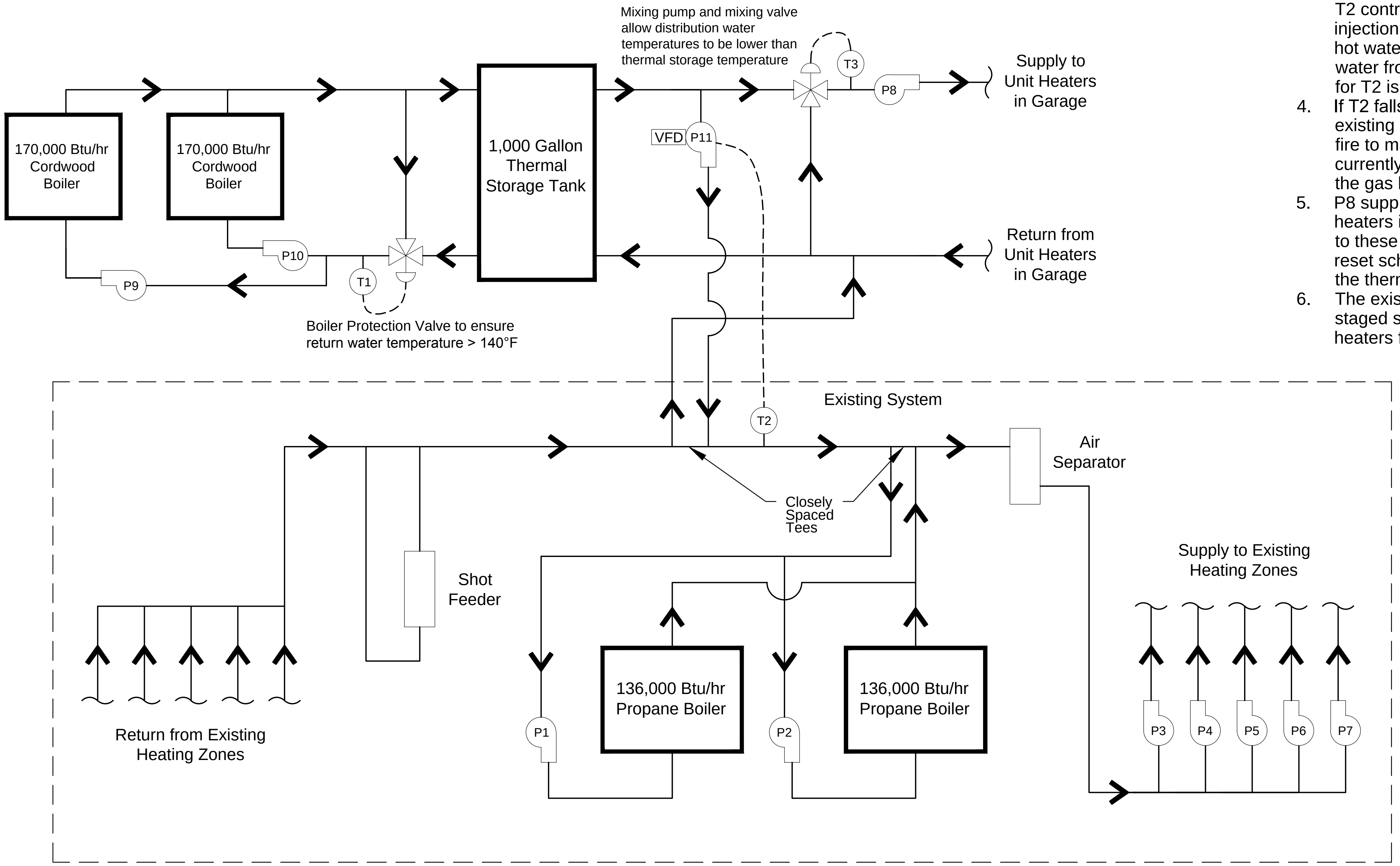
A.3

Sequence of Operations:

1. T1 controls a mixing valve which allows supply water from the cordwood 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. The cordwood boilers will be controlled to maintain good combustion over the course of each firing cycle. The thermal storage tank provides a buffer to allow the boilers to output more heat than the system is demanding, if that is necessary in order to maintain good combustion.
3. P11 injects hot water into the building loop in the existing boiler plant, ahead of where the existing gas boilers tie in. T2 controls the temperature of the water after the injection point by controlling the speed of P11 to blend hot water from the thermal storage tank with cooler return water from the building loop. The temperature set point for T2 is based on an outside reset schedule.
4. If T2 falls 5°F below the set point for 5 minutes, then the existing gas boilers will be enabled. The gas boilers will fire to maintain the building loop temperature as they are currently configured to do. When T2 reaches set point, the gas boilers will be disabled.
5. P8 supplies hot water to the new overhead hydronic unit heaters in the garage area. The water temperature sent to these is regulated by a mixing valve on an outside reset schedule in order to maximize the effectiveness of the thermal storage.
6. The existing radiant heaters in the garage area will be staged such that they will activate if the new hydronic unit heaters fail to supply the necessary heat.



Mixing pump and mixing valve allow distribution water temperatures to be lower than thermal storage temperature

Boiler Protection Valve to ensure return water temperature > 140°F

Notes:

1. This drawing is a conceptual layout for the purposes of showing biomass system options.
2. Final design and layout will change based on equipment selected, designer, and site conditions.
3. Layout shown assumes that cordwood boilers and thermal storage are ASME rated. If a boiler or thermal storage is selected which is not ASME rated, a heat exchanger will be required, so that the distribution system and propane boilers can be pressurized.

