Minnesota Department of Natural Resources

Ely Public Works Garage

Biomass Energy System

Preliminary Feasibility Report

Wilson Engineering Services, PC

FINAL

9/27/2016

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1.0 EXECUTIVE SUMMARY

The St. Louis County highway department operates a maintenance shop and truck garage in Ely, MN. This garage is heated by electric and propane hot water boilers and uses an average of 656,500 kWh per year with an electric rate of $0.0674 per kWh, and an average of 8,850 gallons of propane per year with a five-year average propane price of $1.48 per gallon. A heating system utilizing woody biomass 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. Wood pellets are evaluated for this facility. The system evaluated in this study would require an estimated 193 tons of wood pellets, annually. Table ES1 compares the cost of delivered heat for wood and fossil fuels.

Table ES1 – Fuel Pricing and Cost per mmBtu

Fuel, units	Unit Cost ($/unit)	Heating Value (mmBtu/unit)	Assumed Efficiency	Output Cost ($/mmBtu)
Electric[1], kWh	$0.0674	0.003412	100%	$19.75
Propane[2], gallon	$1.478	0.091333	80%	$20.23
Hardwood Pellets[3], ton	$206	16.4	80%	$15.70
Dry Wood Chips[4], ton	$80	12.0	75%	$8.89

Note 1: Electric unit cost represents the average 2014-2015 "Dual Fuel" electric rate.
Note 2: Propane unit cost represents the 2012-2016 average delivered per gallon propane cost.
Note 3: Pellet unit cost represents a bulk price of $170/ton at the gate plus a delivery cost of $5 per loaded mile.
Note 4: Dry wood chips (25-30% moisture wet basis) are not commercially available in Ely. Cost for dry wood chips is estimated by WES as a fair market price.

The biomass boiler system evaluated for this facility consists of a wood pellet hot water boiler, rated 1,000,000 Btu/hr. A 1,000 gallon thermal storage tank would be installed with the boiler system to provide additional heating capacity and improve system efficiency. The boiler would be installed in a new biomass boiler building located adjacent to the existing generators and connected to the existing hydronic system. The pellet boiler would offset approximately 90% of the facility's annual electric and propane use from the existing boilers.

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
Pellet Boiler System	$422,150

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

Table ES3 – Proposed System Fuel Use Profile

Option	Current Annual Fuel Use		Annual Fuel Use with Proposed Biomass System			
	Electric (kWh)	Propane (gal)	Biomass Demand Coverage	Estimated Pellet Use (tons)		Estimated Propane Use with Biomass System (gal)
				Oct-Mar	Apr-Sep	
Pellet Boiler vs Existing Use[1]	656,500	7,869	90%	170	23	3,853
Pellet Boiler vs 100% Propane[2]	0	38,526	90%	170	23	3,853

Note 1: Represents the fuel profile of a pellet system vs. the current operation of existing boilers.
Note 2: Represents the fuel profile of a pellet system vs. 100% heating by the existing propane boilers.

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 Costs		Estimated Annual Costs with Proposed Biomass System			Estimated First Year Operational Savings	Thermal Production Incentive	Estimated Net Cash Flow
	Electric Cost	Propane Cost	Biomass Cost	Propane Cost	O&M Increase			
Pellet Boiler vs Existing Use[1]	$44,248	$11,634	$39,778	$5,696	$1,650	$8,758	$11,147	$19,905
Pellet Boiler vs 100% Propane[2]	$0	$56,959	$39,778	$5,696	$1,650	$9,834	$11,147	$20,982

Note 1: Represents the fuel profile of a pellet system vs. the current operation of existing boilers.
Note 2: Represents the fuel profile of a pellet system vs. 100% heating by the existing propane boilers.

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[3]	Net Present Value (25 years)
Pellet Boiler vs Existing Use[1]	$ 422,150	$ -	$ 422,150	35.5	$ 26,275
Pellet Boiler vs 100% Propane[2]	$ 422,150	$ -	$ 422,150	31.6	$ 54,561
Pellet Boiler vs Existing Use (with grant)[1]	$ 422,150	$ 105,538	$ 316,613	23.4	$ 131,813
Pellet Boiler vs 100% Propane (with grant)[2]	$ 422,150	$ 105,538	$ 316,613	20.9	$ 160,098

Note 1: Represents the fuel profile of a pellet system vs. the current operation of existing boilers.
Note 2: Represents the fuel profile of a pellet system vs. 100% heating by the existing propane boilers.
Note 3: Simple payback is calculated taking into account the assumption that thermal production incentive payments end after 10 years.

A modern biomass boiler system would allow the Ely Garage to reduce fossil fuel use while utilizing a local and renewable source of energy. The proposed system evaluated in this report would have a capital cost of $422,150, would provide a net cash flow of $19,905 vs. the existing fuel profile, a net cash flow of $20,982 vs. a 100% propane fuel profile, and would have a 25 year net present value of $26,275 vs. the existing fuel profile, and $54,561 vs. a 100% propane fuel profile.

Financial performance of the evaluated system 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 or electric rises, then the savings will increase fairly dramatically. 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 in today's dollars becomes $8,758 vs. the existing fuel profile, and $9,834 vs. a 100% propane fuel profile.

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

- Net reduction of greenhouse gas emissions by 192 - 2,210 metric tonnes annually,
- Keeping ~$40,000/year 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.

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 ELY GARAGE OPPORTUNITY

The St. Louis County Ely Garage is located in Ely, MN and is used for storage and servicing of equipment and as a base for work crews. The building is also shared by the City of Ely Public Works Department. The building was built in 2007 and is heated by propane and electricity. 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 has the potential to reduce fuel costs and greenhouse gas emissions for this facility, while utilizing a renewable, local fuel source.

3.0 FACILITY OVERVIEW

WES personnel conducted a site visit on June 21, 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 70,140 square feet and was constructed in 2007. Figure 1 shows the maintenance garage on the left, the offices on the right, and the truck garage in the background.

Figure 1 – Ely Garage

The facility has 3 boilers that feed a hydronic system that provides the majority of the heating needs. There are also two large air handlers in the garage area that have large propane burners for heating outside air, but these are not typically operating. They are triggered to come on based on sensing NOx and CO, and can also be manually turned on if needed. The boilers include 1 electric and 2 propane units. There are also two domestic hot water (DHW) heaters, but the domestic hot water load is mostly sinks in the office area, and is minimal.

The electric boiler is manufactured by Precision Boilers and is model number PCW4-560D-480-150. The boiler is rated for 560 kW at 480 V 3 phase. It has 2 steps of 40 kW, and 6 steps of 80 kW, for a total output of 1,960,000 Btu/hr. The two propane boilers are identical, and are manufactured by RBI Water Heaters. The model number is LB1480, with an input rating of 1,480,000 Btu/hr, and an output rating of 1,213,600 Btu/hr.

The boilers each have a circulator which injects via closely spaced tees into the building loop. The propane boiler circulators are B&G 60, 2X5.25 3.375BF, 8' of head at 60 GPM, 1/3 HP, 1800 RPM. The building loop has two parallel plumbed pumps which are B&G 1510, BF 6.75, 2.5AB, C035545-02 A70, 40' of head at 167 GPM, 3 HP, 1800 RPM.

The facility uses the electric boiler as the lead boiler, using an interruptible "dual fuel" electric tariff. The propane boilers are used as backup and staff exercises them regularly to keep them in good condition. Hot water is used to heat radiant floors as well as air handlers in the office area. All propane comes from one propane tank which is approximately 15,000 gallons.

The two DHW heaters have the following ratings:

- 300,000 Btu/hr input, 130 gal
- 250,000 Btu/hr input, 100 gal

In the garage area, there are 2 direct fired makeup air handlers that run off of sensors for NOx and CO. These units are manufactured by Titan Air, and are model number TA-130 LP HRH. The units are rated 24,000 SCFM at 0.5" wc, with a maximum firing rate of 2,640,000 Btu/hr and a minimum firing rate of 105,600 Btu/hr, a maximum temperature rise of 120°F, and a maximum discharge temperature of 160°F.

4.0 BUILDING HEAT DEMAND

St. Louis County staff provided WES with propane delivery and costs for the previous five years. Table 1 lists the propane deliveries and costs of the previous five years. The Ely Garage averaged 8,850 gallons of propane per year with an average unit cost of approximately $1.48 per gallon. This average unit cost is used in the economic analysis of this study.

Table 1 – Propane Fuel Deliveries

Date	Propane Delivered (gallons)	Propane Cost ($)	Propane Unit Cost ($/gal)
2/1/2012[1]	8,600	$14,620	$1.700
2/9/2013	8,350	$11,779	$1.411
4/10/2014	9,499	$15,189	$1.599
12/12/2014	8,299	$12,440	$1.499
1/2/2016	9,500	$11,391	$1.199
5-Year Average	***8,850***	***$13,084***	***$1.48***

Note 1: Date of delivery was estimated based on PO number.

