Minnesota Department of Natural Resources

MNDNR

Ely Bloomenson Community Hospital

Biomass Energy System

Preliminary Feasibility Report

FINAL

3/31/2017

Wilson Engineering Services, PC
Meadville, PA ● Charlotte, NC
www.WilsonEngineeringServices.com

Minnesota Department of Natural Resources
500 Lafayette Road
St. Paul, MN 55155-4040
(651) 296-6157
(888) 646-6367
info.dnr@state.mn.us
TTY: (651) 296-5484 or (800) 657-3929
www.dnr.state.mn.us

Prepared by:
Wilson Engineering Services, PC
902 Market Street
Meadville, PA 16335
Phone: 814-337-8223
Fax: 814-333-4342
www.wilsonengineeringservices.com

Table of Contents

1.0 Executive Summary 1
2.0 Introduction 5
2.1 MN SWET Program 5
2.2 Ely Bloomenson Community Hospital Opportunity 5
3.0 Facility Overview 5
3.1 Boiler Plant 5
4.0 Building Heat Demand 7
5.0 Biomass Availability and Price 10
5.1 Pellets 11
5.2 Wood Chips 11
6.0 Evaluated Biomass Systems 12
6.1 Option 1 – Wood Chip Boiler System 13
6.2 Option 2 – Wood Pellet and Dry Chip Boiler System 15
6.3 Option 3 – Wood Pellet Boiler System 18
6.4 Underground Piping 18
7.0 Grants and Incentives 19
7.1 Biomass Thermal Production Incentive 19
7.2 IRRRB Business Energy Retrofit 19
7.3 Rural Energy for America Program (REAP) 20
7.4 Community Facilities Direct Loan and Grant 20
7.5 PACE (Property Assessed Clean Energy) 20
7.6 IRRRB Development Infrastructure 20
7.7 DEED 20
8.0 Biomass System Analysis 20
8.1 Capital Cost Estimates and Operating Cost Savings 21
9.0 Emissions, Permitting, and Licensing 23
9.1 Particulate Matter Emissions 23
9.2 Gaseous Emissions 24
9.3 Greenhouse Gas Emissions Benefits 25
9.4 Air Permitting 25
9.5 Use of Wood Residuals as Fuel 25
9.6 Ash 26
9.7 Boiler Operator Requirements 26
10.0 Conclusions and Recommendations 27

Appendix A – Drawings
Appendix B – Capital Cost Estimates
Appendix C – Financial and Fuel Cost Analyses
Appendix D – UMN Extension By-Products Program Brochure

1.0 EXECUTIVE SUMMARY

The Ely Bloomenson Community Hospital is located in Ely, MN. This 77,000 ft^2 facility is heated by propane and fuel oil and uses an average of 81,373 gallons of propane per year costing an average of approximately $93,756 per year (based on the past 2 years). A wood heating system utilizing wood chips or pellets 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. Options evaluated in this report would require an estimated annual use of up to 775 tons of green wood chips or 438 tons of wood pellets. 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
Green Wood Chip1, ton	$40	10	70%	7	$5.71
Dry Wood Chip2, ton	$80	12	75%	9	$8.89
Wood Pellet3, ton	$206	16.4	80%	13.1	$15.72
Propane (2-year average), gal	$1.15	0.091	85%	0.078	$14.84
Propane (2018 estimate), gal	$0.95	0.091	85%	0.078	$12.24
#2 Fuel Oil, gal	$3.00	0.14	80%	0.11	$26.79

Note 1: Green wood chips are approximately 40-45% moisture content wet basis.
Note 2: Dry wood chips are approximately 25-30% moisture wet basis. They are not commercially available in Ely. Cost for dry wood chips is estimated by WES as a fair market price.
Note 3: Wood pellets are 6-8% moisture content wet basis. Price includes delivery by auger truck.
Note 4: Table 8 contains the assumptions used to develop the above values.

Three biomass boiler options are evaluated for this facility.

Option 1 – Wood Chip Boiler: A wood chip hot water boiler, rated 1.7 mmBtu/hr, would be installed in a new boiler plant located between the ambulance garage and the propane tank. An automatic fuel reclaim and feeding system, and a 1,700 gallon thermal storage tank(s) would be installed with the boiler. The automatic indoor fuel storage would be sized to hold approximately 50 tons of wood chips. The wood chip boiler would tie into the hospital's heating system in the existing central boiler room, and would offset approximately 85% of the fossil fuel used annually by the hospital.

Option 2 – Wood Pellet and Dry Chip Boiler: One wood pellet hot water boiler, rated 1.7 mmBtu/hr, would be installed in a new boiler plant located between the ambulance garage and the propane tank. An automatic fuel reclaim and feeding system, and a 1,300 gallon thermal storage tank(s) would be installed with the boiler. The fuel handling system and boiler would be capable of utilizing dry chips or pellets for maximum fuel flexibility. The automatic indoor fuel storage would be sized to hold approximately 68 tons of wood pellets or 25 tons of dry wood chips. The pellet boiler would tie into the hospital's heating system in the existing central boiler room, and would offset approximately 95% of the fossil fuel used annually by the hospital.

Option 3 – Wood Pellet Boiler: One wood pellet hot water boiler, rated 1.7 mmBtu/hr, would be installed in a new boiler plant located at the northwest corner of the hospital. A 40 ton pellet silo and a 1,300 gallon thermal storage tank(s) would be installed with the boiler. The fuel handling system would automatically feed pellets from the silo to the boiler. The pellet boiler would tie into the hospital's heating system in the existing central boiler room, and would offset approximately 95% of the fossil fuel used annually by the hospital.

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

Table ES2 – Proposed System Fuel Use Profile

Option	Current Annual Fuel Use	Annual Fuel Use with Proposed Biomass System		
	Propane and Propane Equivalent (gal)	Biomass Demand Coverage	Estimated Biomass Use (tons)	Estimated Propane Use with Biomass System (gal)
1 – Chip Boiler	81,373	85%	776	12,206
2 – Pellet and Dry Chip Boiler using pellets	81,373	95%	463	4,069
2 – Pellet and Dry Chip Boiler using dry chips[1]	81,373	95%	675	4,069
3 – Pellet Boiler	81,373	95%	457	4,069

Note 1: Usage of dry chips is shown for comparison purposes only, as dry chips are not available at this time.
Note 2: Table 8 contains the assumptions used to develop the above values.

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

Table ES3 – Fuel and Operating Cost Comparison

Option	Current Annual Fuel Cost	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 – Chip Boiler	$93,756	$31,058	$14,063	$11,005	$37,629	$27,176	$64,805
2 – Pellet and Dry Chip Boiler using pellets	$93,756	$95,516	$4,688	$5,251	($11,698)	$30,380	$18,681
2 – Pellet and Dry Chip Boiler using dry chips[1]	$93,756	$54,009	$4,688	$5,251	$29,809	$30,380	$60,189
3 – Pellet Boiler	$93,756	$94,343	$4,688	$3,764	($9,039)	$30,007	$20,968

Note 1: Usage of dry chips is shown for comparison purposes only, as dry chips are not available at this time.
Note 2: Table 8 contains the assumptions used to develop the above values.

A summary of the estimated capital costs and payback is provided in Table ES4. This table also evaluates the options with an assumed 25% grant. Detailed financial analyses were generated for all options and are included in Appendix C.

Table ES4 – Cost and Payback Analysis

Option	Estimated Capital Cost	Assumed Grant Funding	Financed Amount	Simple Payback Period[2] (years)	Net Present Value (25 years)
1 – Chip Boiler	$1,189,240	$0	$1,189,240	24	$167,436
2 – Pellet and Dry Chip Boiler using pellets	$959,365	$0	$959,365	-	($706,724)
2 – Pellet and Dry Chip Boiler using dry chips[1]	$959,365	$0	$959,365	22	$261,904
3 – Pellet Boiler	$519,500	$0	$519,500	-	($209,893)
1 – Chip Boiler	$1,189,240	$297,310	$891,930	16	$464,746
2 – Pellet and Dry Chip Boiler using pellets	$959,365	$239,841	$719,524	-	($466,883)
2 – Pellet and Dry Chip Boiler using dry chips[1]	$959,365	$239,841	$719,524	14	$501,745
3 – Pellet Boiler	$519,500	$129,875	$389,625	-	($80,018)

Note 1: Usage of dry chips is shown for comparison purposes only, as dry chips are not locally available at this time.
Note 2: 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 Ely Bloomenson Community Hospital to reduce fossil fuel usage while utilizing a local and renewable source of energy. The options evaluated in this report would provide benefits to EBCH as summarized:

- Option 1 is a boiler system capable of utilizing green wood chips. This project would provide a first year net operating savings of $37,629, not including payments from the thermal production incentive, and would have a capital cost of $1,189,240.
- Option 2 is a boiler system capable of utilizing wood pellets or dry wood chips. If pellet fuel was utilized, this project would increase annual operating costs by $11,698, before taking into account payments from the thermal production incentive, and if dry wood chips were utilized, first year net operating savings would be $29,809, not including payments from the thermal production incentive. This project would have a capital cost of $959,365.
- Option 3 is a boiler system capable of utilizing wood pellets. This project would increase annual operating costs by $9,039, before taking into account payments from the thermal production incentive, and would have a capital cost of $519,500.