Options 1 & 2 - Cordwood Boilers

Legend

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

Designed	PFO	8/8/16
Drawn	PFO	8/8/16
Checked	DAW	9/2/16

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Title ________ Job Class ________

St. Louis County Meadowlands Garage
Meadowlands, MN

Schematic for Cordwood Boilers

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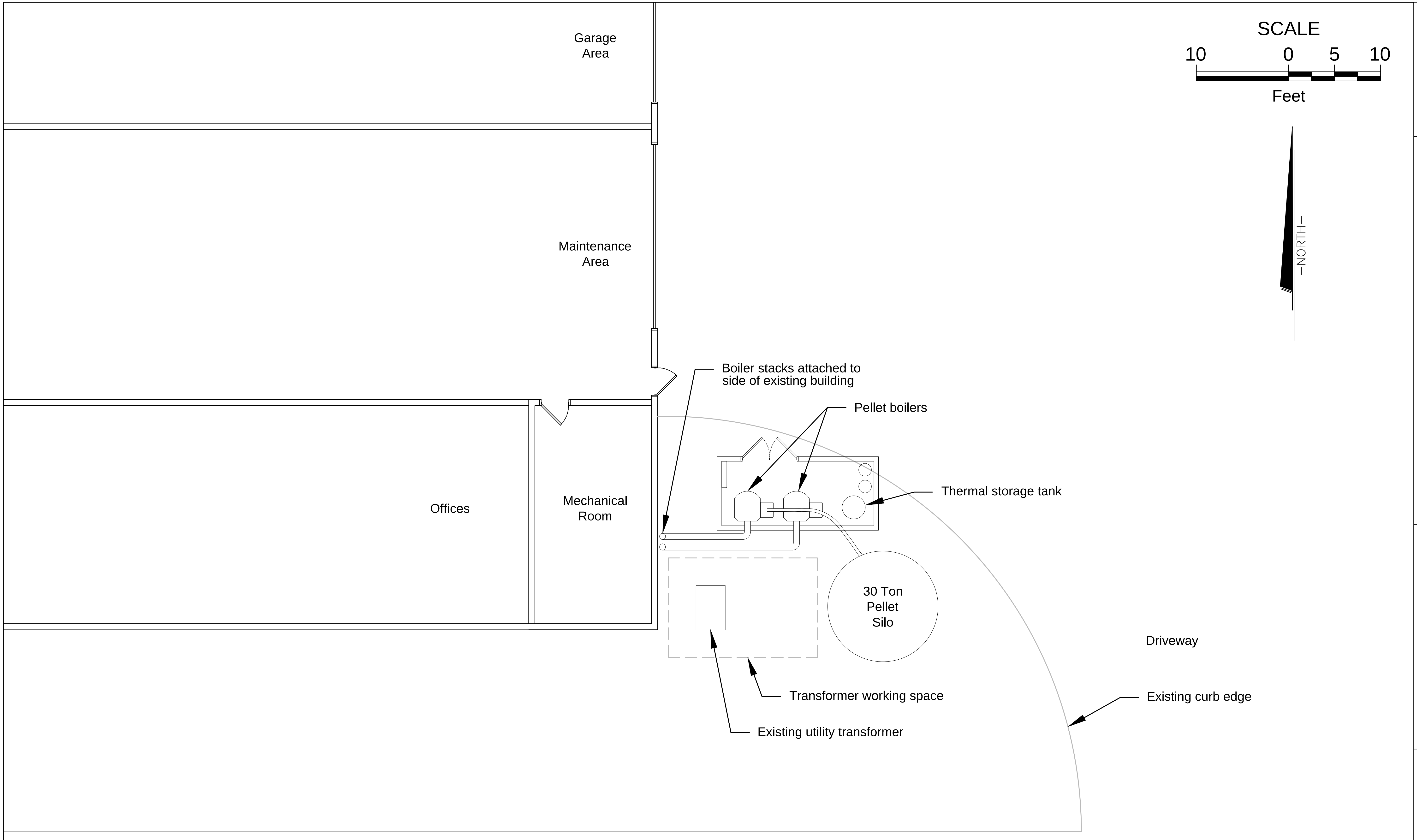
A.4



Option 3 - Pellet Boiler Plan View

St. Louis County Meadowlands Garage
Meadowlands, MN

Pellet Boiler Plan View

Designed	PFO	8/18/16
Drawn	PFO	8/18/16
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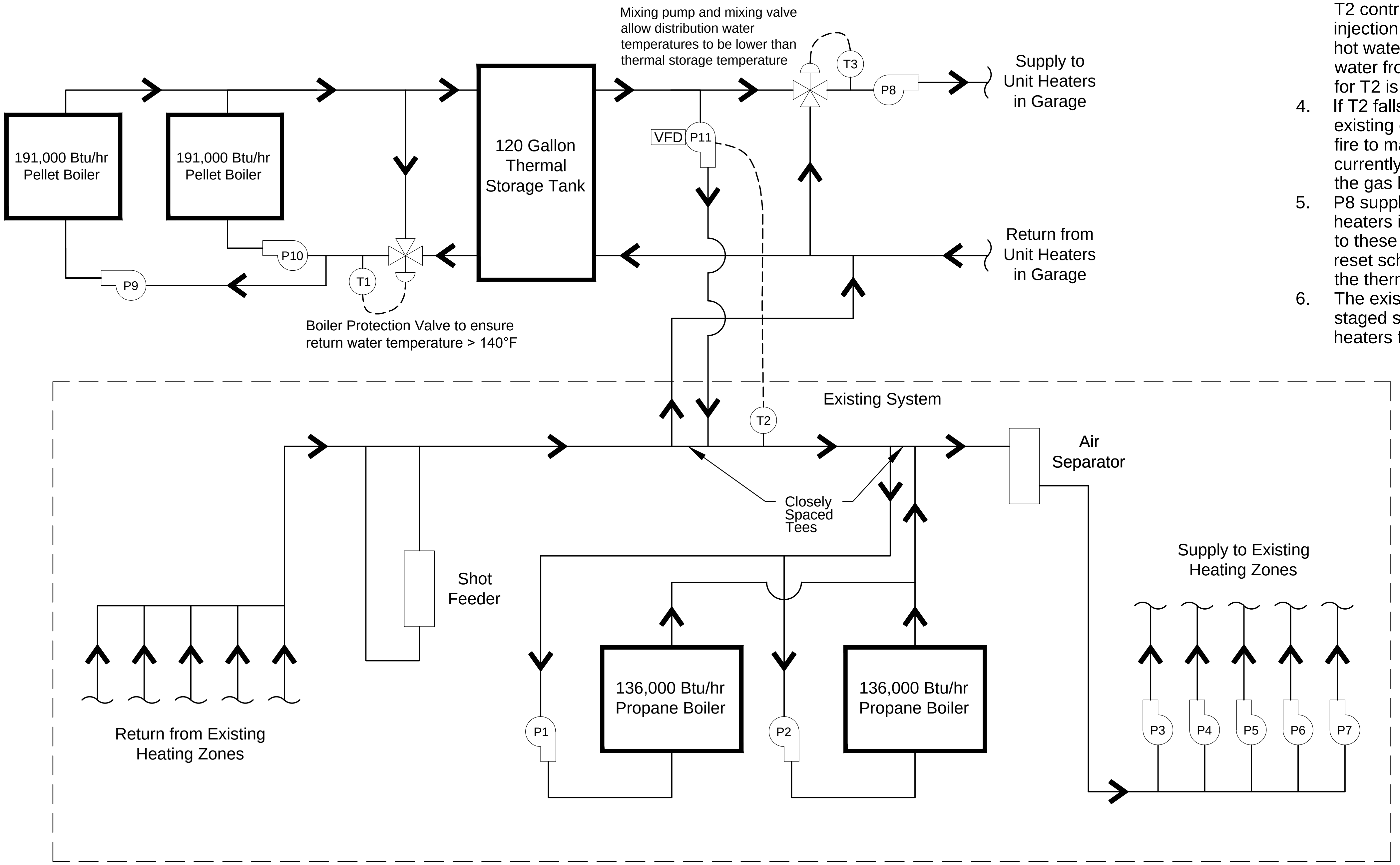