The Ely Garage has one propane tank that serves the propane boilers, domestic hot water heaters, and make-up air unit. The propane use for the domestic hot water heaters and make-up air unit do not represent heating demand for the facility. Propane use for domestic hot water and the make-up air unit were estimated, with the remaining propane attributed to the boilers. The estimated propane use by end user is presented in Table 2. The estimated boiler propane use is used in developing the estimated annual heating demand for the facility.

Table 2 – Estimated Propane Use by End User

Estimated Domestic Hot Water Propane Use[1] (gallons)	Estimated Make-up Air Unit Propane Use[2] (gallons)	Estimated Boiler Propane Use[3] (gallons)	Total Annual Propane Use (gallons)
258	723	7,869	8,850

Note 1: Propane use based on an estimated 5 gallons of hot water per day for 25 occupants.
Note 2: Propane use based on an estimated use of 0.5 hours per day at full output for a total 50 days per year.
Note 3: Estimated boiler propane use represents the total annual use less the estimated domestic hot water and make-up air unit use.

Monthly electric use and cost history were provided for the previous two years. Ely Garage has a separate meter for its electric boiler and receives a lower Dual Fuel electric rate for this use from October 15th to April 15th. The remaining portion of the year, this use is charged at the residential rate, and therefore, the electric boiler isn't used outside of this period. There is no demand charge associated with this meter. Monthly electric use for this meter for 2014 and 2015 are presented in Figure 2.

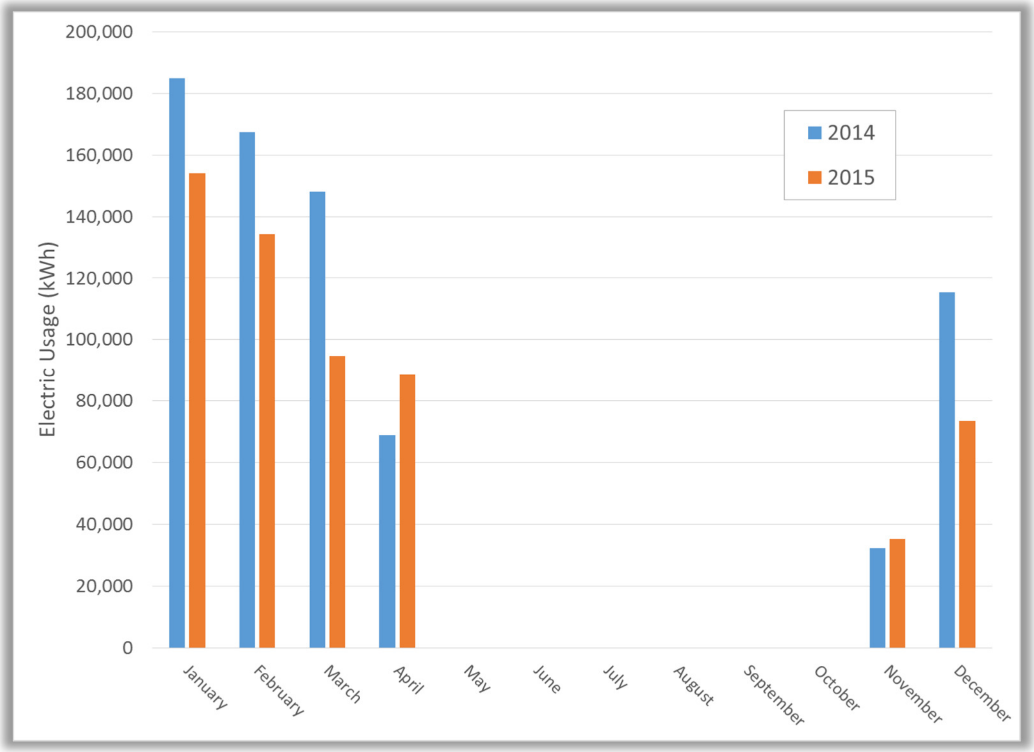


Figure 2 – Monthly Dual Fuel Electric Use

Note: Monthly electric use is from the Ely Public Utilities Commission bill history report for "Dual Fuel".

A summary of the electric use and costs for 2014 and 2015 are presented in Table 3. Ely Garage had an average annual use of 656,500 kWh and cost of $0.0674 per kWh for years 2014 and 2015. This average cost is used as a basis for the economic analysis of this study.

Table 3 – Electric Use and Cost Summary

Calendar Year	Electric Use (kWh)	Electric Cost ($)	Electric Unit Cost ($/kWh)
2014	718,400	$48,420	$0.0674
2015	594,600	$40,076	$0.0674
Average	***656,500***	***$44,248***	***$0.0674***

The annual dual fuel electric use of the electric boiler and the estimated propane use of the propane boilers are used along with the assumed boiler efficiencies to estimate the annual heating demand for the facility. Total heating demand is used in the economic analysis of this study. A summary of annual heating demand for the facility is presented in Table 4.

Table 4 – Annual Heating Demand Summary

Calendar Year	Electric Use (kWh)	Electric Boiler Output[1] (mmBtu)	Estimated Boiler Propane Use (gallons)	Estimated Propane Boiler Output[2] (mmBtu)	Total Annual Heating Demand (mmBtu)
2014	718,400	2,451	7,869	575	3,026
2015	594,600	2,029	7,869	575	2,604
Average	***656,500***	***2,240***	***7,869***	***575***	***2,815***

Note 1: Electric boiler output based on an assumed boiler efficiency of 100%.
Note 2: Propane boiler output based on an assumed boiler efficiency of 80%.

Surface weather data from Ely Municipal Airport was obtained for 2014 and 2015. Daily mean temperatures were used to calculate the heating degree days (HDD) for each day of the year. Models of the daily average hourly heating demand were developed using heating degree days and the total annual heating demand presented in Table 4. These models use a HDD base temperature of 55°F.

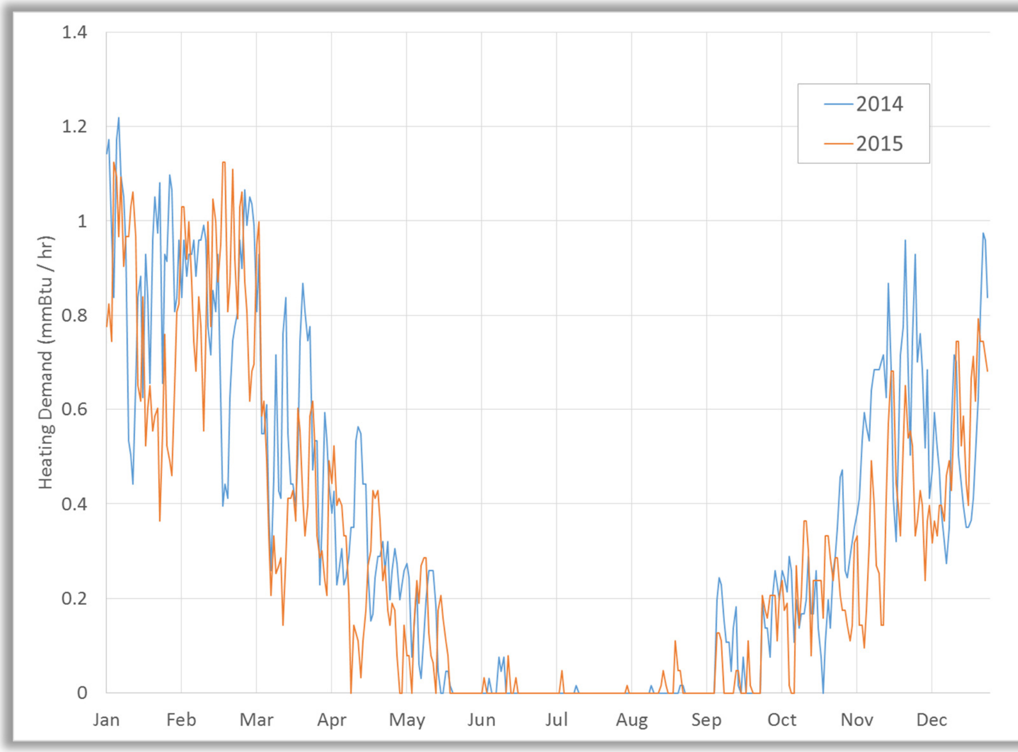


Figure 3 – Daily Average Demand for 2014 & 2015

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

Load duration curve models for 2014 and 2015 are presented in Figure 4. These models are sorted to present the daily average heating loads in descending order, as opposed to chronologically. It is important to note how this curve can be used appropriately. The curves in Figure 4 present the daily average hourly demand. Over the course of a 24 hour period, the loads will vary above and below the average. Thus, the load curves are useful for sizing a biomass boiler, but do not indicate actual peak or minimum heating demands.