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 fossil fuels rises, then the savings will increase fairly dramatically.

Payments from the Minnesota Biomass Thermal Production Incentive are a major driver of savings. For Option 1 the annual payment would be approximately $27,176, for Option 2 the annual payment would be approximately $30,380, and for Option 3 the annual payment would be approximately $30,007. It is important to note that these payments only occur for 10 years following startup of the project.

Without the incentive payments, use of pellet fuel is not economical based on current fossil fuel prices. For a pellet project to even be worthy of consideration, the cost of fossil fuels (propane and fuel oil) would have to rise to the equivalent of a propane cost of approximately $1.50/gallon ($19.32/mmBtu output).

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

- Net reduction of greenhouse gas emissions by 282-393 metric tonnes annually,

- Keeping $31,000-$95,000 per year spent on energy within the region,
- Diversification of fuels used by the Ely Bloomenson Community Hospital,
- 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.

A new ambulance garage is planned north of the new propane tank. There is undeveloped land west of the hospital which is owned by the city, which may be developed eventually. Interconnection of these future loads to the biomass plant would improve the economics of the biomass plant, but the boiler size should not be increased at this time in anticipation of these or future loads. Even if the boiler size is not increased, and significant additional load is connected, the biomass boiler will be able to supply more renewable energy overall, just not at the peak times, which occur for a few weeks per year. These peaks would be seamlessly covered by propane. If significant additional load is expected to be connected in the future, it could be prudent to leave space in the plant to install a second boiler at a later date, taking into account that this second boiler would share the fuel storage bin and the stack.

Should EBCH be interested in pursuing a biomass option, WES recommends that staff 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 EBCH 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).
    - Thermal Production Incentive
    - IRRRB Business Energy Retrofit
    - Rural Energy for America Program (REAP)
    - Community Facilities Direct Loan & Grant Program
    - PACE
    - IRRRB Development Infrastructure
    - DEED
- 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.
- Continue to explore viable options for the wood chip supply, taking into consideration chip size, moisture content, and fuel quality, relative to boiler capabilities.
- Network with regional planning agencies to encourage widespread community support for this renewable energy project.

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 BLOOMENSON COMMUNITY HOSPITAL OPPORTUNITY

Ely Bloomenson Community Hospital is located in Ely, MN and provides a full range of medical care to the community. The hospital was built in 1958 and was expanded in 1966, 1970 and 1973. The hospital is currently heated with propane and fuel oil. Because of the abundance of wood resources in the area, the hospital is investigating whether it is feasible to install a wood energy system to supply heat. In recent years, studies have been conducted in Ely to look at the possibility of implementing a community-wide biomass district heating system; however, this was determined to be infeasible. This study takes a fresh look at the hospital by itself to determine what the costs and benefits would be of a biomass system sized and situated to best serve the hospital alone.

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.

Ely Bloomenson Community Hospital (EBCH) is a community hospital located in Ely, MN, which consists of a hospital, clinic, and nursing home that make up one building complex. The facility was converted from steam to hot water in 2014. Heat is supplied to the building via air handlers with hot water coils. The facility is occupied at all times.

3.1 BOILER PLANT

The central plant operates in a summer mode and a winter mode. There are two boilers that provide the needed heating demands in the winter, and three smaller boilers that provide the heating demands in the summer. The summer load consists of several zones for reheats as well as domestic hot water

(DHW) from the central plant. At the time of the site visit, the plant was running at 145°F, with the load being met by one Weil McLain boiler. The plant was on summer operation mode (typically May – Oct).

The facility is set up to supply all heating needs from the central plant, and was recently converted over from steam and fuel oil to hot water and propane. The 2014 renovation was done by JK Mechanical out of Nashwauk, MN. The system runs on 30% glycol. In the kitchen there is an electric booster for the dishwasher. The overall system is on outside reset and can operate as high as 190°F. For example, on Feb 22, 2016, the outside air temperature was 2°F and the hot water loop setpoint was 182°F. In the summer, the water temperature varies to maintain the needed temperature to the heat exchanger for heating DHW.

The plant has two KN-30 boilers (Figure 1) which were installed in 2014. The rated input to each boiler is 3,000 MBH, the rated output is 2,781 MBH, minimum input is 600 MBH, and minimum output is 556.2 MBH. These two meet all of the winter load, and anecdotally, full fire on both at the same time has not yet been needed. For summer operation, there are (3) Weil McLain Ultra 399 CT boilers (Figure 2) rated 399 MBH input each and 365 MBH output (when condensing). The small boilers are used in the summer, and a bypass of the main building loop is turned to isolate these boilers with a few hydronic zones and the DHW from the larger system.

Figure 1 – KN-30 Propane Boilers

Figure 2 – Weil McLain Ultra Boilers

There is a steam boiler left over from the old steam plant which only supplies steam to a shell and tube heat exchanger which is plumbed in parallel with the two KN-30 boilers. The steam boiler is a Kewanee rated for 4,184 MBH output (125 HP). This boiler runs on fuel oil with a propane pilot. Theoretically it could fire on propane, but it couldn't be tuned right for whatever reason, and this was not important since the purpose of this boiler is to provide an alternative fuel choice.

The 2 pumps used in the winter for circulating through the two KN-30 boilers and the steam heat exchanger as well as the building loops are B&G e-1510 4BD, 761 GPM, 69 FT, 1800 RPM. For summer operation, there are two inline pumps which circulate water through the reduced system. At the time of the visit, the (summer) inline circulator pump was supplying the summer zones with a pressure of 22 psi on the inlet and 31 psi on the outlet. This circulator is B&G 80 4X7 6.375, 238 GPM, 30 FT, S/N 1AF008LEK31.

The only real issue the facility has seen since operation of the new hydronic system is a lack of adequate flow through the two propane boilers when they do their periodic (short) full fire cycle for cleaning. The system in the winter is setup to run all the water flow that goes to the building through the two propane boilers and the heat exchanger for the steam boiler. Balancing valves are used to proportion the flow through each. The issue with this is that there is sometimes inadequate flow through the propane boilers when they both hit their full firing rate. This has been alleviated by manually limiting the flow through the heat exchanger for the steam boiler.

The main pipes in the boiler room are 6". Pipes to the clinic mechanical room are 4". There is a remote mechanical room near the NW corner of the building where there are some air handlers. The hot water pipes to this room start out as 3" in the boiler room and then reduce to 2.5" by the time they get to the mechanical room.

4.0 BUILDING HEAT DEMAND

EBCH provided WES with propane fuel delivery data and weekly propane and #2 fuel oil tank levels for heating seasons 2014-2015 and 2015-2016. Table 1 lists the propane delivery amounts and costs.

Table 1 – Propane Fuel Deliveries

Date	Gallons	Price/Gal	Cost
7/17/2014	8,901	$1.3250	$11,794
10/9/2014	9,000	$1.3250	$11,925
11/13/2014	8,901	$1.3250	$11,794
12/3/2014	9,000	$1.3250	$11,925
12/29/2014	9,001	$1.3250	$11,926
1/26/2015	9,000	$1.3250	$11,925
2/24/2015	9,001	$1.3250	$11,926
3/13/2015	9,075	$1.3250	$12,024
4/20/2015	9,001	$1.3250	$11,926
5/26/2015	9,075	$1.3250	$12,024
10/7/2015	9,001	$0.9215	$8,294
11/19/2015	9,001	$0.9215	$8,294
12/22/2015	9,001	$0.9215	$8,294
1/13/2016	9,001	$0.9215	$8,294
2/3/2016	9,001	$0.9215	$8,294
3/1/2016	9,001	$0.9215	$8,294
3/30/2016	9,637	$0.9215	$8,881
5/5/2016	9,000	$0.9215	$8,294

Table 2 summarizes the propane and fuel oil usage for the past 2 heating seasons. Because so little fuel oil was used, and because it is considered a backup fuel, the fuel oil usage was converted to propane equivalent in order to simplify analysis, based on the efficiencies and heating values listed in Table 8.

Table 2 – Fuel Usage Summary

Heating Year	Starting Amount in Propane Tank (gal)	Ending Amount in Propane Tank (gal)	Propane Delivered (gal)	Propane Used (gal)	Cost of Propane Used	Weighted Unit Price for Propane ($/gal)	#2 Fuel Oil Used (gal)	Propane Equivalent of #2 Fuel Oil (gal)	Total Propane and Propane Equivalent Used (gal)
2014-2015	1,602	12,870	89,955	78,687	$104,260	$1.325	3,796	5,476	84,163
2015-2016	12,870	6,930	72,643	78,583	$76,961	$0.979	0	0	78,583
Average		.				**$1.15**			**81,373**

Note: Assumptions are listed in Table 8.

Daily mean temperature weather data from Ely Municipal Airport 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, which are then used to proportionally distribute the weekly fuel usage totals derived from the tank level records, to individual days in each week.

Figure 3 shows modeled daily average heat demand for heating seasons 2014-2015 and 2015-2016 (July-June), including propane and fuel oil usage. These models are based on the weekly tank level measurements, and use a HDD base temperature of 70°F.