Sequence of Operations:

1. T1 controls a mixing valve which allows supply water from the pellet 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. The pellet boilers will be controlled to maintain 210°F in the thermal storage tank. Depending on the return water temperature and the temperature in the thermal storage tank, one or both of the pellet boilers will fire in order to most efficiently meet the heat demand.
3. P11 injects hot water into the building loop in the existing boiler plant, ahead of where the existing gas boilers tie in. T2 controls the temperature of the water after the injection point by controlling the speed of P11 to blend hot water from the thermal storage tank with cooler return water from the building loop. The temperature set point for T2 is based on an outside reset schedule.
4. If T2 falls 5°F below the set point for 5 minutes, then the existing gas boilers will be enabled. The gas boilers will fire to maintain the building loop temperature as they are currently configured to do. When T2 reaches set point, the gas boilers will be disabled.
5. P8 supplies hot water to the new overhead hydronic unit heaters in the garage area. The water temperature sent to these is regulated by a mixing valve on an outside reset schedule in order to maximize the effectiveness of the thermal storage.
6. The existing radiant heaters in the garage area will be staged such that they will activate if the new hydronic unit heaters fail to supply the necessary heat.

Notes:

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

Option 3 - Pellet Boilers

Legend

Butterfly Valve

Control Valve

Three Way Mixing Valve

Pump

(T) Temperature Transmitter

VFD Variable Frequency Drive

Designed	PFO	8/8/16
Drawn	PFO	8/8/16
Checked	DAW	9/2/16

Approved ______ Date ______

Title ______ Job Class ______

St. Louis County Meadowlands Garage

Meadowlands, MN

Schematic for Pellet Boilers

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Date	Description	Approved

A.6

Appendix B – Capital Cost Estimates

- B.1 Option 1 – Indoor Cordwood Boiler System
- B.2 Option 2 – Outdoor Cordwood Boiler System
- B.3 Option 3 – Pellet Boiler System

Option 1 - Indoor Cordwood Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item	Cost
(2) 170,000 Btu/hr cordwood boilers, EPA certified, ASME rated	$ 25,000
1,000 gallon thermal storage tank(s)	$ 15,000
Boiler system controls, circulation pumps, containerization	$ 30,000
Total Boiler Manufacturer Contract	**$ 70,000**

General Contract

Line Item	Cost
Site work for container	$ 10,000
Electrical and plumbing interconnection to main boiler room	$ 10,000
Hydronic unit heaters in garage area	$ 10,000
Wood storage sheds/racks	$ 5,000
Sub-Total	$ 35,000
Contractor profit, overhead, and insurance 16%	*$ 5,600*
Total General Contract Building and Site[2]	**$ 40,600**

Total Project Cost

Line Item	Cost
Project Sub-Total (Boiler, General Contract, Additional Items)	$ 110,600
Professional Services[3] 10%	*$ 11,060*
Contingency 15%	*$ 16,590*
Total Project Cost	**$ 138,250**

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 - Outdoor Cordwood Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item	Cost
(2) 170,000 Btu/hr outdoor cordwood boilers, EPA certified, ASME rated	$ 29,000
Shipping	$ 1,000
Total Boiler Manufacturer Contract	**$ 30,000**

General Contract

Line Item	Cost
1,000 gallon thermal storage tank(s)	$ 15,000
Electrical and plumbing interconnection to thermal storage tank and main boiler room	$ 10,000
Hydronic unit heaters in garage area	$ 10,000
Wood storage sheds/racks	$ 5,000
Sub-Total	$ 40,000
Contractor profit, overhead, and insurance 16%	*$ 6,400*
Total General Contract Building and Site[2]	**$ 46,400**

Total Project Cost

Line Item	Cost
Project Sub-Total (Boiler, General Contract, Additional Items)	$ 76,400
Professional Services[3] 10%	*$ 7,640*
Contingency 15%	*$ 11,460*
Total Project Cost	**$ 95,500**

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 - Pellet Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item		Cost
(2) 191,000 Btu/hr pellet boilers and controls	$	42,000
Circulation pumps, expansion tanks, wiring, lighting, containerization	$	35,000
Shipping	$	10,000
Total Boiler Manufacturer Contract	**$**	**87,000**

General Contract

Line Item			Cost
Site work for silo and container		$	5,000
30 ton pellet silo and flex auger system		$	15,000
120 gallon thermal storage tank and indirect domestic hot water		$	3,250
Electrical and plumbing interconnection to main boiler room		$	10,000
Hydronic unit heaters in garage area		$	10,000
Sub-Total		$	43,250
Contractor profit, overhead, and insurance	*16%*	*$*	*6,920*
Total General Contract Building and Site[2]		**$**	**50,170**