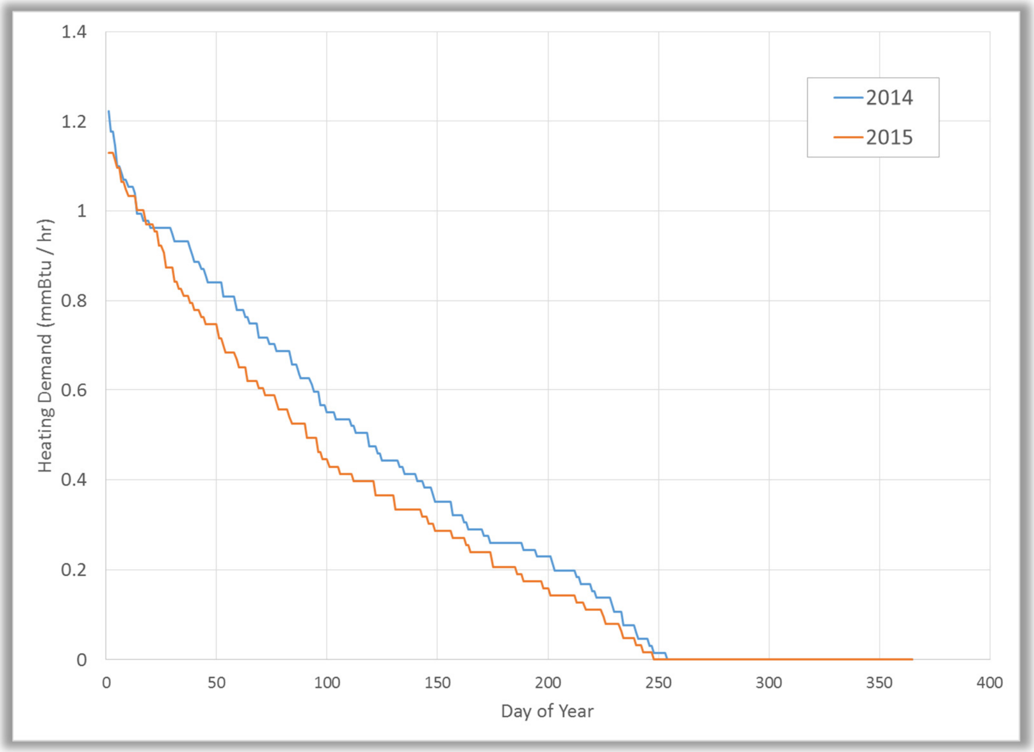


Figure 4 – Load Duration Curve

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

5.0 BIOMASS AVAILABILITY AND FUEL COST COMPARISONS

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.

Due to the operating constraints and heating demands of the Ely Garage facility, wood pellets were selected as the most appropriate fuel type. Green wood chips would require more complex and expensive fuel handling equipment, and cordwood would require much more man power to operate.

The proposed biomass system evaluated in this report would require an estimated annual use of approximately 193 tons of wood pellets. Table 5 compares the cost of delivered heat for existing fossil fuels and potential wood pellets.

Table 5 – Fuel Pricing and Output Cost

Fuel, units	Unit Cost ($/unit)	Heating Value (mmBtu/unit)	Assumed Efficiency	Output Cost ($/mmBtu)
Electric[1], kWh	$0.0674	0.003412	100%	$19.75
Propane[2], gallon	$1.478	0.091333	80%	$20.23
Hardwood Pellets[3], ton	$206	16.4	80%	$15.70
Dry Wood Chips[4], ton	$80	12.0	75%	$8.89

Note 1: Electric unit cost represents the average 2014-2015 "Dual Fuel" electric rate.
Note 2: Propane unit cost represents the 2012-2016 average delivered per gallon propane cost.
Note 3: Pellet unit cost represents a bulk price of $170/ton at the gate plus a delivery cost of $5 per loaded mile.
Note 4: Dry wood chips (25-30% moisture wet basis) are not commercially available in Ely. Cost for dry wood chips is estimated by WES as a fair market price.

Note that the current operation of the boiler systems at Ely Garage uses the electric boiler as the lead boiler. Ely Garage staff have indicated that the electric boiler cannot meet peak heating demands during the peak of the heating season. Once the heating demand exceeds the capacity of the electric boiler a propane boiler fires to cover the peak loads. The delivered propane prices have ranged from $1.20 to $1.70 per gallon over the previous five years with an average of $1.48 as shown in Table 1. However, calls to Ely Garage's propane vendor have indicated that current propane prices are under $1.00 per gallon. With a duel fuel electric rate of $0.0674/kWh, the breakeven price of propane for operation of the propane boilers is approximately $1.44 per gallon. At current prices, Ely Garage would see a significant reduction in heating costs by operating the propane boilers as the lead boilers. Operation of the propane boilers over the electric boilers would also provide a significant reduction in greenhouse gas emissions as shown in Table 14. Greenhouse gas emissions from the production and transmission of electricity are much higher than from the combustion of propane for every unit of heat produced.

5.1 Pellets

Wood pellets are typically delivered in bulk loads of 10–30 tons, and 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 as 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'. Pneumatic truck delivery 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 capacity and/or lower cost of walking floor trailers or end dump trucks can result in a lower delivery cost. However, these methods would require a conveyor system to carry the pellets up to the top of the silo. A pellet silo using auger delivery trucks is the storage and delivery method considered for this study. 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, 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 approximately $5 per loaded mile.

5.2 WOOD CHIPS

Although a wood chip system is not evaluated for the Ely 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.

The primary reason why a green chip or dry chip system is not evaluated for the Ely 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 day bin using a skid steer loader. Wood chips may also be blown into storage using specialty blower trucks that are common in the commercial mulch industry.

6.0 EVALUATED BIOMASS SYSTEM

6.1 WOOD PELLET BOILER SYSTEM

The biomass heating system proposed in this study consists of a wood pellet boiler rated 1,000,000 Btu/hr and a 1,000 gallon thermal storage tank installed in a new 20'x20' building, and a 30 ton pellet silo. Pellets would be automatically conveyed to the boiler system as needed via a flexible auger. The boiler would be used to heat a 1,000 gallon hot water thermal storage tank. The thermal storage tank would typically be maintained around 200°F. Using a VFD controlled pump, hot water from the thermal storage would be injected into the supply header of the heating distribution system to maintain the supply water set-point temperature. Storing water at temperatures that are higher than the distribution temperature allows for the maximization of the potential heat storage in the thermal storage tank and allows for coverage of temporary peak loads above the pellet boiler capacity. The existing boiler systems would be kept in place to provide for peak load coverage and maintain system redundancy.

The pellet boiler system would be installed in a new building sited adjacent to the existing generator building. Plumbing and electrical connections would be made from the boiler room to the new building. The pellet silo would be sited adjacent to the new building. A site plan, conceptual boiler plant layout, and schematic for the system are presented in Appendix A.

Wood pellet fueled biomass boilers operate most efficiently between 20% and 100% of their rated heating output. The pellet boiler would have an efficient operating range of 200,000 Btu/hr to 1,000,000 Btu/hr. Coverage for the pellet boilers is evaluated using data from the 2014 and 2015. Figure 5 shows the expected load coverage to be approximately 94% based on the 2014 LDC model. Figure 6 shows the expected load coverage to be approximately 93% based on the 2015 LDC model. This study assumes a 90% load coverage for the biomass heating system for purposes of estimating existing fuel offset. Exact sizing of the boiler(s) depends on the vendor selected, and their product offerings.