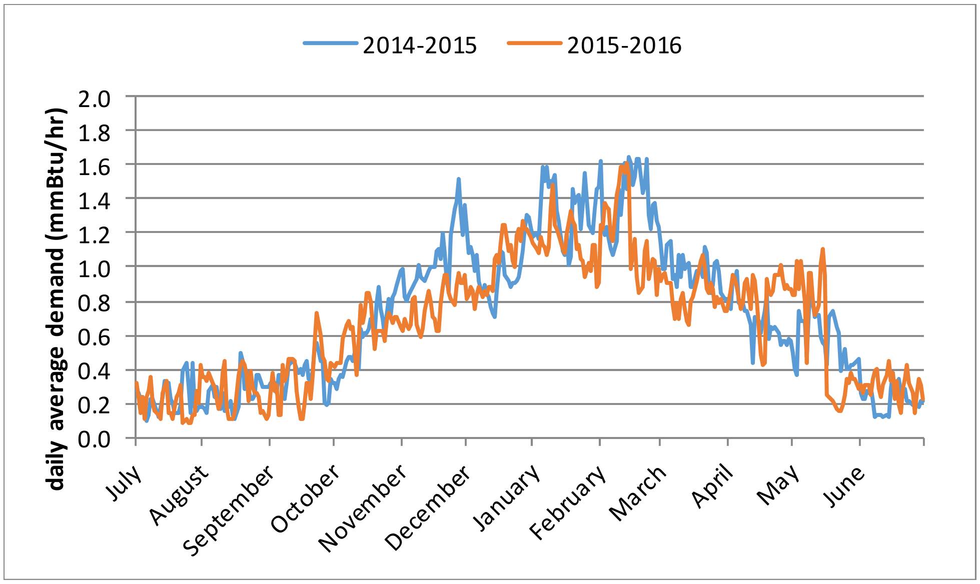


Figure 3 – Daily Average Demand for the Past 2 Heating Seasons

Note: Assumptions regarding system efficiencies are listed in Table 8. 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 4 presents load duration curves (LDC) for FY 2014 and FY 2015. These charts are 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 these curves can be used appropriately. The curves shown in Figure 4 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.

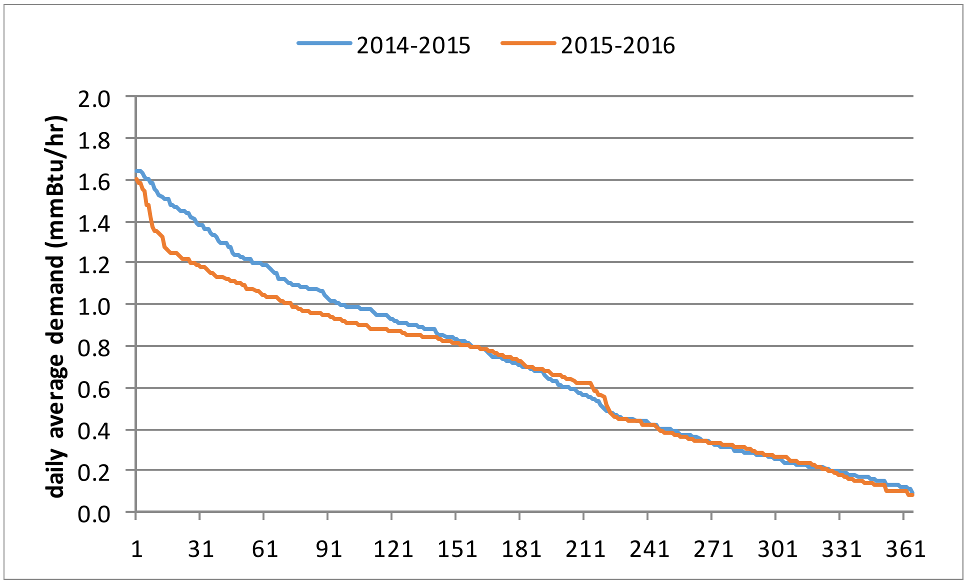


Figure 4 – Load Duration Curves

Note: Assumptions regarding system efficiencies are listed in Table 8. 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.

From Figure 4, it is apparent that the coldest day's average heat demand is approximately 1.6 mmBtu/hr. Using the models and values previously discussed, WES estimates that the peak hourly demand for the facility is approximately 3.0-3.5 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.

The options evaluated in this report would require an estimated annual use of up to 821 tons of wood chips assuming 40% moisture content wet basis, or 463 tons of wood pellets.

Table 3 compares the cost of delivered heat for wood and fossil fuel (propane). The propane cost shown is the average of the past 2 years.

Table 3 – Fuel Pricing and Cost per mmBtu

Technology, Unit	Cost/Unit	Input mmBtu /Unit	Assumed Efficiency	Output mmBtu /Unit	Output Cost /mmBtu
Green Wood Chip1, ton	$40	10	70%	7	$5.71
Dry Wood Chip2, ton	$80	12	75%	9	$8.89
Wood Pellet3, ton	$206	16.4	80%	13.1	$15.72
Propane (2-year average), gal	$1.15	0.091	85%	0.078	$14.84
Propane (2018 estimate), gal	$0.95	0.091	85%	0.078	$12.24
#2 Fuel Oil, gal	$3.00	0.14	80%	0.11	$26.79

Note 1: Green wood chips are approximately 40-45% moisture content wet basis.
Note 2: Dry wood chips are approximately 25-30% moisture wet basis. They are not commercially available in Ely. Cost for dry wood chips is estimated by WES as a fair market price.
Note 3: Wood pellets are 6-8% moisture content wet basis. Price includes delivery by auger truck.
Note 4: Table 8 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)
- Mulch blower truck (nearest is in Minneapolis)

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

The nearest wood pellet plant that could supply the hospital is Great Lakes Renewable Energy, 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. If a silo was used to store pellets, 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. Because Option 2 is designed with below-grade storage, it could receive deliveries from walking floor trailers. Option 3, which utilizes a silo, could only take deliveries from auger, pneumatic, or mulch blower trucks. A delivery cost of $5 per loaded mile is reflected in the pellet cost shown in Table 3.

5.2 WOOD CHIPS

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, or their wood yard in Mountain Iron, 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. Boilers which burn green chips are generally designed for larger scale installations, while the dry chip boilers are tailored to smaller facilities. The heating demand at EBCH is at the low end of the range covered by green chip boilers, and is ideally covered by equipment available for dried chips. However, dry chips are not available locally. Local loggers would most likely be able to supply "whole tree chips" which would be generated by in-woods chipping operations and would contain bark, sticks, needles, leaves, and the occasional oversized chip.

Boiler fuel quality is also affected by what equipment is used in chipping or grinding the feedstock. Chips are produced by equipment with knives which cleanly slice through wood. Options include drum or disc chippers. Hog fuel is produced by pulverizing wood using hammers or blunt force. Options include hammermills and tub grinders. Chips are preferred to grindings because chips are smoother and flow better. Hog fuel tends to be stringy and "fuzzy" which increases the chances of bridging. With the proper handling system, such as that proposed for Option 1, either fuel will work fine. The design of Option 2 is such that carefully screened chips (or pellets) are preferred.

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. Delivery of screened dry chips into a silo can be performed by a mulch blower truck. Although no such trucks exist in the local area, if this option was available, it would significantly reduce the capital cost for a dry chip system by allowing the use of an above grade silo rather than a below grade storage bunker.

Unacceptable feedstocks for wood chip boilers would include contaminated C&D waste, treated lumber, painted lumber, non-wood fuels such as coal or tires, or garbage of any kind. These fuels have the potential to generate significantly elevated emissions, and may damage the combustion unit or boiler.

6.0 EVALUATED BIOMASS SYSTEMS

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

Option 1 – Wood Chip Boiler: A wood chip hot water boiler, rated 1.7 mmBtu/hr, would be installed in a new boiler plant located between the ambulance garage and the propane tank. An automatic fuel reclaim and feeding system, and a 1,700 gallon thermal storage tank(s) would be installed with the boiler. The wood chip boiler would tie into the hospital's heating system in the existing central boiler room.

Option 2 – Wood Pellet and Dry Chip Boiler: One wood pellet hot water boiler, rated 1.7 mmBtu/hr, would be installed in a new boiler plant located between the ambulance garage and the propane tank. An automatic fuel reclaim and feeding system, and a 1,300 gallon thermal storage tank(s) would be installed with the boiler. The fuel handling system and boiler would be capable of utilizing dry chips or pellets for maximum fuel flexibility. The pellet boiler would tie into the hospital's heating system in the existing central boiler room.

Option 3 – Wood Pellet Boiler: One wood pellet hot water boiler, rated 1.7 mmBtu/hr, would be installed in a new boiler plant located adjacent to the hospital. A 40 ton pellet silo with a flexible auger would be installed to provide automatic fuel feed to the boiler. A 1,300 gallon thermal storage tank(s) would also be installed with the boiler. The pellet boiler would tie into the hospital's heating system in the existing central boiler room.