Total Project Cost

Line Item			Cost
Project Sub-Total (Boiler and General Contract)		$	137,170
Professional Services [3]	*10%*	*$*	*13,717*
Contingency	*15%*	*$*	*20,576*
Total Project Cost		**$**	**171,463**

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 Financial Analysis
- C.2 Option 1 Financial Analysis with 25% Grant
- C.3 Option 1 Fuel Cost Sensitivity Analysis
- C.4 Option 2 Financial Analysis
- C.5 Option 2 Financial Analysis with 25% Grant
- C.6 Option 2 Fuel Cost Sensitivity Analysis
- C.7 Option 3 Financial Analysis
- C.8 Option 3 Financial Analysis with 25% Grant
- C.9 Option 3 Fuel Cost Sensitivity Analysis

Appendix C

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

Input Variables	Value	Units
Project Costs Financed	$138,250	$
Grant Amount	$0	$
Project Costs Financed	$138,250	$
Annual Propane Usage	11,391	gal
Average Propane Price	$1.49	$/gal
Cordwood Usage	46	cords/yr
Year 1 Cordwood Price	$220	$/cord
Annual Propane Usage w/ Wood System	2,848	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	$5,480	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (138,250)	$ (138,250)
1	$ 16,972	$ (10,204)	$ (4,243)	$ (5,480)	$ (2,954)	$ 2,916	$ (38)	$ (37)
2	$ 17,227	$ (10,255)	$ (4,307)	$ (5,480)	$ (2,814)	$ 2,839	$ 25	$ 25
3	$ 17,485	$ (10,306)	$ (4,371)	$ (5,480)	$ (2,671)	$ 2,765	$ 93	$ 91
4	$ 17,748	$ (10,357)	$ (4,437)	$ (5,480)	$ (2,526)	$ 2,692	$ 166	$ 159
5	$ 18,014	$ (10,409)	$ (4,503)	$ (5,480)	$ (2,378)	$ 2,621	$ 243	$ 231
6	$ 18,284	$ (10,461)	$ (4,571)	$ (5,480)	$ (2,228)	$ 2,552	$ 325	$ 306
7	$ 18,558	$ (10,514)	$ (4,640)	$ (5,480)	$ (2,074)	$ 2,485	$ 411	$ 383
8	$ 18,837	$ (10,566)	$ (4,709)	$ (5,480)	$ (1,918)	$ 2,420	$ 502	$ 463
9	$ 19,119	$ (10,619)	$ (4,780)	$ (5,480)	$ (1,759)	$ 2,356	$ 597	$ 546
10	$ 19,406	$ (10,672)	$ (4,852)	$ (5,480)	$ (1,597)	$ 2,294	$ 697	$ 631
11	$ 19,697	$ (10,725)	$ (4,924)	$ (5,480)	$ (1,432)		$ (1,432)	$ (1,284)
12	$ 19,993	$ (10,779)	$ (4,998)	$ (5,480)	$ (1,264)		$ (1,264)	$ (1,122)
13	$ 20,292	$ (10,833)	$ (5,073)	$ (5,480)	$ (1,093)		$ (1,093)	$ (960)
14	$ 20,597	$ (10,887)	$ (5,149)	$ (5,480)	$ (919)		$ (919)	$ (799)
15	$ 20,906	$ (10,941)	$ (5,226)	$ (5,480)	$ (742)		$ (742)	$ (639)
16	$ 21,219	$ (10,996)	$ (5,305)	$ (5,480)	$ (561)		$ (561)	$ (479)
17	$ 21,538	$ (11,051)	$ (5,384)	$ (5,480)	$ (377)		$ (377)	$ (319)
18	$ 21,861	$ (11,106)	$ (5,465)	$ (5,480)	$ (190)		$ (190)	$ (159)
19	$ 22,189	$ (11,162)	$ (5,547)	$ (5,480)	$ 0		$ 0	$ 0
20	$ 22,522	$ (11,218)	$ (5,630)	$ (5,480)	$ 194		$ 194	$ 159
21	$ 22,859	$ (11,274)	$ (5,715)	$ (5,480)	$ 391		$ 391	$ 317
22	$ 23,202	$ (11,330)	$ (5,801)	$ (5,480)	$ 592		$ 592	$ 476
23	$ 23,550	$ (11,387)	$ (5,888)	$ (5,480)	$ 796		$ 796	$ 633
24	$ 23,904	$ (11,444)	$ (5,976)	$ (5,480)	$ 1,004		$ 1,004	$ 791
25	$ 24,262	$ (11,501)	$ (6,066)	$ (5,480)	$ 1,216		$ 1,216	$ 948
							25-year Net Present Value	**$ (137,888)**

Note: All values are in real dollars.