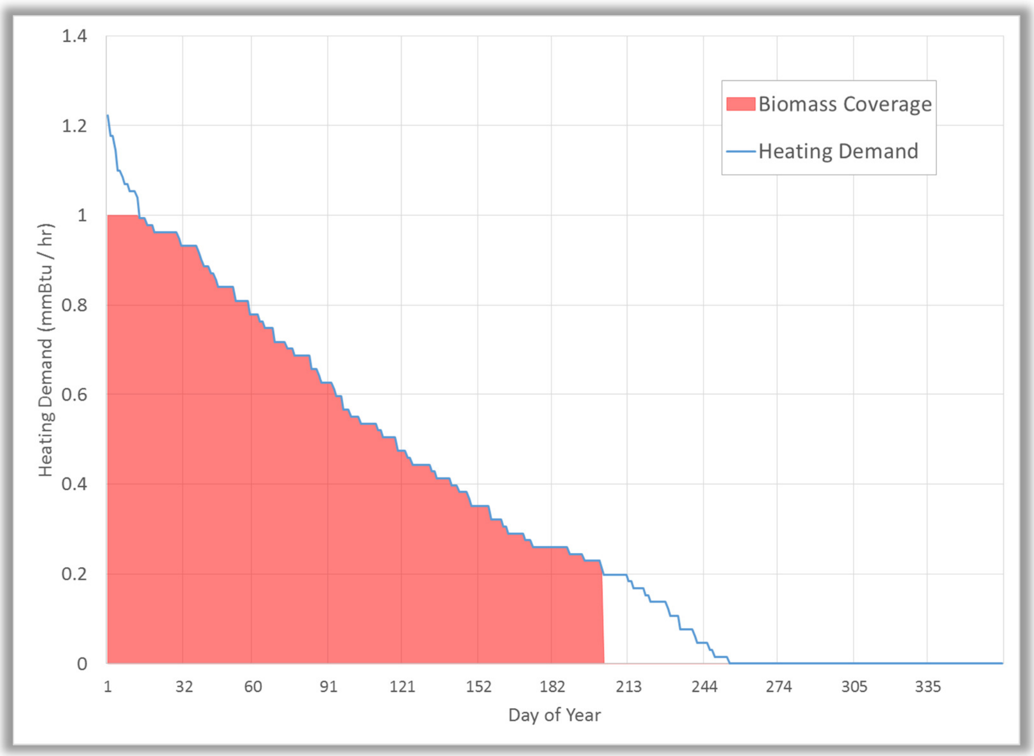


Figure 5 – 2014 LDC and Coverage of Wood Pellet Boiler

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

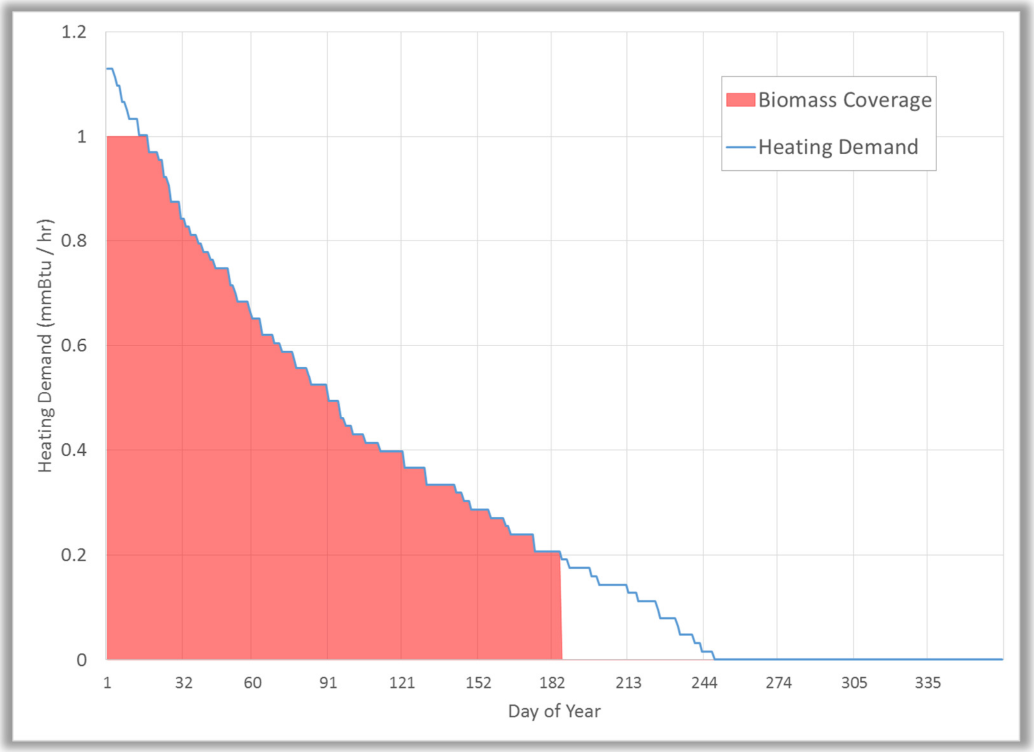


Figure 6 – 2015 LDC and Coverage of Wood Pellet Boiler

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

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 6, 250 mmBtu of thermal output is approximately equal to 19 tons of wood pellets (assuming 80% seasonal boiler efficiency). It is likely that the Ely Garage could qualify for this incentive during the quarters October – December and January – March. During qualifying quarters, this incentive would effectively reduce the price of pellets by $66/ton, to a price of $140/ton.

Specific sustainable harvesting and sourcing requirements have to be met. For facilities within 50 miles of the state border (this includes the Ely 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 6 lists the values and assumptions used in the analysis.

Table 6 – Values and Assumptions

Assumption	Value	Unit	Source
Propane HHV	0.091333	mmBtu/gal	WES Assumption
Propane Cost	$1.478	$/gal	St. Louis County
Propane Boiler Efficiency	80%	percent	WES Assumption
Propane Air Handler Efficiency	100%	percent	WES Assumption
Electric HHV	3,412	Btu/kWh	WES Assumption
Electric Cost (Dual Fuel Rate)	$0.0674	$/kWh	St. Louis County
Electric Boiler Efficiency	100%	percent	WES Assumption
Wood Pellet HHV	16.4	mmBtu/ton	WES Assumption
Wood Pellet Cost	$206	$/ton	WES Assumption
Wood Pellet Boiler Efficiency	80%	Percent	WES Assumption
HDD Base Temp	55	˚F	WES Assumption
Heating demand coverage by biomass	90%	Percent	WES Assumption
Percentage annual heating demand in Oct-Mar	88%	Percent	WES Assumption
Commercial Electric Rate	$0.10	$/kWh	Ely Utilities Commission
Labor Cost (at Biomass Plant)	$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	* CO_2	IPCC
N_2O 100-year Global Warming Potential	298	* CO_2	IPCC

8.1 CAPITAL COST ESTIMATES AND OPERATING COST SAVINGS

Estimated capital costs are listed in Table 7.

Table 7 – Capital Cost Estimate Summary

Option	Estimated Capital Cost
Pellet Boiler System	$422,150

Costs for the system includes the boiler, pumps, controls, thermal storage, piping, automatic fuel storage and handling, turnkey containerized boiler room, and installation. A detailed breakdown of capital costs is provided in Appendix B.

A breakdown of estimated operating and maintenance costs is presented in Table 8. The pellet heating system is estimated to require an operator's time for 1 hour per week.

Table 8 – Estimated Operating and Maintenance Costs

Electric Use Cost	Ash Removal Cost	Maintenance / Wear Parts Cost	Staff Time Cost	Total O&M Cost
$240	$70	$500	$840	$1,650

A proposed system fuel use profile is presented in Table 9 showing the estimated annual fuel use for a wood pellet boiler system vs. the existing fuel profile and vs. a 100% propane fuel operation.

Table 9 – Proposed System Fuel Use Profile

Option	Current Annual Fuel Use		Annual Fuel Use with Proposed Biomass System			
	Electric (kWh)	Propane (gal)	Biomass Demand Coverage	Estimated Pellet Use (tons)		Estimated Propane Use with Biomass System (gal)
				Oct-Mar	Apr-Sep	
Pellet Boiler vs Existing Use[1]	656,500	7,869	90%	170	23	3,853
Pellet Boiler vs 100% Propane[2]	0	38,526	90%	170	23	3,853

Note 1: Represents the fuel profile of a pellet system vs. the current operation of existing boilers.
Note 2: Represents the fuel profile of a pellet system vs. 100% heating by the existing propane boilers.

A comparison of fuel and operating costs for the pellet system vs. the existing operation and 100% propane operation is presented in Table 10.

Table 10 – Fuel and Operating Cost Comparison

Option	Current Annual Fuel Costs		Estimated Annual Costs with Proposed Biomass System			Estimated First Year Operational Savings	Thermal Production Incentive	Estimated Net Cash Flow
	Electric Cost	Propane Cost	Biomass Cost	Propane Cost	O&M Increase			
Pellet Boiler vs Existing Use[1]	$44,248	$11,634	$39,778	$5,696	$1,650	$8,758	$11,147	$19,905
Pellet Boiler vs 100% Propane[2]	$0	$56,959	$39,778	$5,696	$1,650	$9,834	$11,147	$20,982

Note 1: Represents the fuel profile of a pellet system vs. the current operation of existing boilers.
Note 2: Represents the fuel profile of a pellet system vs. 100% heating by the existing propane boilers.

A summary of the estimated capital costs and payback is provided in Table 11. This table also evaluates the heating system with an assumed 25% grant. No specific grant funding opportunity has been identified.

Table 11 – Costs and Payback Analysis

Option	Estimated Capital Cost	Assumed Grant Funding	Financed Amount	Simple Payback Period[3]	Net Present Value (25 years)
Pellet Boiler vs Existing Use[1]	$ 422,150	$ -	$ 422,150	35.5	$ 26,275
Pellet Boiler vs 100% Propane[2]	$ 422,150	$ -	$ 422,150	31.6	$ 54,561
Pellet Boiler vs Existing Use (with grant)[1]	$ 422,150	$ 105,538	$ 316,613	23.4	$ 131,813
Pellet Boiler vs 100% Propane (with grant)[2]	$ 422,150	$ 105,538	$ 316,613	20.9	$ 160,098

Note 1: Represents the fuel profile of a pellet system vs. the current operation of existing boilers.
Note 2: Represents the fuel profile of a pellet system vs. 100% heating by the existing propane boilers.
Note 3: Simple payback is calculated taking into account the assumption that thermal production incentive payments end after 10 years.

Detailed financial analyses are presented in Appendix C.

9.0 PERMITTING AND EMISSIONS

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 6, the proposed pellet boiler would have a maximum fuel input rate of 1.25 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 12 presents these emissions factors along with the expected emissions factors for wood boilers based on stack test data obtained by WES.