6.1 Option 1 – Wood Chip Boiler System

A new boiler room and fuel storage building would be built adjacent to the ambulance garage. A 1.7 mmBtu/hr boiler would be installed to burn woodchips which would be automatically fed from a fuel storage bunker. The wood chip fuel for this boiler would be wood chips sized 2.5" minus, with a moisture content of approximately 40% wet basis.

The boiler would be used to heat a 1,700 gallon hot water thermal storage tank(s). The thermal storage tank(s) would be typically maintained around 200°F. Using a mixing valve and a variable speed injection pump, hot water from the thermal storage would be blended with cooler return water from the heating distribution system to maintain a distribution supply water temperature based on an outside reset schedule. Storing water at temperatures that are higher than distributed allows maximization of the potential storage in the fixed tank volume and allows coverage of temporary peaks above wood boiler capacity.

A new 1,300 ft^2 building would be constructed as a boiler room and fuel bunker. The fuel bunker would be sized to hold approximately 50 tons of wood chips. Table 4 shows the approximate amount of time that a full bunker would last at different boiler firing rates. The fuel storage is designed to be emptied one side at a time to allow space for a new delivery on one side before the other side is exhausted. A traveling auger or rake system in the fuel bunker would automatically pull wood chips from the floor of the bunker onto a conveyor system. The conveyors will move the chips through a screening system to remove oversize chips, and then into a metering bin. Wood chips from the metering bin will be fed into the combustion unit to maintain the required boiler output.

Table 4 – Option 1 Fuel Storage Capacity

Firing Rate	Days of Fuel Supply
	Option 1 (Green Chips)
Summer (0.3 mmBtu/hr)	47
Winter (1.7 mmBtu/hr)	8

Note: Assumptions regarding system efficiencies and heating values are listed in Table 8.

Because the chip boiler is sized smaller than the peak load of the hospital, it will require fossil fuel boilers for peaking and backup. The existing boiler plant has an excellent size range of boilers and can fulfill this function.

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

Wood chip fueled biomass boilers operate most efficiently between 25% and 100% of their rated heating output. The 1.7 mmBtu/hr wood chip boiler would have an efficient operating range of 425,000 Btu/hr to 1.7 mmBtu/hr. Coverage for the biomass boiler is evaluated in both heating seasons for which data is available. Figure 5 shows the chip boiler covering approximately 88% of the 2014-2015 load, while Figure 6 shows the chip boiler covering approximately 86% of the 2015-2016 load.

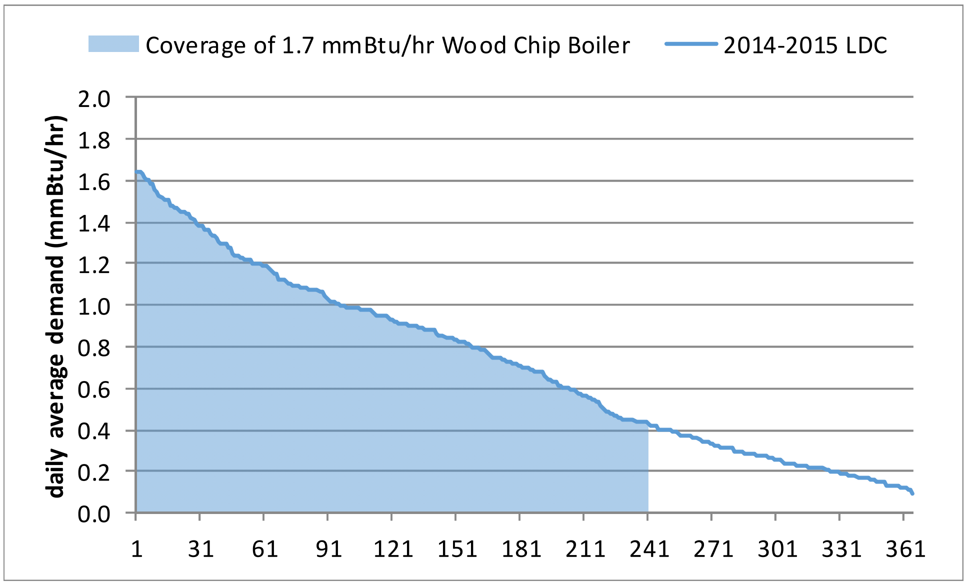


Figure 5 – 2014-2015 LDC and Coverage of 1.7 mmBtu/hr Chip Boiler

Note: Assumptions regarding system efficiencies are listed in Table 8. 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.

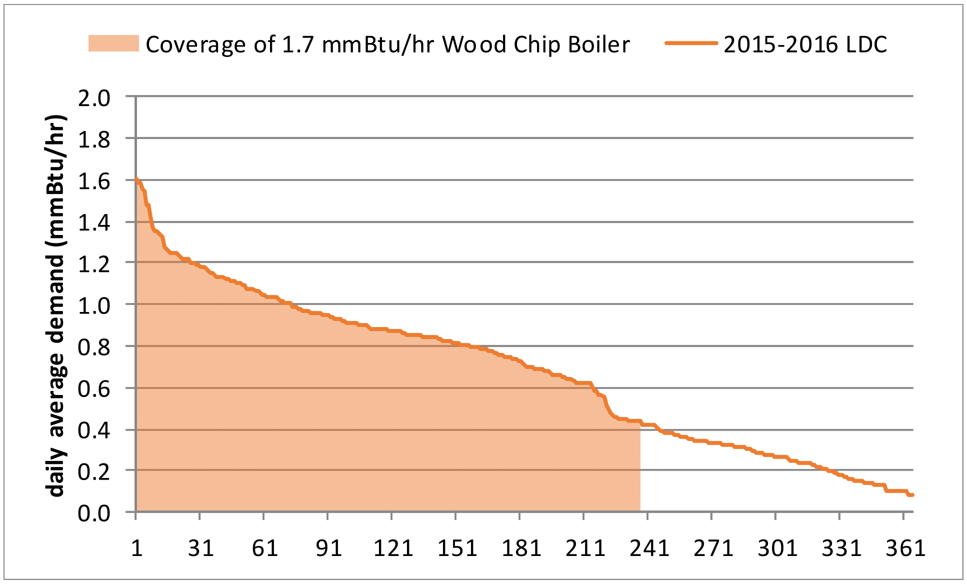


Figure 6 – 2015-2016 LDC and Coverage of 1.7 mmBtu/hr Chip Boiler

Note: Assumptions regarding system efficiencies are listed in Table 8. 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 85% coverage of the load by the chip boiler is estimated for the economic analysis in an average year. Exact sizing of the boiler would depend on the vendor selected, and their product offerings.

6.2 Option 2 – Wood Pellet and Dry Chip Boiler System

A new boiler room and fuel storage building would be built adjacent to the ambulance garage. A pellet boiler sized at 1.7 mmBtu/hr would be installed to burn pellets which would be automatically fed from a fuel storage bunker. The boiler and fuel storage would be set up to alternatively burn dry wood chips sized 1.5" minus.

The boiler would be used to heat a 1,300 gallon hot water thermal storage tank(s). The thermal storage tank(s) would be typically maintained around 200°F. Using a mixing valve and a variable speed injection pump, 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.

A new 830 ft^2 building would be constructed as a boiler room and fuel bunker. The fuel bunker would be sized to hold approximately 68 tons of pellets or 25 tons of dry wood chips. Table 5 shows the approximate amount of time that a full bunker would last at different boiler firing rates for each fuel type. The fuel storage is designed to be emptied one side at a time to allow space for a new delivery on one side before the other side is exhausted. Depending on truck capacity, a truck carrying dry chips may have to partially unload on one side and then move over to empty the remainder, due to the low density of dry chips. Two spring agitators in the bottom of the fuel bunker would automatically pull pellets or chips from the bottom of the bunker into an auger system. The augers would feed the fuel into the boiler to maintain the required boiler output. Because pellets are a manufactured product, they are a consistent size and shape, and can easily be handled by small diameter augers. For this reason, screening equipment will not be installed in the fuel handing system. If the system is fired on dry wood chips, it will be essential that the fuel be of a consistent size and quality to prevent any bridging or jams.

Table 5 – Option 2 Fuel Storage Capacity

Firing Rate	**Days of Fuel Supply**	
	Option 2 (Pellets)	**Option 2 (Dry Chips)**
Summer (0.3 mmBtu/hr)	123	32
Winter (1.7 mmBtu/hr)	22	6

Note: Assumptions regarding system efficiencies and heating values are listed in Table 8.

Pellet fuel is able to be stored in silos with sloping bottoms; however, dry wood chips cannot be stored in this way. A pellet-only system could utilize a smaller building, a less costly boiler, and a simple silo, but it would sacrifice fuel flexibility. Based on Table 3, pellets are more costly per Btu than propane currently, although that may change in the future. Provided that a supplier of screened chips can be located, a system set up for pellets or dry chips provides a cost effective alternative to the green chip boiler presented in Option 1. A pellet-only system is proposed in Option 3.

The boiler proposed in this option is representative of equipment which is able to be supplied from several U.S. manufacturers. Different manufacturers have different fuel specifications, but all generally require pellets or screened chips in order to prevent jams. In terms of moisture content, some manufacturers allow for screened green chips, while others require the chips to be no more than 30% moisture content wet basis. If green chips are used, the boiler output will be derated due to the energy required to evaporate the extra water. Depending on the available fuel options, however, this may be an acceptable tradeoff.