Appendix C

Option 1 - Indoor Cordwood Boiler
25-year Cash Flow Analysis with 25% Grant

Input Variables	Value	Units
Project Costs Financed	$138,250	$
Grant Amount	$34,563	$
Project Costs Financed	$103,688	$
Annual Propane Usage	11,391	gal
Average Propane Price	$1.49	$/gal
Cordwood Usage	46	cords/yr
Year 1 Cordwood Price	$220	$/cord
Annual Propane Usage w/ Wood System	2,848	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	$5,480	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (103,688)	$ (103,688)
1	$ 16,972	$ (10,204)	$ (4,243)	$ (5,480)	$ (2,954)	$ 2,916	$ (38)	$ (37)
2	$ 17,227	$ (10,255)	$ (4,307)	$ (5,480)	$ (2,814)	$ 2,839	$ 25	$ 25
3	$ 17,485	$ (10,306)	$ (4,371)	$ (5,480)	$ (2,671)	$ 2,765	$ 93	$ 91
4	$ 17,748	$ (10,357)	$ (4,437)	$ (5,480)	$ (2,526)	$ 2,692	$ 166	$ 159
5	$ 18,014	$ (10,409)	$ (4,503)	$ (5,480)	$ (2,378)	$ 2,621	$ 243	$ 231
6	$ 18,284	$ (10,461)	$ (4,571)	$ (5,480)	$ (2,228)	$ 2,552	$ 325	$ 306
7	$ 18,558	$ (10,514)	$ (4,640)	$ (5,480)	$ (2,074)	$ 2,485	$ 411	$ 383
8	$ 18,837	$ (10,566)	$ (4,709)	$ (5,480)	$ (1,918)	$ 2,420	$ 502	$ 463
9	$ 19,119	$ (10,619)	$ (4,780)	$ (5,480)	$ (1,759)	$ 2,356	$ 597	$ 546
10	$ 19,406	$ (10,672)	$ (4,852)	$ (5,480)	$ (1,597)	$ 2,294	$ 697	$ 631
11	$ 19,697	$ (10,725)	$ (4,924)	$ (5,480)	$ (1,432)		$ (1,432)	$ (1,284)
12	$ 19,993	$ (10,779)	$ (4,998)	$ (5,480)	$ (1,264)		$ (1,264)	$ (1,122)
13	$ 20,292	$ (10,833)	$ (5,073)	$ (5,480)	$ (1,093)		$ (1,093)	$ (960)
14	$ 20,597	$ (10,887)	$ (5,149)	$ (5,480)	$ (919)		$ (919)	$ (799)
15	$ 20,906	$ (10,941)	$ (5,226)	$ (5,480)	$ (742)		$ (742)	$ (639)
16	$ 21,219	$ (10,996)	$ (5,305)	$ (5,480)	$ (561)		$ (561)	$ (479)
17	$ 21,538	$ (11,051)	$ (5,384)	$ (5,480)	$ (377)		$ (377)	$ (319)
18	$ 21,861	$ (11,106)	$ (5,465)	$ (5,480)	$ (190)		$ (190)	$ (159)
19	$ 22,189	$ (11,162)	$ (5,547)	$ (5,480)	$ 0		$ 0	$ 0
20	$ 22,522	$ (11,218)	$ (5,630)	$ (5,480)	$ 194		$ 194	$ 159
21	$ 22,859	$ (11,274)	$ (5,715)	$ (5,480)	$ 391		$ 391	$ 317
22	$ 23,202	$ (11,330)	$ (5,801)	$ (5,480)	$ 592		$ 592	$ 476
23	$ 23,550	$ (11,387)	$ (5,888)	$ (5,480)	$ 796		$ 796	$ 633
24	$ 23,904	$ (11,444)	$ (5,976)	$ (5,480)	$ 1,004		$ 1,004	$ 791
25	$ 24,262	$ (11,501)	$ (6,066)	$ (5,480)	$ 1,216		$ 1,216	$ 948
							25-year Net Present Value	**$ (103,325)**

Note: All values are in real dollars.

Option 1 - Indoor Cordwood Boiler
Fuel Cost Sensitivity Analysis

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

Price of Cordwood - $/cord	Fossil Fuel Price, $/gal						
	$0.75	**$1.00**	**$1.25**	**$1.49**	**$1.75**	**$2.00**	**$2.25**
$120	($4,638)	($2,502)	($366)	$1,684	$3,905	$6,041	$8,177
$130	($5,102)	($2,966)	($830)	$1,220	$3,442	$5,577	$7,713
$140	($5,565)	($3,430)	($1,294)	$757	$2,978	$5,114	$7,249
$150	($6,029)	($3,893)	($1,758)	$293	$2,514	$4,650	$6,786
$160	($6,493)	($4,357)	($2,221)	($171)	$2,050	$4,186	$6,322
$170	($6,957)	($4,821)	($2,685)	($635)	$1,586	$3,722	$5,858
$180	($7,421)	($5,285)	($3,149)	($1,099)	$1,123	$3,258	$5,394
$190	($7,884)	($5,749)	($3,613)	($1,562)	$659	$2,795	$4,930
$200	($8,348)	($6,212)	($4,077)	($2,026)	$195	$2,331	$4,467
$210	($8,812)	($6,676)	($4,540)	($2,490)	($269)	$1,867	$4,003
$220	($9,276)	($7,140)	($5,004)	($2,954)	($733)	$1,403	$3,539
$230	($9,740)	($7,604)	($5,468)	($3,418)	($1,196)	$939	$3,075
$240	($10,203)	($8,068)	($5,932)	($3,881)	($1,660)	$476	$2,611
$250	($10,667)	($8,531)	($6,396)	($4,345)	($2,124)	$12	$2,148