Table 12 – Emissions Factors for PM

Fuel and Source	PM Emissions	Unit
Wood Pellet Boiler[1]	0.05 – 0.15	lb/mmBtu
Propane Boiler[2]	0.008	lb/mmBtu

Note 1: Value is representative of independent lab testing of boilers comparable to proposed system

Note 2: Value is based on the EPA's AP-42 for propane combustion.

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. Emissions factors for the gaseous pollutants mentioned are presented in Table 13.

Table 13 – Emissions Factors for Gaseous Pollutants

Fuel and Source	Emission Factors (lbs/mmBtu)			
	VOC	NO_x	SO_x	CO
Wood Pellet Boiler[1]	0.004	0.140	0.001	0.150
Propane Boiler[2]	0.005	0.142	0.0002	0.082

Note 1: Wood pellet values are obtained from stack test results.

Note 2: Propane factors are taken from AP-42, S content of 0.2 g/100ft^3

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.

9.3 Greenhouse Gas Emissions Benefits

By displacing the existing fossil fuel used for heating (electric and propane), the installation of a biomass boiler system would result in a reduction of St. Louis County's annual net CO_2 equivalent greenhouse gas emissions by 192 to 2,210 metric tonnes, as shown in Table 14. 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 6.

Table 14 – Greenhouse Gas Emission (CO_2 equivalent) Reductions

Option	Current System		With Proposed Biomass System			Reduction in CO_2 Equivalent Emissions (tonnes)
	Electric CO_2 Equivalent Emissions (tonnes)	Propane CO_2 Equivalent Emissions (tonnes)	Biomass CO_2 Equivalent Emissions (tonnes)	Biomass Boiler Electric CO_2 Equivalent Emissions[3] (tonnes)	Propane CO_2 Equivalent Emissions (tonnes)	
Pellet Boiler vs Existing Use[1]	2,195	45	0	8	22	2,210
Pellet Boiler vs 100% Propane[2]	0	222	0	8	22	192

Note 1: Represents the fuel profile of a pellet system vs. the current operation of existing boilers.
Note 2: Represents the fuel profile of a pellet system vs. 100% heating by the existing propane boilers.
Note 3: Biomass boilers use more electricity than comparable propane boilers due to fuel handling equipment, larger blowers, etc.

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 Ely Garage would not exceed the state or federal emissions thresholds for air pollutants with the proposed wood pellet system. 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 Ely Garage would not be subject to any NSPS (New Source Performance Standards). Based on these calculations and assumptions, the addition of a wood pellet heating system as described 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

Wood pellets contain 0.5–1.0% ash by weight. Modern 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 7.

Figure 7 – Automated Ash Collection from Pellet/Chip Boiler

The proposed biomass system described in this report has the potential to generate <1 ton of ash (pellet fuel) 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 Ely 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 could be used beneficially at no cost to the facility, however for purposes of this study, ash is assumed to be removed from site. In the Ely area, use of ash would most likely be on timber harvest sites. The Carlton County Extension Office can assist with finding beneficial use sites, and applying for a CSBUD.

10.0 CONCLUSIONS AND RECOMMENDATIONS

A modern biomass boiler system would allow the Ely Garage to reduce fossil fuel use while utilizing a local and renewable source of energy. The proposed system evaluated in this report would have a capital cost of $422,150, would provide a net cash flow of $19,905 vs. the existing fuel profile, a net cash flow of $20,982 vs. a 100% propane fuel profile, and would have a 25 year net present value of $26,275 vs. the existing fuel profile, and $54,561 vs. a 100% propane fuel profile.

Financial performance of the evaluated system 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 or electric rises, then the savings will increase fairly dramatically. 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

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

following startup of the project. Without the incentive payments, the annual savings in today's dollars becomes $8,758 vs. the existing fuel profile, and $9,834 vs. a 100% propane fuel profile.

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

- Net reduction of greenhouse gas emissions by 192 - 2,210 metric tonnes annually,
- Keeping ~$40,000/year 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.

Appendix A – Drawings

- A.1 Facility Site Plan
- A.2 Pellet System Plan View
- A.3 Pellet System Schematic

Designed SFK 9/7/16
Drawn SFK 9/7/16
Checked

Approved
Date
Title
Job Class

Ely Public Works Garage

Ely, MN

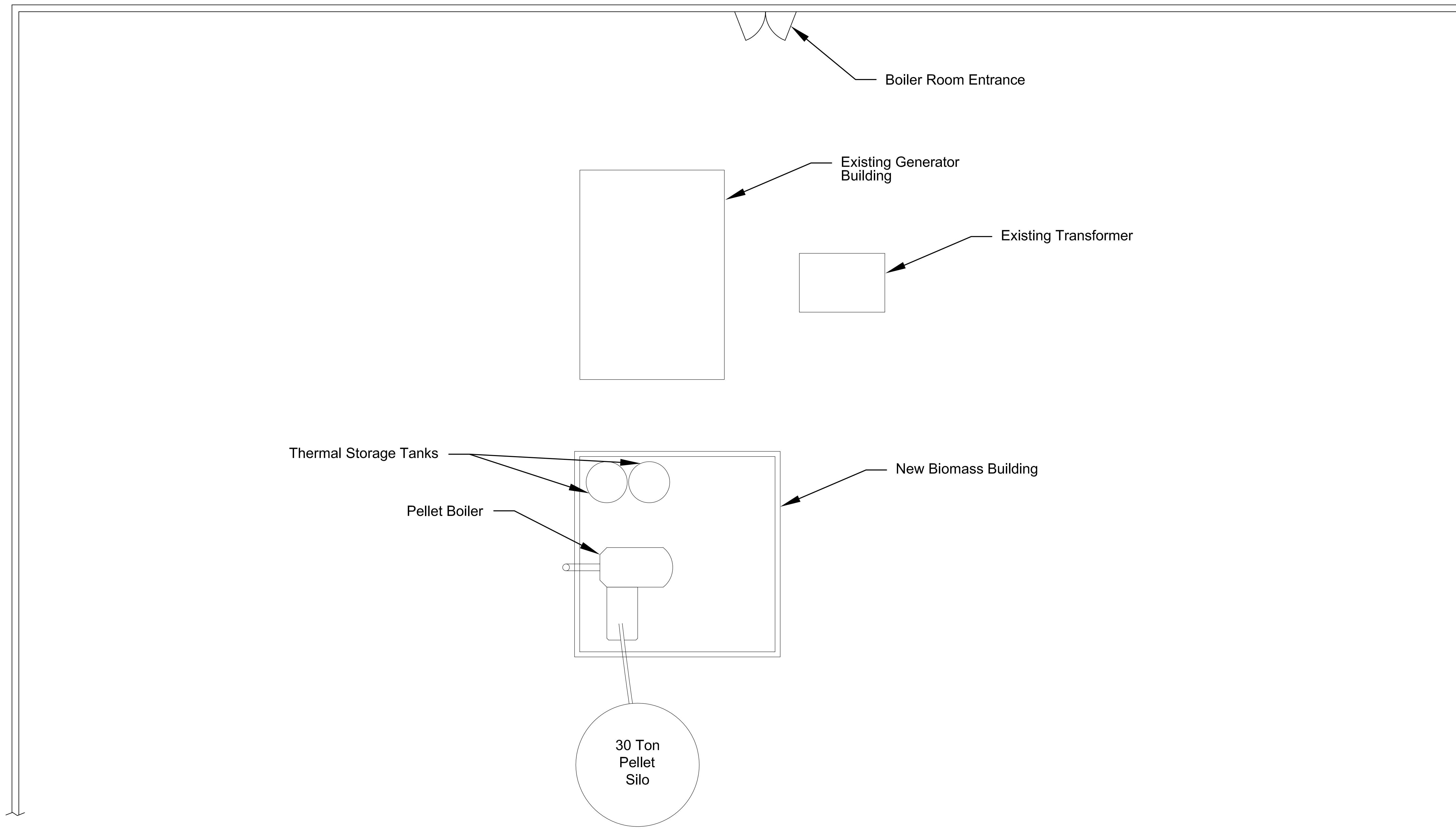
Aerial Site Plan

WES

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

REVISIONS		
Date	Description	Approved

A.1



Pellet Boiler System Plan View

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.