Because the rated output of the pellet boiler is smaller than the peak load of the hospital, it will require fossil fuel boilers for peaking and backup. The existing boiler plant has an excellent size range of boilers and can fulfill this function.

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 boiler would have an efficient operating range of 340,000 Btu/hr to 1.7 mmBtu/hr. Coverage for the biomass boiler is evaluated in both heating seasons for which data is available. Figure 7 shows the pellet boiler covering approximately 92% of the 2014-2015 load, while Figure 8 shows the pellet boiler covering approximately 91% of the 2015-2016 load.

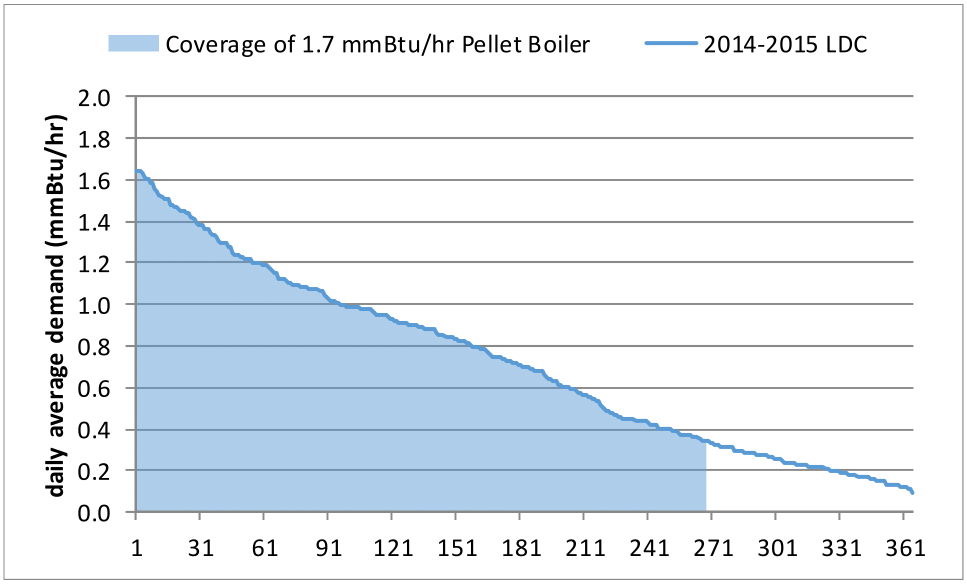


Figure 7 – 2014-2015 LDC and Coverage of 1.7 mmBtu/hr Pellet Boiler

Note: Assumptions regarding system efficiencies are listed in Table 8. 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.

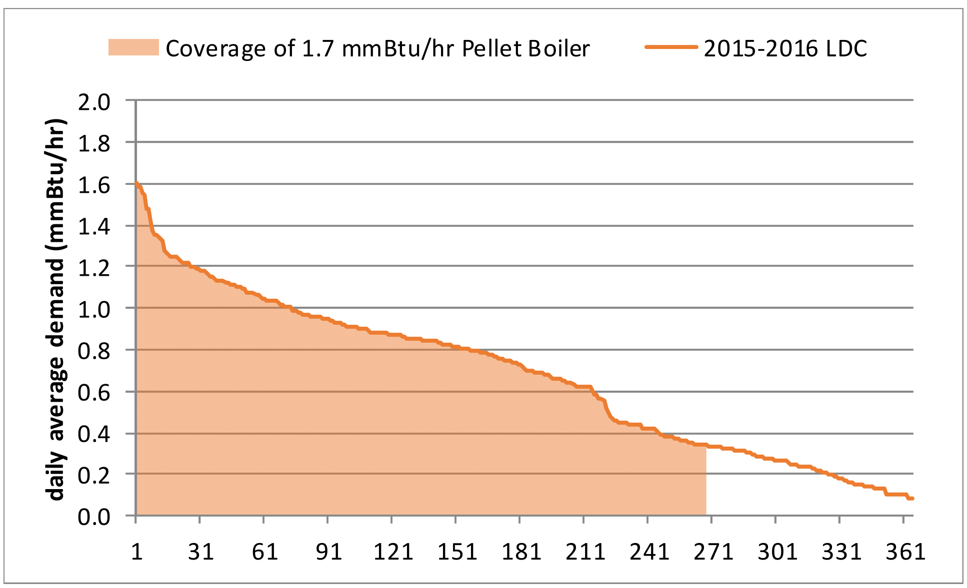


Figure 8 – 2015-2016 LDC and Coverage of 1.7 mmBtu/hr Pellet Boiler

Note: Assumptions regarding system efficiencies are listed in Table 8. 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, a value of 95% coverage of the load by the pellet boiler is estimated for the economic analysis. Exact sizing of the boiler would depend on the vendor selected, and their product offerings.

6.3 OPTION 3 – WOOD PELLET BOILER SYSTEM

A new boiler room and fuel silo would be at the northwest corner of the hospital. A pellet boiler sized at 1.7 mmBtu/hr would be installed to burn pellets which would be automatically fed from the silo.

The boiler would be used to heat a 1,300 gallon hot water thermal storage tank(s). The thermal storage tank(s) would be typically maintained around 200°F. Using a mixing valve and a variable speed injection pump, 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.

A new 400 ft^2 building would be constructed as a boiler room. Adjacent to the boiler room would be a silo capable of holding 40 tons of wood pellets. Table 6 shows the approximate amount of time that a full bunker would last at different boiler firing rates for each fuel type. A flexible auger would feed the fuel into the boiler to maintain the required boiler output.

Table 6 – Option 3 Fuel Storage Capacity

Firing Rate	Days of Fuel Supply
	Option 3 (Pellets)
Summer (0.3 mmBtu/hr)	73
Winter (1.7 mmBtu/hr)	13

Note: Assumptions regarding system efficiencies and heating values are listed in Table 8.

Based on Table 3, pellets are more costly per Btu than propane currently, although that may change in the future. This option would not be economically viable unless the prices of propane and fuel oil were to rise compared to the price of pellets.

Because the rated output of the pellet boiler is smaller than the peak load of the hospital, it will require fossil fuel boilers for peaking and backup. The existing boiler plant has an excellent size range of boilers and can fulfill this function.

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 boiler would have an efficient operating range of 340,000 Btu/hr to 1.7 mmBtu/hr. Coverage for the biomass boiler is evaluated in both heating seasons for which data is available, and is the same as that shown in Figure 7 and Figure 8 for Option 2. In a typical year, a value of 95% coverage of the load by the pellet boiler is estimated for the economic analysis. Exact sizing of the boiler would depend on the vendor selected, and their product offerings.

6.4 UNDERGROUND PIPING

The new boiler plant for Options 1 and 2 would be connected to the hospital via underground PEX piping. The PEX piping is pre-insulated with polyurethane foam and is encased in a protective but flexible plastic jacket. The pipe comes in continuous rolls up to 600 feet long, which eliminates the need for underground joints in almost all cases. To allow for vehicle traffic, it is normally buried 2 feet below the ground surface. Because water is continuously circulating, there is no risk of freezing. The relatively shallow depth of burial can avoid the need for expensive ledge removal, which is a concern in Ely.

Thermal loss to the ground was calculated for the underground connection to the hospital. For Option 1, assumptions were: mean fluid temperature of 170°F, mean outside air temperature of 30°F, and 290 days of run time. Assumptions for Option 2 were: mean fluid temperature of 170°F, mean outside air temperature of 30°F, and 330 days of run time. The calculated loss, per foot of pipe, is 23.2 Btu/hr. These losses, shown in Table 7, are added to the demands shown in the load duration curves for the project options, and are used to determine the total fuel demands in chips and pellets of each system shown in Table 11. Because the Option 3 boiler plant is built next to the hospital, no underground pipe is required, and thus there is no heat loss to the ground.

Table 7 – Heat Loss Calculation Summary

Description	Option 1	Option 2	Unit
Assumed Heat Loss	23.2	23.2	btu/hr/ft
Run Time	6,960	7,920	hours
Pipe Length	406	406	ft
Total Annual Loss	66	75	mmBtu
Additional Chip Fuel Required	9	-	tons
Additional Pellet Fuel Required	-	6	tons
Additional Dry Chips Required (if using dry chips rather than pellets)	-	8	tons

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 8, 250 mmBtu of thermal output is approximately equal to using 3,422 gallons of propane, 36 tons of green chips, 28 tons of dry chips, or 19 tons of pellets. It is likely that EBCH could qualify for this incentive during all four quarters, based on the historical fuel usage data. During qualifying quarters, this incentive would effectively reduce the price of green chips by $35/ton, dry chips by $45/ton, and pellets by $66/ton.

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

7.2 IRRRB BUSINESS ENERGY RETROFIT

The Business Energy Retrofit program is designed to assist business owners with energy efficient improvements. The program is funded by the Iron Range Resources and Rehabilitation Board (IRRRB). It offers a grant of 1/3 of energy retrofit project expenses, up to a limit of $20,000, for businesses in the IRRRB service area. All bids for the funded work must meet current state funded commercial prevailing wage.