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

Option 2 - Outdoor Cordwood Boiler
25-year Cash Flow Analysis

Input Variables	Value	Units
Project Costs Financed	$95,500	$
Grant Amount	$0	$
Project Costs Financed	$95,500	$
Annual Propane Usage	11,391	gal
Average Propane Price	$1.49	$/gal
Cordwood Usage	50	cords/yr
Year 1 Cordwood Price	$220	$/cord
Annual Propane Usage w/ Wood System	2,848	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	$5,480	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (95,500)	$ (95,500)
1	$ 16,972	$ (11,054)	$ (4,243)	$ (5,480)	$ (3,804)	$ 2,916	$ (888)	$ (879)
2	$ 17,227	$ (11,109)	$ (4,307)	$ (5,480)	$ (3,668)	$ 2,839	$ (829)	$ (813)
3	$ 17,485	$ (11,165)	$ (4,371)	$ (5,480)	$ (3,530)	$ 2,765	$ (766)	$ (743)
4	$ 17,748	$ (11,220)	$ (4,437)	$ (5,480)	$ (3,389)	$ 2,692	$ (697)	$ (670)
5	$ 18,014	$ (11,277)	$ (4,503)	$ (5,480)	$ (3,246)	$ 2,621	$ (625)	$ (594)
6	$ 18,284	$ (11,333)	$ (4,571)	$ (5,480)	$ (3,099)	$ 2,552	$ (547)	$ (515)
7	$ 18,558	$ (11,390)	$ (4,640)	$ (5,480)	$ (2,950)	$ 2,485	$ (465)	$ (434)
8	$ 18,837	$ (11,447)	$ (4,709)	$ (5,480)	$ (2,799)	$ 2,420	$ (379)	$ (350)
9	$ 19,119	$ (11,504)	$ (4,780)	$ (5,480)	$ (2,644)	$ 2,356	$ (288)	$ (263)
10	$ 19,406	$ (11,561)	$ (4,852)	$ (5,480)	$ (2,486)	$ 2,294	$ (192)	$ (174)
11	$ 19,697	$ (11,619)	$ (4,924)	$ (5,480)	$ (2,326)		$ (2,326)	$ (2,085)
12	$ 19,993	$ (11,677)	$ (4,998)	$ (5,480)	$ (2,162)		$ (2,162)	$ (1,919)
13	$ 20,292	$ (11,736)	$ (5,073)	$ (5,480)	$ (1,996)		$ (1,996)	$ (1,754)
14	$ 20,597	$ (11,794)	$ (5,149)	$ (5,480)	$ (1,826)		$ (1,826)	$ (1,589)
15	$ 20,906	$ (11,853)	$ (5,226)	$ (5,480)	$ (1,653)		$ (1,653)	$ (1,424)
16	$ 21,219	$ (11,913)	$ (5,305)	$ (5,480)	$ (1,477)		$ (1,477)	$ (1,260)
17	$ 21,538	$ (11,972)	$ (5,384)	$ (5,480)	$ (1,298)		$ (1,298)	$ (1,096)
18	$ 21,861	$ (12,032)	$ (5,465)	$ (5,480)	$ (1,116)		$ (1,116)	$ (933)
19	$ 22,189	$ (12,092)	$ (5,547)	$ (5,480)	$ (930)		$ (930)	$ (770)
20	$ 22,522	$ (12,153)	$ (5,630)	$ (5,480)	$ (741)		$ (741)	$ (607)
21	$ 22,859	$ (12,213)	$ (5,715)	$ (5,480)	$ (548)		$ (548)	$ (445)
22	$ 23,202	$ (12,274)	$ (5,801)	$ (5,480)	$ (352)		$ (352)	$ (283)
23	$ 23,550	$ (12,336)	$ (5,888)	$ (5,480)	$ (153)		$ (153)	$ (121)
24	$ 23,904	$ (12,397)	$ (5,976)	$ (5,480)	$ 51		$ 51	$ 40
25	$ 24,262	$ (12,459)	$ (6,066)	$ (5,480)	$ 258		$ 258	$ 201
						25-year Net Present Value		**$ (114,981)**

Note: All values are in real dollars.

Appendix C

Option 2 - Outdoor Cordwood Boiler
25-year Cash Flow Analysis with 25% Grant

Input Variables	Value	Units
Project Costs Financed	$95,500	$
Grant Amount	$23,875	$
Project Costs Financed	$71,625	$
Annual Propane Usage	11,391	gal
Average Propane Price	$1.49	$/gal
Cordwood Usage	50	cords/yr
Year 1 Cordwood Price	$220	$/cord
Annual Propane Usage w/ Wood System	2,848	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	$5,480	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (71,625)	$ (71,625)
1	$ 16,972	$ (11,054)	$ (4,243)	$ (5,480)	$ (3,804)	$ 2,916	$ (888)	$ (879)
2	$ 17,227	$ (11,109)	$ (4,307)	$ (5,480)	$ (3,668)	$ 2,839	$ (829)	$ (813)
3	$ 17,485	$ (11,165)	$ (4,371)	$ (5,480)	$ (3,530)	$ 2,765	$ (766)	$ (743)
4	$ 17,748	$ (11,220)	$ (4,437)	$ (5,480)	$ (3,389)	$ 2,692	$ (697)	$ (670)
5	$ 18,014	$ (11,277)	$ (4,503)	$ (5,480)	$ (3,246)	$ 2,621	$ (625)	$ (594)
6	$ 18,284	$ (11,333)	$ (4,571)	$ (5,480)	$ (3,099)	$ 2,552	$ (547)	$ (515)
7	$ 18,558	$ (11,390)	$ (4,640)	$ (5,480)	$ (2,950)	$ 2,485	$ (465)	$ (434)
8	$ 18,837	$ (11,447)	$ (4,709)	$ (5,480)	$ (2,799)	$ 2,420	$ (379)	$ (350)
9	$ 19,119	$ (11,504)	$ (4,780)	$ (5,480)	$ (2,644)	$ 2,356	$ (288)	$ (263)
10	$ 19,406	$ (11,561)	$ (4,852)	$ (5,480)	$ (2,486)	$ 2,294	$ (192)	$ (174)
11	$ 19,697	$ (11,619)	$ (4,924)	$ (5,480)	$ (2,326)		$ (2,326)	$ (2,085)
12	$ 19,993	$ (11,677)	$ (4,998)	$ (5,480)	$ (2,162)		$ (2,162)	$ (1,919)
13	$ 20,292	$ (11,736)	$ (5,073)	$ (5,480)	$ (1,996)		$ (1,996)	$ (1,754)
14	$ 20,597	$ (11,794)	$ (5,149)	$ (5,480)	$ (1,826)		$ (1,826)	$ (1,589)
15	$ 20,906	$ (11,853)	$ (5,226)	$ (5,480)	$ (1,653)		$ (1,653)	$ (1,424)
16	$ 21,219	$ (11,913)	$ (5,305)	$ (5,480)	$ (1,477)		$ (1,477)	$ (1,260)
17	$ 21,538	$ (11,972)	$ (5,384)	$ (5,480)	$ (1,298)		$ (1,298)	$ (1,096)
18	$ 21,861	$ (12,032)	$ (5,465)	$ (5,480)	$ (1,116)		$ (1,116)	$ (933)
19	$ 22,189	$ (12,092)	$ (5,547)	$ (5,480)	$ (930)		$ (930)	$ (770)
20	$ 22,522	$ (12,153)	$ (5,630)	$ (5,480)	$ (741)		$ (741)	$ (607)
21	$ 22,859	$ (12,213)	$ (5,715)	$ (5,480)	$ (548)		$ (548)	$ (445)
22	$ 23,202	$ (12,274)	$ (5,801)	$ (5,480)	$ (352)		$ (352)	$ (283)
23	$ 23,550	$ (12,336)	$ (5,888)	$ (5,480)	$ (153)		$ (153)	$ (121)
24	$ 23,904	$ (12,397)	$ (5,976)	$ (5,480)	$ 51		$ 51	$ 40
25	$ 24,262	$ (12,459)	$ (6,066)	$ (5,480)	$ 258		$ 258	$ 201
							25-year Net Present Value	**$ (91,106)**

Note: All values are in real dollars.