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Ely Public Works Garage
Ely, MN

Pellet Boiler System Plan View

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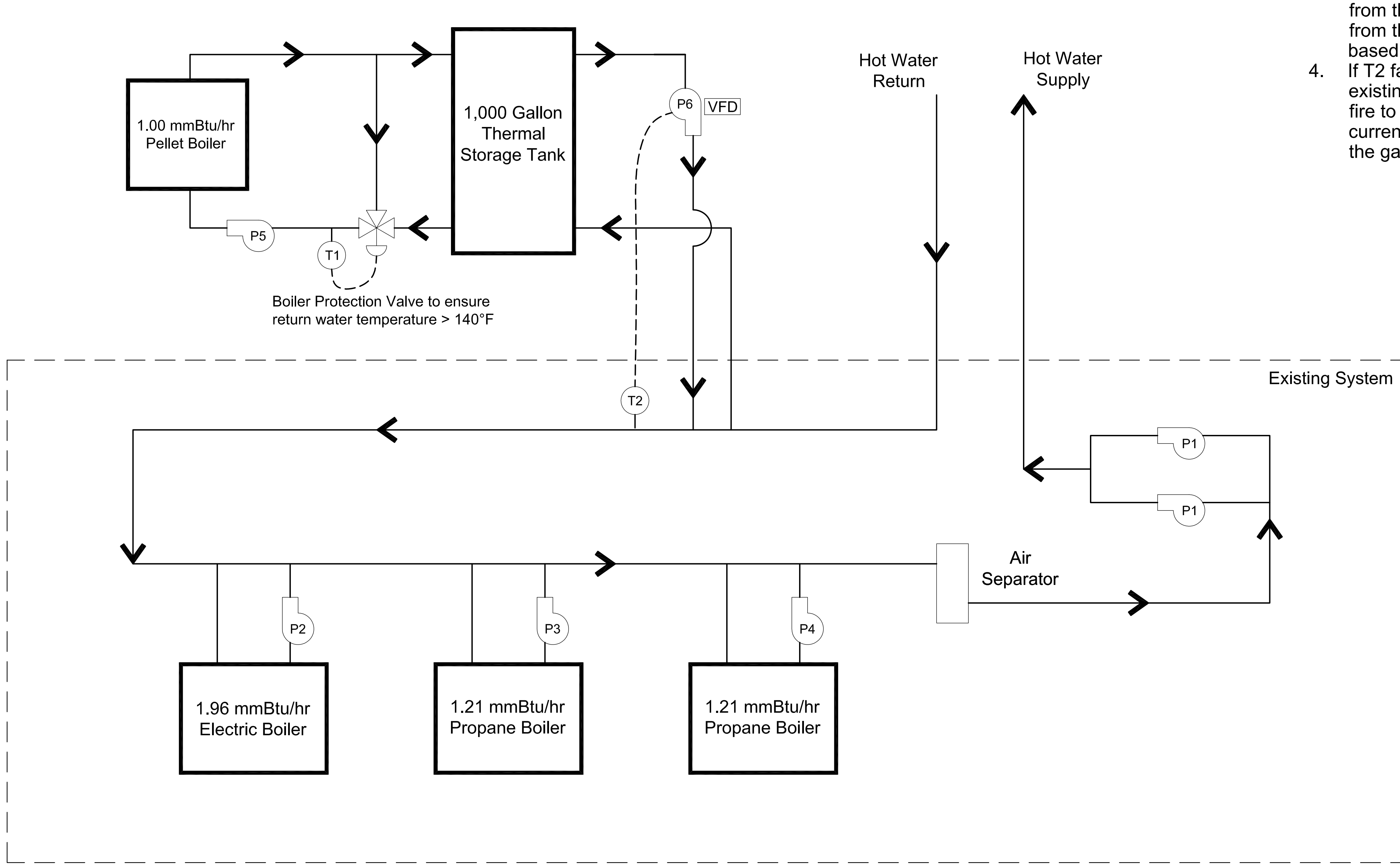
REVISIONS

Date	Description	Approved

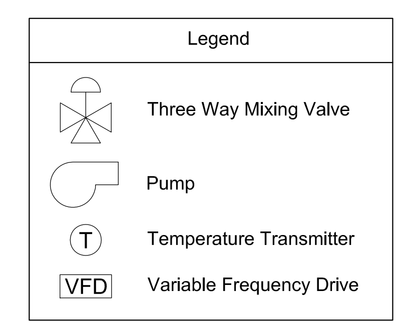
A.2

Sequence of Operations:
1. T1 controls a mixing valve which allows supply water from the pellet boiler to bypass the thermal storage, in order to maintain a return water temperature of at least 140°F to prevent flue gas condensation. This is mainly a concern during boiler startup and at times of heavy load.
2. The pellet boiler will be controlled to maintain 200°F in the thermal storage tank. Depending on the return water temperature and the temperature in the thermal storage tank, the pellet boiler will fire in order to most efficiently meet the heat demand.
3. P6 injects hot water into the building loop in the existing boiler plant, ahead of where the existing boilers tie in. T2 controls the temperature of the water after the injection point by controlling the speed of P6 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.



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.

Pellet Boiler System



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Approved ___ Date ___
Title ___ Job Class ___

Ely Public Works Garage
Ely, MN

Pellet Boiler System Schematic

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Appendix B – Capital Cost Estimates

- B.1 Pellet System Capital Cost

Pellet Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item		Cost
1,000,000 Btu/hr pellet boiler, controls, cyclone, engineering, startup		$ 150,000
30 ton pellet silo and auger system		$ 15,000
750 gallon thermal storage tank		$ 8,000
Total Boiler Manufacturer Contract		**$ 173,000**

General Contract

Line Item		Cost
Site work for silo and utilities		$ 25,000
New 20'x20' building to house boiler		$ 60,000
Boiler room mechanical, electrical, plumbing, controls, startup		$ 45,000
Electrical and plumbing interconnection in main boiler room		$ 12,000
Sub-Total		$ 142,000
Contractor profit, overhead, and insurance	*16%*	*$ 22,720*
Total General Contract Building and Site[2]		**$ 164,720**

Total Project Cost

Line Item		Cost
Project Sub-Total (Boiler and General Contract)		$ 337,720
Professional Services [3]	*10%*	*$ 33,772*
Contingency	*15%*	*$ 50,658*
Total Project Cost		**$ 422,150**

Notes:
1 - Assumes that biomass boiler and general contract are bid seperately.
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 Existing Fuel Use - Financial Analysis
- C.2 Existing Fuel Use - Financial Analysis with 25% Grant
- C.3 Existing Fuel Use - Fuel Cost Sensitivity Analysis
- C.4 100% Propane Fuel - Financial Analysis
- C.5 100% Propane Fuel - Financial Analysis with 25% Grant
- C.6 100% Propane Fuel - Fuel Cost Sensitivity Analysis

Appendix C

Pellet Boiler vs Existing Fuel Use
25-year Cash Flow Analysis

Input Variables	Value	Units
Total Project Costs	$422,150	$
Grant Amount	$0	$
Project Costs Financed	$422,150	$
Annual Electric (fuel) Usage	656,500	kWh
Annual Electric (fuel) Price	$0.0674	$/kWh
Annual Propane Usage	7,869	gal
5-Yr Average Propane Price	$1.48	$/gal
Pellet Usage	193	tons/yr
Year 1 Pellet Price	$206	$/ton
Annual Propane Usage w/ Wood System	3,853	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	$1,650	$/year

Year	Total Fuel Cost w/ Current System	Pellet Fuel Cost	Propane Cost w/ Pellet System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (422,150)	$ (422,150)
1	$ 55,882	$ (39,778)	$ (5,696)	$ (1,650)	$ 8,758	$ 11,147	$ 19,905	$ 19,708
2	$ 56,721	$ (39,977)	$ (5,781)	$ (1,650)	$ 9,312	$ 10,854	$ 20,166	$ 19,769
3	$ 57,572	$ (40,177)	$ (5,868)	$ (1,650)	$ 9,876	$ 10,569	$ 20,445	$ 19,844
4	$ 58,435	$ (40,378)	$ (5,956)	$ (1,650)	$ 10,451	$ 10,291	$ 20,742	$ 19,933
5	$ 59,312	$ (40,580)	$ (6,045)	$ (1,650)	$ 11,036	$ 10,020	$ 21,057	$ 20,035
6	$ 60,201	$ (40,783)	$ (6,136)	$ (1,650)	$ 11,632	$ 9,757	$ 21,389	$ 20,150
7	$ 61,104	$ (40,987)	$ (6,228)	$ (1,650)	$ 12,239	$ 9,500	$ 21,740	$ 20,277
8	$ 62,021	$ (41,192)	$ (6,322)	$ (1,650)	$ 12,858	$ 9,251	$ 22,108	$ 20,417
9	$ 62,951	$ (41,398)	$ (6,416)	$ (1,650)	$ 13,487	$ 9,007	$ 22,495	$ 20,568
10	$ 63,895	$ (41,605)	$ (6,513)	$ (1,650)	$ 14,128	$ 8,771	$ 22,899	$ 20,730
11	$ 64,854	$ (41,813)	$ (6,610)	$ (1,650)	$ 14,781		$ 14,781	$ 13,248
12	$ 65,827	$ (42,022)	$ (6,709)	$ (1,650)	$ 15,445		$ 15,445	$ 13,707
13	$ 66,814	$ (42,232)	$ (6,810)	$ (1,650)	$ 16,122		$ 16,122	$ 14,166
14	$ 67,816	$ (42,443)	$ (6,912)	$ (1,650)	$ 16,811		$ 16,811	$ 14,625
15	$ 68,834	$ (42,655)	$ (7,016)	$ (1,650)	$ 17,512		$ 17,512	$ 15,084
16	$ 69,866	$ (42,869)	$ (7,121)	$ (1,650)	$ 18,226		$ 18,226	$ 15,544
17	$ 70,914	$ (43,083)	$ (7,228)	$ (1,650)	$ 18,953		$ 18,953	$ 16,004
18	$ 71,978	$ (43,298)	$ (7,336)	$ (1,650)	$ 19,693		$ 19,693	$ 16,464
19	$ 73,057	$ (43,515)	$ (7,446)	$ (1,650)	$ 20,446		$ 20,446	$ 16,924
20	$ 74,153	$ (43,732)	$ (7,558)	$ (1,650)	$ 21,213		$ 21,213	$ 17,385
21	$ 75,266	$ (43,951)	$ (7,672)	$ (1,650)	$ 21,993		$ 21,993	$ 17,846
22	$ 76,395	$ (44,171)	$ (7,787)	$ (1,650)	$ 22,787		$ 22,787	$ 18,307
23	$ 77,541	$ (44,392)	$ (7,903)	$ (1,650)	$ 23,595		$ 23,595	$ 18,769
24	$ 78,704	$ (44,614)	$ (8,022)	$ (1,650)	$ 24,418		$ 24,418	$ 19,231
25	$ 79,884	$ (44,837)	$ (8,142)	$ (1,650)	$ 25,255		$ 25,255	$ 19,693
							25-year Net Present Value	**$ 26,275**