7.3 Rural Energy for America Program (REAP)

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

7.4 Community Facilities Direct Loan and Grant

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

7.5 PACE (Property Assessed Clean Energy)

PACE is available in specific cities and counties in Minnesota, including Ely. This program provides funding for clean energy projects through increased property tax assessments on the property receiving the upgrades, for a term of 5-20 years. This is similar to a loan, except the amount does not appear “on the books” since the property tax is considered an operating cost. The host entity obtains financing on behalf of the project owner to provide the upfront funding, and repays the bond via the increased property t axes. For projects of the size being considered for EBCH, the funding would be equivalent to a loan with an interest rate of approximately 6-7%. Funding through this vehicle can be obtained either before or after a project is implemented. If funding is obtained prior to a project, then project must adhere to Davis-Bacon wage rates.

7.6 IRRRB Development Infrastructure

Another IRRRB program known as Development Infrastructure is a grant program for funding community development projects up to 50%. If future development west of the hospital is a possibility, then this program could be applicable, because the biomass plant could become a low-cost source of heat for other commercial and industrial buildings which would be constructed. IRRRB was contacted, and the recommendation was that EBCH should meet with IRRRB’s head of this program to discuss the project if they are interested in pursuing it.

7.7 DEED

The Minnesota Department of Employment and Economic Development (DEED) administers numerous tax incentive, loan, and grant programs. Especially if EBCH’s project has the potential to affect logging jobs or provide low cost heat to other local businesses, then there may be an opportunity for funding. It is recommended that a meeting be scheduled with DEED to discuss the project if the EBCH is interested in pursuing the project.

8.0 BIOMASS SYSTEM ANALYSIS

Table 8 lists the values and assumptions used in the analysis.

Table 8 – Values and Assumptions

Assumption	Value	Unit	Source
Propane HHV	0.091333	mmBtu/gal	WES Assumption
Propane Cost (2 year average)	$1.15	$/gal	EBCH
Propane Cost (2018 estimate)	$0.95	$/gal	EBCH
Propane Boiler Efficiency	85%	percent	WES Assumption
#2 Fuel OIl HHV	0.14	mmBtu/gal	WES Assumption
#2 Fuel Oil Cost	$3.00	$/gal	WES Assumption
#2 Fuel Oil Boiler Efficiency	80%	percent	Nameplate
Wood Chip HHV (40% moisture wet basis)	10	mmBtu/ton	WES Assumption
Wood Chip Cost	$40	$/ton	WES Assumption
Wood Chip Boiler Efficiency	70%	Percent	WES Assumption
Wood Chip Density	0.01	$tons/ft^3$	WES Assumption
Dry Wood Chip HHV (30% moisture wet basis)	12	mmBtu/ton	WES Assumption
Dry Wood Chip Cost	$80	$/ton	WES Assumption
Dry Wood Chip Boiler Efficiency	75%	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	70	˚F	WES Assumption
Electric Cost	$0.10	$/kWh	EBCH
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	* 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 9.

Table 9 – Capital Cost Estimate Summary

Option	Estimated Capital Cost
1 – Chip Boiler	$1,189,240
2 – Pellet and Dry Chip Boiler	$959,365
3 – Pellet Boiler	$519,500

Installed costs for the new systems include the combustion unit and hot water boilers, new boiler building, automatic fuel handling, underground hot water piping, and interconnection with the main boiler room. A detailed breakdown of capital costs for each option is provided in Appendix B.

Table 10 gives a breakdown of estimated operating and maintenance costs for each option. During the heating season, Option 1 is estimated to require an average of 45 minutes of maintenance per day, Option 2 is estimated to require an average of 15 minutes per day, and Option 3 is estimated to require an average of 12 minutes per day. This daily time estimate includes the annual tube cleaning, which can be done by facility staff, and would alternatively cost $4,000-$5,000 if done by the boiler manufacturer.

Table 10 – Estimated Operating and Maintenance Costs

Option	Electric Usage	Maintenance / Wear Parts	Staff Time	Total O&M Cost
1 – Chip Boiler	$3,480	$1,000	$6,525	**$11,005**
2 – Pellet and Dry Chip Boiler	$2,376	$400	$2,475	**$5,251**
3 – Pellet Boiler	$1,584	$200	$1,980	**$3,764**

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

Table 11 – Proposed System Fuel Use Profile

Option	Current Annual Fuel Use	Annual Fuel Use with Proposed Biomass System		
	Propane and Propane Equivalent (gal)	Biomass Demand Coverage	Estimated Biomass Use (tons)	Estimated Propane Use with Biomass System (gal)
1 – Chip Boiler	81,373	85%	776	12,206
2 – Pellet and Dry Chip Boiler using pellets	81,373	95%	463	4,069
2 – Pellet and Dry Chip Boiler using dry chips[1]	81,373	95%	675	4,069
3 – Pellet Boiler	81,373	95%	457	4,069

Note 1: Usage of dry chips is shown for comparison purposes only, as dry chips are not available at this time.
Note 2: Table 8 contains the assumptions used to develop the above values.

Table 12 provides a comparison of fuel costs and operating costs for the options.

Table 12 – Fuel and Operating Cost Comparison

Option	Current Annual Fuel Cost	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 – Chip Boiler	$93,756	$31,058	$14,063	$11,005	$37,629	$27,176	$64,805
2 – Pellet and Dry Chip Boiler using pellets	$93,756	$95,516	$4,688	$5,251	($11,698)	$30,380	$18,681
2 – Pellet and Dry Chip Boiler using dry chips[1]	$93,756	$54,009	$4,688	$5,251	$29,809	$30,380	$60,189
3 – Pellet Boiler	$93,756	$94,343	$4,688	$3,764	($9,039)	$30,007	$20,968

Note 1: Usage of dry chips is shown for comparison purposes only, as dry chips are not available at this time.
Note 2: Table 8 contains the assumptions used to develop the above values.

A summary of the estimated capital costs and payback is provided in Table 13. This table also evaluates the options with an assumed 25% grant.

Table 13 – Cost and Payback Analysis

Option	Estimated Capital Cost	Assumed Grant Funding	Financed Amount	Simple Payback Period[2] (years)	Net Present Value (25 years)
1 – Chip Boiler	$1,189,240	$0	$1,189,240	24	$167,436
2 – Pellet and Dry Chip Boiler using pellets	$959,365	$0	$959,365	-	($706,724)
2 – Pellet and Dry Chip Boiler using dry chips[1]	$959,365	$0	$959,365	22	$261,904
3 – Pellet Boiler	$519,500	$0	$519,500	-	($209,893)
1 – Chip Boiler	$1,189,240	$297,310	$891,930	16	$464,746
2 – Pellet and Dry Chip Boiler using pellets	$959,365	$239,841	$719,524	-	($466,883)
2 – Pellet and Dry Chip Boiler using dry chips[1]	$959,365	$239,841	$719,524	14	$501,745
3 – Pellet Boiler	$519,500	$129,875	$389,625	-	($80,018)

Note 1: Usage of dry chips is shown for comparison purposes only, as dry chips are not locally available at this time.
Note 2: Simple payback is calculated taking into account the assumption that thermal production incentive payments end after 10 years.

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

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 8, the wood chip boiler proposed in Option 1 would have a maximum fuel input rate of 2.4 mmBtu/hr and the pellet boiler proposed in Options 2 and 3 would have a maximum fuel input rate of 2.1 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 14 presents these emissions factors along with the expected emissions factors for wood boilers based on stack test data obtained by WES.

Table 14 – 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
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

None of the options include an Electrostatic Precipitator (ESP) for particulate emission control, because it is not required for boilers in this size range. However, an ESP could be added if there are concerns or perceived concerns about particulate emissions, especially near the hospital. Adding an ESP to any of the options would add about $150,000 to the capital cost and would result in particulate emissions at or below 0.03 lb/mmBtu (guaranteed by ESP supplier).

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 15 presents emissions factors for the gaseous pollutants mentioned.

Table 15 – 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.
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 EBCH's annual net CO_2 equivalent greenhouse gas emissions by up to 393 metric tonnes, as shown in Table 16. 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 8.

Table 16 – 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 – Chip Boiler	469	0	116	70	282
2 – Pellet and Dry Chip Boiler	469	0	79	23	366
3 – Pellet Boiler	469	0	53	23	393

Note 1: Biomass boilers use more electricity than comparable gas boilers due to fuel handling equipment, larger blowers, etc. Table 8 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 Ely Bloomenson Community Hospital, with either wood boiler option implemented, would not exceed the state or federal emissions thresholds for air pollutants. The PTE of a facility also includes non-combustion emissions sources such as VOCs and dust. WES estimates that there are no significant emissions sources at this facility that would affect the permitting status other than the boilers. Additionally, EBCH 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 clean wood chips, regardless of their source, as a fuel without any further action from MPCA's solid waste program.

9.6 ASH

Whole tree wood chips generally contain about 3% 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 9.

Figure 9 – Automated Ash Collection from Pellet/Chip Boiler

Options described in this report have the potential to generate 2-5 tons of ash (pellet fuel) or 20-23 tons of ash (wood chip 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.