Appendix C

Option 2 - Outdoor Cordwood Boiler
Fuel Cost Sensitivity Analysis

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

		Fossil Fuel Price, $/gal						
		$0.75	**$1.00**	**$1.25**	**$1.49**	**$1.75**	**$2.00**	**$2.25**
Price of Cordwood - $/cord	**$120**	($5,102)	($2,966)	($830)	$1,220	$3,442	$5,577	$7,713
	$130	($5,604)	($3,468)	($1,332)	$718	$2,939	$5,075	$7,211
	$140	($6,106)	($3,971)	($1,835)	$216	$2,437	$4,573	$6,708
	$150	($6,609)	($4,473)	($2,337)	($287)	$1,934	$4,070	$6,206
	$160	($7,111)	($4,976)	($2,840)	($789)	$1,432	$3,568	$5,703
	$170	($7,614)	($5,478)	($3,342)	($1,292)	$929	$3,065	$5,201
	$180	($8,116)	($5,980)	($3,845)	($1,794)	$427	$2,563	$4,699
	$190	($8,619)	($6,483)	($4,347)	($2,297)	($76)	$2,060	$4,196
	$200	($9,121)	($6,985)	($4,850)	($2,799)	($578)	$1,558	$3,694
	$210	($9,624)	($7,488)	($5,352)	($3,302)	($1,080)	$1,055	$3,191
	$220	($10,126)	($7,990)	($5,854)	($3,804)	($1,583)	$553	$2,689
	$230	($10,628)	($8,493)	($6,357)	($4,307)	($2,085)	$50	$2,186
	$240	($11,131)	($8,995)	($6,859)	($4,809)	($2,588)	($452)	$1,684
	$250	($11,633)	($9,498)	($7,362)	($5,311)	($3,090)	($954)	$1,181

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

Option 3 - Pellet Boiler
25-year Cash Flow Analysis

Input Variables	Value	Units
Project Costs Financed	$171,463	$
Grant Amount	$0	$
Project Costs Financed	$171,463	$
Annual Propane Usage	11,391	gal
Average Propane Price	$1.49	$/gal
Pellet Usage	64	tons/yr
Year 1 Pellet Price	$194	$/ton
Annual Propane Usage w/ Wood System	570	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	$1,727	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (171,463)	$ (171,463)
1	$ 16,972	$ (12,422)	$ (849)	$ (1,727)	$ 1,974	$ 3,693	$ 5,668	$ 5,612
2	$ 17,227	$ (12,484)	$ (861)	$ (1,727)	$ 2,154	$ 3,596	$ 5,751	$ 5,637
3	$ 17,485	$ (12,547)	$ (874)	$ (1,727)	$ 2,337	$ 3,502	$ 5,839	$ 5,667
4	$ 17,748	$ (12,609)	$ (887)	$ (1,727)	$ 2,524	$ 3,410	$ 5,933	$ 5,702
5	$ 18,014	$ (12,672)	$ (901)	$ (1,727)	$ 2,714	$ 3,320	$ 6,034	$ 5,741
6	$ 18,284	$ (12,736)	$ (914)	$ (1,727)	$ 2,907	$ 3,233	$ 6,140	$ 5,784
7	$ 18,558	$ (12,799)	$ (928)	$ (1,727)	$ 3,104	$ 3,148	$ 6,252	$ 5,831
8	$ 18,837	$ (12,863)	$ (942)	$ (1,727)	$ 3,304	$ 3,065	$ 6,369	$ 5,882
9	$ 19,119	$ (12,928)	$ (956)	$ (1,727)	$ 3,508	$ 2,985	$ 6,493	$ 5,937
10	$ 19,406	$ (12,992)	$ (970)	$ (1,727)	$ 3,716	$ 2,906	$ 6,622	$ 5,995
11	$ 19,697	$ (13,057)	$ (985)	$ (1,727)	$ 3,928		$ 3,928	$ 3,521
12	$ 19,993	$ (13,123)	$ (1,000)	$ (1,727)	$ 4,143		$ 4,143	$ 3,677
13	$ 20,292	$ (13,188)	$ (1,015)	$ (1,727)	$ 4,362		$ 4,362	$ 3,833
14	$ 20,597	$ (13,254)	$ (1,030)	$ (1,727)	$ 4,586		$ 4,586	$ 3,989
15	$ 20,906	$ (13,320)	$ (1,045)	$ (1,727)	$ 4,813		$ 4,813	$ 4,146
16	$ 21,219	$ (13,387)	$ (1,061)	$ (1,727)	$ 5,044		$ 5,044	$ 4,302
17	$ 21,538	$ (13,454)	$ (1,077)	$ (1,727)	$ 5,280		$ 5,280	$ 4,458
18	$ 21,861	$ (13,521)	$ (1,093)	$ (1,727)	$ 5,519		$ 5,519	$ 4,614
19	$ 22,189	$ (13,589)	$ (1,109)	$ (1,727)	$ 5,763		$ 5,763	$ 4,770
20	$ 22,522	$ (13,657)	$ (1,126)	$ (1,727)	$ 6,011		$ 6,011	$ 4,927
21	$ 22,859	$ (13,725)	$ (1,143)	$ (1,727)	$ 6,264		$ 6,264	$ 5,083
22	$ 23,202	$ (13,794)	$ (1,160)	$ (1,727)	$ 6,521		$ 6,521	$ 5,239
23	$ 23,550	$ (13,863)	$ (1,178)	$ (1,727)	$ 6,783		$ 6,783	$ 5,395
24	$ 23,904	$ (13,932)	$ (1,195)	$ (1,727)	$ 7,049		$ 7,049	$ 5,552
25	$ 24,262	$ (14,002)	$ (1,213)	$ (1,727)	$ 7,320		$ 7,320	$ 5,708
							25-year Net Present Value	**$ (44,461)**

Note: All values are in real dollars.