Note: All values are in real dollars.

Appendix C

Pellet Boiler vs Existing Fuel Use
25-year Cash Flow Analysis with 25% Grant Funding

Input Variables	Value	Units
Total Project Costs	$422,150	$
Grant Amount	$105,538	$
Project Costs Financed	$316,613	$
Annual Electric (fuel) Usage	656,500	kWh
Annual Electric (fuel) Price	$0.0674	$/kWh
Annual Propane Usage	7,869	gal
5-Yr Average Propane Price	$1.48	$/gal
Pellet Usage	193	tons/yr
Year 1 Pellet Price	$206	$/ton
Annual Propane Usage w/ Wood System	3,853	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	$1,650	$/year

Year	Total Fuel Cost w/ Current System	Pellet Fuel Cost	Propane Cost w/ Pellet System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (316,613)	$ (316,613)
1	$ 55,882	$ (39,778)	$ (5,696)	$ (1,650)	$ 8,758	$ 11,147	$ 19,905	$ 19,708
2	$ 56,721	$ (39,977)	$ (5,781)	$ (1,650)	$ 9,312	$ 10,854	$ 20,166	$ 19,769
3	$ 57,572	$ (40,177)	$ (5,868)	$ (1,650)	$ 9,876	$ 10,569	$ 20,445	$ 19,844
4	$ 58,435	$ (40,378)	$ (5,956)	$ (1,650)	$ 10,451	$ 10,291	$ 20,742	$ 19,933
5	$ 59,312	$ (40,580)	$ (6,045)	$ (1,650)	$ 11,036	$ 10,020	$ 21,057	$ 20,035
6	$ 60,201	$ (40,783)	$ (6,136)	$ (1,650)	$ 11,632	$ 9,757	$ 21,389	$ 20,150
7	$ 61,104	$ (40,987)	$ (6,228)	$ (1,650)	$ 12,239	$ 9,500	$ 21,740	$ 20,277
8	$ 62,021	$ (41,192)	$ (6,322)	$ (1,650)	$ 12,858	$ 9,251	$ 22,108	$ 20,417
9	$ 62,951	$ (41,398)	$ (6,416)	$ (1,650)	$ 13,487	$ 9,007	$ 22,495	$ 20,568
10	$ 63,895	$ (41,605)	$ (6,513)	$ (1,650)	$ 14,128	$ 8,771	$ 22,899	$ 20,730
11	$ 64,854	$ (41,813)	$ (6,610)	$ (1,650)	$ 14,781		$ 14,781	$ 13,248
12	$ 65,827	$ (42,022)	$ (6,709)	$ (1,650)	$ 15,445		$ 15,445	$ 13,707
13	$ 66,814	$ (42,232)	$ (6,810)	$ (1,650)	$ 16,122		$ 16,122	$ 14,166
14	$ 67,816	$ (42,443)	$ (6,912)	$ (1,650)	$ 16,811		$ 16,811	$ 14,625
15	$ 68,834	$ (42,655)	$ (7,016)	$ (1,650)	$ 17,512		$ 17,512	$ 15,084
16	$ 69,866	$ (42,869)	$ (7,121)	$ (1,650)	$ 18,226		$ 18,226	$ 15,544
17	$ 70,914	$ (43,083)	$ (7,228)	$ (1,650)	$ 18,953		$ 18,953	$ 16,004
18	$ 71,978	$ (43,298)	$ (7,336)	$ (1,650)	$ 19,693		$ 19,693	$ 16,464
19	$ 73,057	$ (43,515)	$ (7,446)	$ (1,650)	$ 20,446		$ 20,446	$ 16,924
20	$ 74,153	$ (43,732)	$ (7,558)	$ (1,650)	$ 21,213		$ 21,213	$ 17,385
21	$ 75,266	$ (43,951)	$ (7,672)	$ (1,650)	$ 21,993		$ 21,993	$ 17,846
22	$ 76,395	$ (44,171)	$ (7,787)	$ (1,650)	$ 22,787		$ 22,787	$ 18,307
23	$ 77,541	$ (44,392)	$ (7,903)	$ (1,650)	$ 23,595		$ 23,595	$ 18,769
24	$ 78,704	$ (44,614)	$ (8,022)	$ (1,650)	$ 24,418		$ 24,418	$ 19,231
25	$ 79,884	$ (44,837)	$ (8,142)	$ (1,650)	$ 25,255		$ 25,255	$ 19,693
							25-year Net Present Value	**$ 131,813**

Pellet Boiler vs Existing Fuel Use
Fuel Cost Sensitivity Analysis

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

Price of Pellets - $/ton	Propane Price, $/gal						
	$0.75	**$1.00**	**$1.25**	**$1.48**	**$1.75**	**$2.00**	**$2.25**
$170	$12,784	$13,788	$14,792	$15,710	$16,800	$17,805	$18,809
$175	$11,818	$12,822	$13,827	$14,744	$15,835	$16,839	$17,843
$180	$10,853	$11,857	$12,861	$13,779	$14,869	$15,874	$16,878
$185	$9,887	$10,891	$11,896	$12,813	$13,904	$14,908	$15,912
$190	$8,922	$9,926	$10,930	$11,848	$12,938	$13,943	$14,947
$195	$7,956	$8,960	$9,965	$10,882	$11,973	$12,977	$13,981
$200	$6,991	$7,995	$8,999	$9,917	$11,007	$12,012	$13,016
$206	$5,832	$6,836	$7,841	$8,758	$9,849	$10,853	$11,857
$210	$5,060	$6,064	$7,068	$7,986	$9,076	$10,081	$11,085
$215	$4,094	$5,098	$6,103	$7,020	$8,111	$9,115	$10,119
$220	$3,129	$4,133	$5,137	$6,055	$7,145	$8,150	$9,154
$225	$2,163	$3,167	$4,172	$5,089	$6,180	$7,184	$8,188
$230	$1,198	$2,202	$3,206	$4,124	$5,214	$6,219	$7,223
$235	$232	$1,236	$2,241	$3,158	$4,249	$5,253	$6,257

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

Appendix C

Pellet Boiler vs 100% Propane Use
25-year Cash Flow Analysis

Input Variables	Value	Units
Total Project Costs	$422,150	$
Grant Amount	$0	$
Project Costs Financed	$422,150	$
Annual Electric (fuel) Usage	0	kWh
Annual Electric (fuel) Price	$0.0674	$/kWh
Annual Propane Usage	38,526	gal
5-Yr Average Propane Price	$1.48	$/gal
Pellet Usage	193	tons/yr
Year 1 Pellet Price	$206	$/ton
Annual Propane Usage w/ Wood System	3,853	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	$1,650	$/year