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 Ely area, use of ash will primarily be on timber harvest sites, rather than 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.

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

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 17. Licenses classes are also divided into Grade A, B, C licenses. Grade C licenses allow for the operation of low pressure boilers (steam less than 15 psig, or hot water less than 160 psig or 250°F). Grade B licenses allow for the operation of low or high pressure boilers. Grade A licenses allow for the operation of low or high pressure boilers with engines, turbines or other appurtenances.

Table 17 – 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 existing aggregate input rate for the hospital boiler plant is approximately 12.5 mmBtu/hr. Addition of a wood boiler would increase the input capacity by about 2.4 mmBtu/hr, to a total of 14.9 mmBtu/hr. Therefore, no change in license class would be required, according to the class designations in Table 17.

10.0 CONCLUSIONS AND RECOMMENDATIONS

A modern biomass boiler system would allow Ely Bloomenson Community Hospital to reduce fossil fuel usage while utilizing a local and renewable source of energy. The options evaluated in this report would provide benefits to EBCH as summarized:

- Option 1 is a boiler system capable of utilizing green wood chips. This project would provide a first year net operating savings of $37,629, not including payments from the thermal production incentive, and would have a capital cost of $1,189,240.
- Option 2 is a boiler system capable of utilizing wood pellets or dry wood chips. If pellet fuel was utilized, this project would increase annual operating costs by $11,698, before taking into account payments from the thermal production incentive, and if dry wood chips were utilized, first year net operating savings would be $29,809, not including payments from the thermal production incentive. This project would have a capital cost of $959,365.
- Option 3 is a boiler system capable of utilizing wood pellets. This project would increase annual operating costs by $9,039, before taking into account payments from the thermal production incentive, and would have a capital cost of $519,500.

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 fossil fuels rises, then the savings will increase fairly dramatically.

Payments from the Minnesota Biomass Thermal Production Incentive are a major driver of savings. For Option 1 the annual payment would be approximately $27,176, for Option 2 the annual payment would be approximately $30,380, and for Option 3 the annual payment would be approximately $30,007. It is important to note that these payments only occur for 10 years following startup of the project.

Without the incentive payments, use of pellet fuel is not economical based on current fossil fuel prices. For a pellet project to even be worthy of consideration, the cost of fossil fuels (propane and fuel oil) would have to rise to the equivalent of a propane cost of approximately $1.50/gallon ($19.32/mmBtu output).

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

- Net reduction of greenhouse gas emissions by 282-393 metric tonnes annually,
- Keeping $31,000-$95,000 per year spent on energy within the region,
- Diversification of fuels used by the Ely Bloomenson Community Hospital,
- 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.

A new ambulance garage is planned north of the new propane tank. There is undeveloped land west of the hospital which is owned by the city, which may be developed eventually. Interconnection of these future loads to the biomass plant would improve the economics of the biomass plant, but the boiler size should not be increased at this time in anticipation of these or future loads. Even if the boiler size is not increased, and significant additional load is connected, the biomass boiler will be able to supply more renewable energy overall, just not at the peak times, which occur for a few weeks per year. These peaks would be seamlessly covered by propane. If significant additional load is expected to be connected in the future, it could be prudent to leave space in the plant to install a second boiler at a later date, taking into account that this second boiler would share the fuel storage bin and the stack.

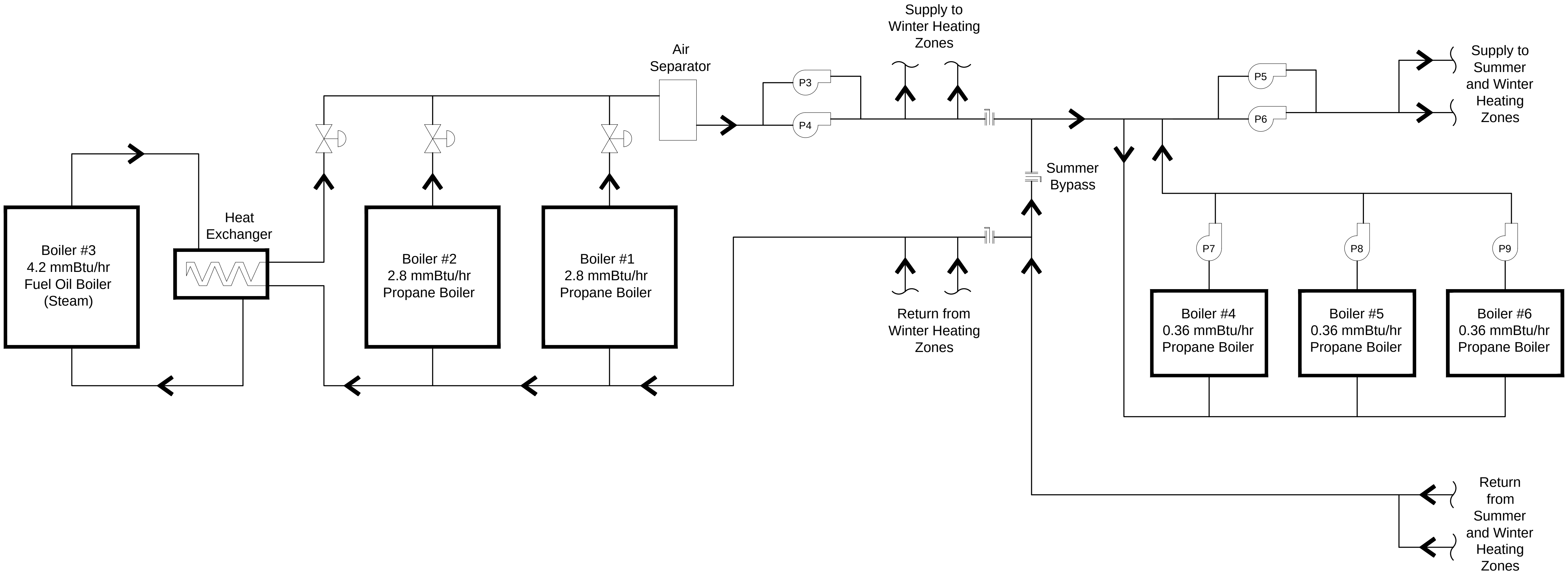
Should EBCH be interested in pursuing a biomass option, WES recommends that staff visit modern biomass boiler installations to develop a detailed understanding of the equipment and its capabilities. The MN SWET is available to assist in arranging tours of existing facilities. As EBCH continues to pursue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

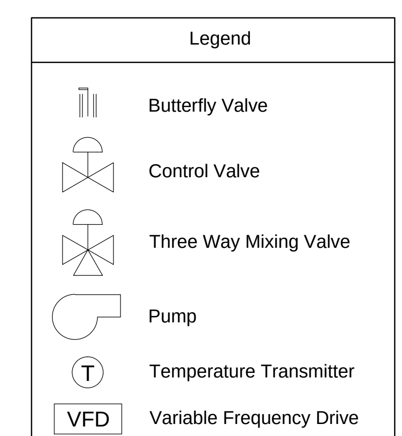
- Work with the MN SWET to identify alternative funding sources (low interest loans, grants, and incentives).
  - Thermal Production Incentive
  - IRRRB Business Energy Retrofit
  - Rural Energy for America Program (REAP)
  - Community Facilities Direct Loan & Grant Program
  - PACE
  - IRRRB Development Infrastructure
  - DEED

- 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.
- Continue to explore viable options for the wood chip supply, taking into consideration chip size, moisture content, and fuel quality, relative to boiler capabilities.
- Network with regional planning agencies to encourage widespread community support for this renewable energy project.

Appendix A – Drawings

- A.1 Existing Boiler Plant Schematic
- A.2 Biomass Interconnection Schematic
- A.3 Site Plan
- A.4 Option 1 Layout
- A.5 Option 1 Elevation
- A.6 Option 2 Layout
- A.7 Option 2 Elevation
- A.8 Option 3 Layout





Notes:
1. This drawing is a general layout of the existing system and is not intended to show all equipment connected.