Option 3 - Pellet Boiler
25-year Cash Flow Analysis with 25% Grant

St. Louis County Department of Public Works
Meadowlands, MN

Input Variables	Value	Units
Project Costs Financed	$171,463	$
Grant Amount	$42,866	$
Project Costs Financed	$128,597	$
Annual Propane Usage	11,391	gal
Average Propane Price	$1.49	$/gal
Pellet Usage	64	tons/yr
Year 1 Pellet Price	$194	$/ton
Annual Propane Usage w/ Wood System	570	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	$1,727	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (128,597)	$ (128,597)
1	$ 16,972	$ (12,422)	$ (849)	$ (1,727)	$ 1,974	$ 3,693	$ 5,668	$ 5,612
2	$ 17,227	$ (12,484)	$ (861)	$ (1,727)	$ 2,154	$ 3,596	$ 5,751	$ 5,637
3	$ 17,485	$ (12,547)	$ (874)	$ (1,727)	$ 2,337	$ 3,502	$ 5,839	$ 5,667
4	$ 17,748	$ (12,609)	$ (887)	$ (1,727)	$ 2,524	$ 3,410	$ 5,933	$ 5,702
5	$ 18,014	$ (12,672)	$ (901)	$ (1,727)	$ 2,714	$ 3,320	$ 6,034	$ 5,741
6	$ 18,284	$ (12,736)	$ (914)	$ (1,727)	$ 2,907	$ 3,233	$ 6,140	$ 5,784
7	$ 18,558	$ (12,799)	$ (928)	$ (1,727)	$ 3,104	$ 3,148	$ 6,252	$ 5,831
8	$ 18,837	$ (12,863)	$ (942)	$ (1,727)	$ 3,304	$ 3,065	$ 6,369	$ 5,882
9	$ 19,119	$ (12,928)	$ (956)	$ (1,727)	$ 3,508	$ 2,985	$ 6,493	$ 5,937
10	$ 19,406	$ (12,992)	$ (970)	$ (1,727)	$ 3,716	$ 2,906	$ 6,622	$ 5,995
11	$ 19,697	$ (13,057)	$ (985)	$ (1,727)	$ 3,928		$ 3,928	$ 3,521
12	$ 19,993	$ (13,123)	$ (1,000)	$ (1,727)	$ 4,143		$ 4,143	$ 3,677
13	$ 20,292	$ (13,188)	$ (1,015)	$ (1,727)	$ 4,362		$ 4,362	$ 3,833
14	$ 20,597	$ (13,254)	$ (1,030)	$ (1,727)	$ 4,586		$ 4,586	$ 3,989
15	$ 20,906	$ (13,320)	$ (1,045)	$ (1,727)	$ 4,813		$ 4,813	$ 4,146
16	$ 21,219	$ (13,387)	$ (1,061)	$ (1,727)	$ 5,044		$ 5,044	$ 4,302
17	$ 21,538	$ (13,454)	$ (1,077)	$ (1,727)	$ 5,280		$ 5,280	$ 4,458
18	$ 21,861	$ (13,521)	$ (1,093)	$ (1,727)	$ 5,519		$ 5,519	$ 4,614
19	$ 22,189	$ (13,589)	$ (1,109)	$ (1,727)	$ 5,763		$ 5,763	$ 4,770
20	$ 22,522	$ (13,657)	$ (1,126)	$ (1,727)	$ 6,011		$ 6,011	$ 4,927
21	$ 22,859	$ (13,725)	$ (1,143)	$ (1,727)	$ 6,264		$ 6,264	$ 5,083
22	$ 23,202	$ (13,794)	$ (1,160)	$ (1,727)	$ 6,521		$ 6,521	$ 5,239
23	$ 23,550	$ (13,863)	$ (1,178)	$ (1,727)	$ 6,783		$ 6,783	$ 5,395
24	$ 23,904	$ (13,932)	$ (1,195)	$ (1,727)	$ 7,049		$ 7,049	$ 5,552
25	$ 24,262	$ (14,002)	$ (1,213)	$ (1,727)	$ 7,320		$ 7,320	$ 5,708
							25-year Net Present Value	**$ (1,596)**

Note: All values are in real dollars.

Option 3 - Pellet Boiler
Fuel Cost Sensitivity Analysis

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

Price of Pellets - $/ton	Fossil Fuel Price, $/gal						
	$0.75	**$1.00**	**$1.25**	**$1.49**	**$1.75**	**$2.00**	**$2.25**
$170	($4,497)	($1,791)	$914	$3,511	$6,325	$9,030	$11,735
$175	($4,817)	($2,111)	$594	$3,191	$6,005	$8,710	$11,415
$180	($5,137)	($2,432)	$274	$2,871	$5,684	$8,390	$11,095
$185	($5,457)	($2,752)	($46)	$2,551	$5,364	$8,070	$10,775
$190	($5,777)	($3,072)	($367)	$2,231	$5,044	$7,749	$10,455
$194	($6,033)	($3,328)	($623)	$1,974	$4,788	$7,493	$10,199
$200	($6,417)	($3,712)	($1,007)	$1,590	$4,404	$7,109	$9,814
$205	($6,738)	($4,032)	($1,327)	$1,270	$4,084	$6,789	$9,494
$210	($7,058)	($4,352)	($1,647)	$950	$3,764	$6,469	$9,174
$215	($7,378)	($4,673)	($1,967)	$630	$3,443	$6,149	$8,854
$220	($7,698)	($4,993)	($2,287)	$310	$3,123	$5,829	$8,534
$225	($8,018)	($5,313)	($2,608)	($11)	$2,803	$5,508	$8,214
$230	($8,338)	($5,633)	($2,928)	($331)	$2,483	$5,188	$7,894
$235	($8,659)	($5,953)	($3,248)	($651)	$2,163	$4,868	$7,573

**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
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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.