Year	Total Fuel Cost w/ Current System	Pellet Fuel Cost	Propane Cost w/ Pellet System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (422,150)	$ (422,150)
1	$ 56,959	$ (39,778)	$ (5,696)	$ (1,650)	$ 9,834	$ 11,147	$ 20,982	$ 20,774
2	$ 57,813	$ (39,977)	$ (5,781)	$ (1,650)	$ 10,404	$ 10,854	$ 21,259	$ 20,840
3	$ 58,680	$ (40,177)	$ (5,868)	$ (1,650)	$ 10,985	$ 10,569	$ 21,554	$ 20,920
4	$ 59,561	$ (40,378)	$ (5,956)	$ (1,650)	$ 11,576	$ 10,291	$ 21,867	$ 21,014
5	$ 60,454	$ (40,580)	$ (6,045)	$ (1,650)	$ 12,179	$ 10,020	$ 22,199	$ 21,122
6	$ 61,361	$ (40,783)	$ (6,136)	$ (1,650)	$ 12,792	$ 9,757	$ 22,549	$ 21,242
7	$ 62,281	$ (40,987)	$ (6,228)	$ (1,650)	$ 13,416	$ 9,500	$ 22,917	$ 21,375
8	$ 63,215	$ (41,192)	$ (6,322)	$ (1,650)	$ 14,052	$ 9,251	$ 23,303	$ 21,520
9	$ 64,164	$ (41,398)	$ (6,416)	$ (1,650)	$ 14,700	$ 9,007	$ 23,707	$ 21,676
10	$ 65,126	$ (41,605)	$ (6,513)	$ (1,650)	$ 15,359	$ 8,771	$ 24,129	$ 21,844
11	$ 66,103	$ (41,813)	$ (6,610)	$ (1,650)	$ 16,030		$ 16,030	$ 14,368
12	$ 67,095	$ (42,022)	$ (6,709)	$ (1,650)	$ 16,713		$ 16,713	$ 14,832
13	$ 68,101	$ (42,232)	$ (6,810)	$ (1,650)	$ 17,409		$ 17,409	$ 15,297
14	$ 69,122	$ (42,443)	$ (6,912)	$ (1,650)	$ 18,117		$ 18,117	$ 15,761
15	$ 70,159	$ (42,655)	$ (7,016)	$ (1,650)	$ 18,838		$ 18,838	$ 16,226
16	$ 71,212	$ (42,869)	$ (7,121)	$ (1,650)	$ 19,572		$ 19,572	$ 16,691
17	$ 72,280	$ (43,083)	$ (7,228)	$ (1,650)	$ 20,319		$ 20,319	$ 17,157
18	$ 73,364	$ (43,298)	$ (7,336)	$ (1,650)	$ 21,079		$ 21,079	$ 17,623
19	$ 74,465	$ (43,515)	$ (7,446)	$ (1,650)	$ 21,853		$ 21,853	$ 18,089
20	$ 75,582	$ (43,732)	$ (7,558)	$ (1,650)	$ 22,641		$ 22,641	$ 18,555
21	$ 76,715	$ (43,951)	$ (7,672)	$ (1,650)	$ 23,443		$ 23,443	$ 19,022
22	$ 77,866	$ (44,171)	$ (7,787)	$ (1,650)	$ 24,259		$ 24,259	$ 19,489
23	$ 79,034	$ (44,392)	$ (7,903)	$ (1,650)	$ 25,089		$ 25,089	$ 19,957
24	$ 80,219	$ (44,614)	$ (8,022)	$ (1,650)	$ 25,934		$ 25,934	$ 20,425
25	$ 81,423	$ (44,837)	$ (8,142)	$ (1,650)	$ 26,794		$ 26,794	$ 20,893
							25-year Net Present Value	**$ 54,561**

Note: All values are in real dollars.

Appendix C

Pellet Boiler vs 100% Propane Use
25-year Cash Flow Analysis with 25% Grant Funding

Input Variables	Value	Units
Total Project Costs	$422,150	$
Grant Amount	$105,538	$
Project Costs Financed	$316,613	$
Annual Electric (fuel) Usage	0	kWh
Annual Electric (fuel) Price	$0.0674	$/kWh
Annual Propane Usage	38,526	gal
5-Yr Average Propane Price	$1.48	$/gal
Pellet Usage	193	tons/yr
Year 1 Pellet Price	$206	$/ton
Annual Propane Usage w/ Wood System	3,853	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	$1,650	$/year

Year	Total Fuel Cost w/ Current System	Pellet Fuel Cost	Propane Cost w/ Pellet System	Added O&M Cost	Net Operating Savings	Thermal Production Incentive	Net Cash Flow	Present Value of Net Cash Flow
0	$ -	$ -	$ -	$ -	$ -	$ -	$ (316,613)	$ (316,613)
1	$ 56,959	$ (39,778)	$ (5,696)	$ (1,650)	$ 9,834	$ 11,147	$ 20,982	$ 20,774
2	$ 57,813	$ (39,977)	$ (5,781)	$ (1,650)	$ 10,404	$ 10,854	$ 21,259	$ 20,840
3	$ 58,680	$ (40,177)	$ (5,868)	$ (1,650)	$ 10,985	$ 10,569	$ 21,554	$ 20,920
4	$ 59,561	$ (40,378)	$ (5,956)	$ (1,650)	$ 11,576	$ 10,291	$ 21,867	$ 21,014
5	$ 60,454	$ (40,580)	$ (6,045)	$ (1,650)	$ 12,179	$ 10,020	$ 22,199	$ 21,122
6	$ 61,361	$ (40,783)	$ (6,136)	$ (1,650)	$ 12,792	$ 9,757	$ 22,549	$ 21,242
7	$ 62,281	$ (40,987)	$ (6,228)	$ (1,650)	$ 13,416	$ 9,500	$ 22,917	$ 21,375
8	$ 63,215	$ (41,192)	$ (6,322)	$ (1,650)	$ 14,052	$ 9,251	$ 23,303	$ 21,520
9	$ 64,164	$ (41,398)	$ (6,416)	$ (1,650)	$ 14,700	$ 9,007	$ 23,707	$ 21,676
10	$ 65,126	$ (41,605)	$ (6,513)	$ (1,650)	$ 15,359	$ 8,771	$ 24,129	$ 21,844
11	$ 66,103	$ (41,813)	$ (6,610)	$ (1,650)	$ 16,030		$ 16,030	$ 14,368
12	$ 67,095	$ (42,022)	$ (6,709)	$ (1,650)	$ 16,713		$ 16,713	$ 14,832
13	$ 68,101	$ (42,232)	$ (6,810)	$ (1,650)	$ 17,409		$ 17,409	$ 15,297
14	$ 69,122	$ (42,443)	$ (6,912)	$ (1,650)	$ 18,117		$ 18,117	$ 15,761
15	$ 70,159	$ (42,655)	$ (7,016)	$ (1,650)	$ 18,838		$ 18,838	$ 16,226
16	$ 71,212	$ (42,869)	$ (7,121)	$ (1,650)	$ 19,572		$ 19,572	$ 16,691
17	$ 72,280	$ (43,083)	$ (7,228)	$ (1,650)	$ 20,319		$ 20,319	$ 17,157
18	$ 73,364	$ (43,298)	$ (7,336)	$ (1,650)	$ 21,079		$ 21,079	$ 17,623
19	$ 74,465	$ (43,515)	$ (7,446)	$ (1,650)	$ 21,853		$ 21,853	$ 18,089
20	$ 75,582	$ (43,732)	$ (7,558)	$ (1,650)	$ 22,641		$ 22,641	$ 18,555
21	$ 76,715	$ (43,951)	$ (7,672)	$ (1,650)	$ 23,443		$ 23,443	$ 19,022
22	$ 77,866	$ (44,171)	$ (7,787)	$ (1,650)	$ 24,259		$ 24,259	$ 19,489
23	$ 79,034	$ (44,392)	$ (7,903)	$ (1,650)	$ 25,089		$ 25,089	$ 19,957
24	$ 80,219	$ (44,614)	$ (8,022)	$ (1,650)	$ 25,934		$ 25,934	$ 20,425
25	$ 81,423	$ (44,837)	$ (8,142)	$ (1,650)	$ 26,794		$ 26,794	$ 20,893
							25-year Net Present Value	**$ 160,098**

Appendix C

Pellet Boiler vs 100% Propane Use
Fuel Cost Sensitivity Analysis

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

Price of Pellets - $/ton	Propane Price, $/gal						
	$0.75	$1.00	$1.25	$1.48	$1.75	$2.00	$2.25
$170	($8,472)	$197	$8,865	$16,786	$26,202	$34,870	$43,538
$175	($9,437)	($769)	$7,899	$15,820	$25,236	$33,905	$42,573
$180	($10,403)	($1,734)	$6,934	$14,855	$24,271	$32,939	$41,607
$185	($11,368)	($2,700)	$5,968	$13,890	$23,305	$31,974	$40,642
$190	($12,334)	($3,665)	$5,003	$12,924	$22,340	$31,008	$39,676
$194	($13,106)	($4,438)	$4,231	$12,152	$21,567	$30,236	$38,904
$200	($14,265)	($5,596)	$3,072	$10,993	$20,409	$29,077	$37,745
$206	($15,423)	($6,755)	$1,913	$9,834	$19,250	$27,918	$36,587
$210	($16,196)	($7,527)	$1,141	$9,062	$18,478	$27,146	$35,814
$215	($17,161)	($8,493)	$175	$8,097	$17,512	$26,181	$34,849
$220	($18,127)	($9,458)	($790)	$7,131	$16,547	$25,215	$33,883
$225	($19,092)	($10,424)	($1,756)	$6,166	$15,581	$24,250	$32,918
$230	($20,058)	($11,389)	($2,721)	$5,200	$14,616	$23,284	$31,952
$235	($21,023)	($12,355)	($3,687)	$4,235	$13,650	$22,319	$30,987

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