Boiler Plant Existing Conditions

Designed PFO 7/26/16
Drawn PFO 7/26/16
Checked SFK 10/10/16
Approved ____ Date ____
Title ____ Job Class ____

Ely Bloomenson Community Hospital
Ely, MN

Existing Boiler Plant Schematic

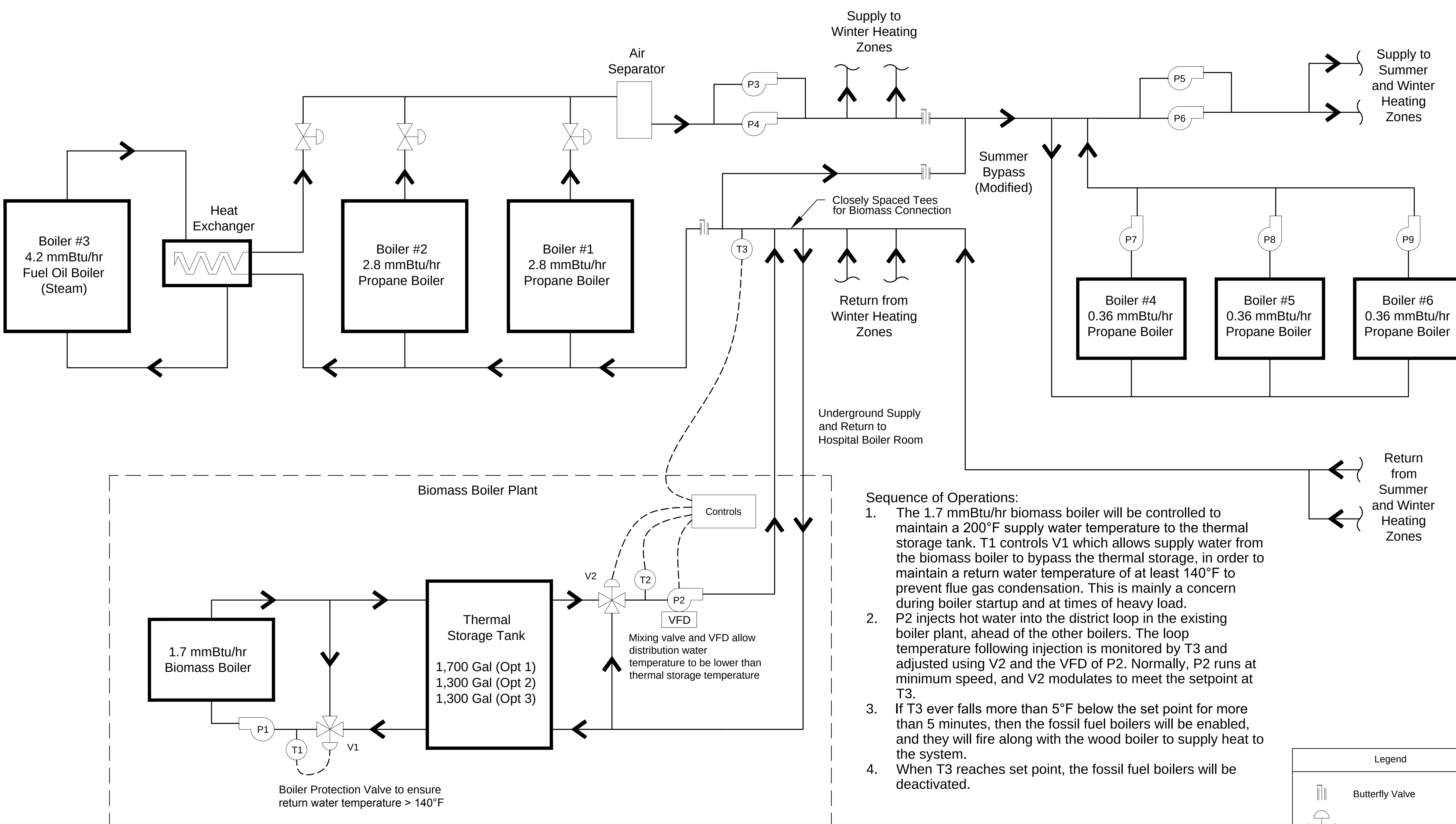
WES
Wilson Engineering Services, PC
www.wilsonengineeringservices.com
902 Market St. Meadville, PA 16335

REVISIONS

Date	Description	Approved

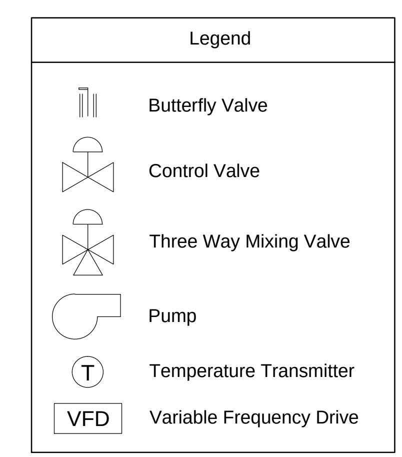
A.1

Interconnection Schematic for Wood Chip or Wood Pellet Boiler



Sequence of Operations:

1. The 1.7 mmBtu/hr biomass boiler will be controlled to maintain a 200°F supply water temperature to the thermal storage tank. T1 controls V1 which allows supply water from the biomass boiler to bypass the thermal storage, in order to maintain a return water temperature of at least 140°F to prevent flue gas condensation. This is mainly a concern during boiler startup and at times of heavy load.
2. P2 injects hot water into the district loop in the existing boiler plant, ahead of the other boilers. The loop temperature following injection is monitored by T3 and adjusted using V2 and the VFD of P2. Normally, P2 runs at minimum speed, and V2 modulates to meet the setpoint at T3.
3. If T3 ever falls more than 5°F below the set point for more than 5 minutes, then the fossil fuel boilers will be enabled, and they will fire along with the wood boiler to supply heat to the system.
4. When T3 reaches set point, the fossil fuel boilers will be deactivated.



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.

Designed PFO 9/8/16
Drawn PFO 9/8/16
Checked SFK 10/10/16
Approved
Date
Title
Job Class

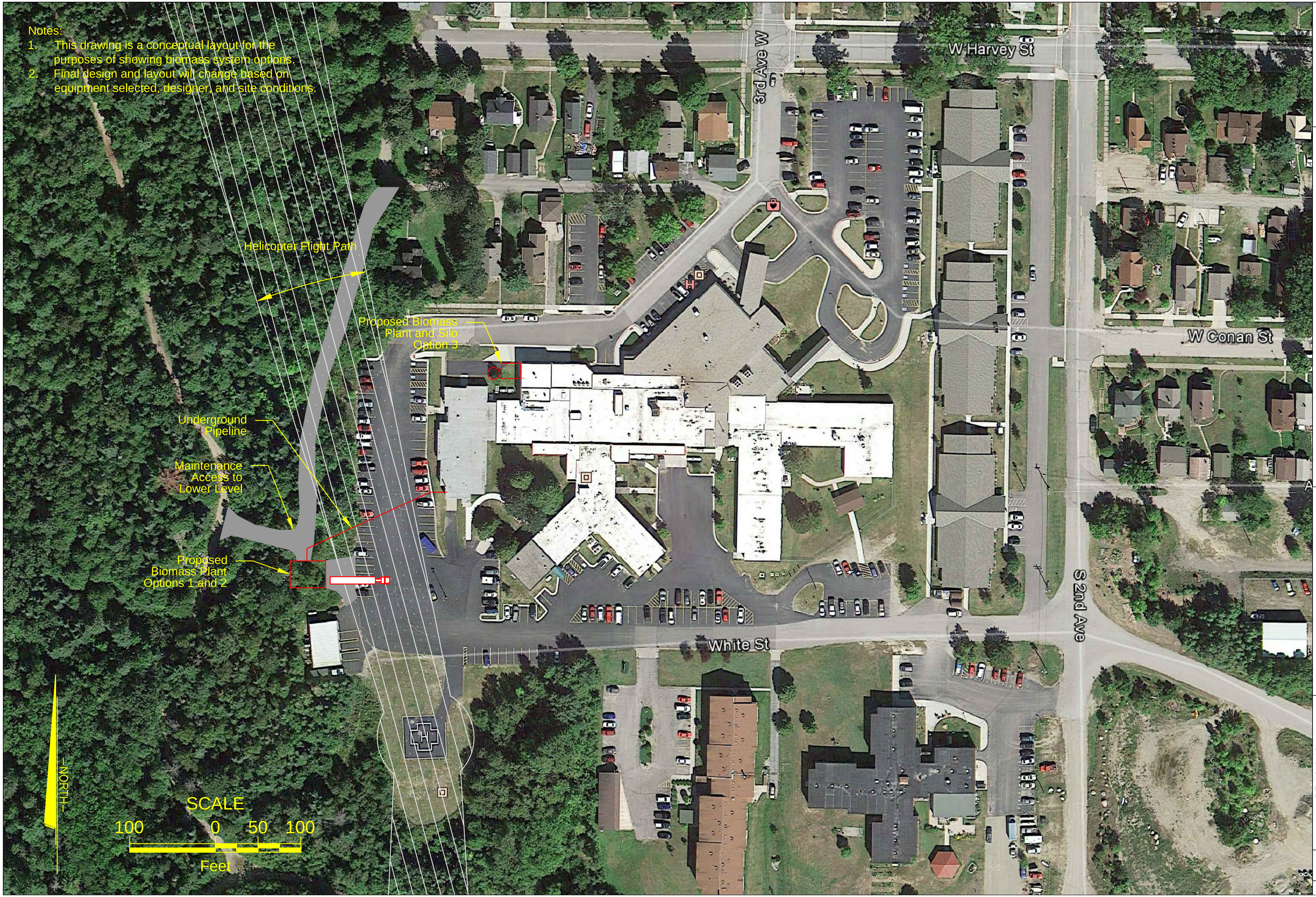
Ely Bloomenson Community Hospital
Ely, MN

Biomass Interconnection Schematic

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

REVISIONS
Date
Description
Approved

A.2



Ely Bloomenson Community Hospital

Ely, MN

Site Plan

Designed	PFO	7/26/16
Drawn	PFO	7/26/16
Checked	SFK	10/10/16

Approved ______ Date ______

Title ______ Job Class ______

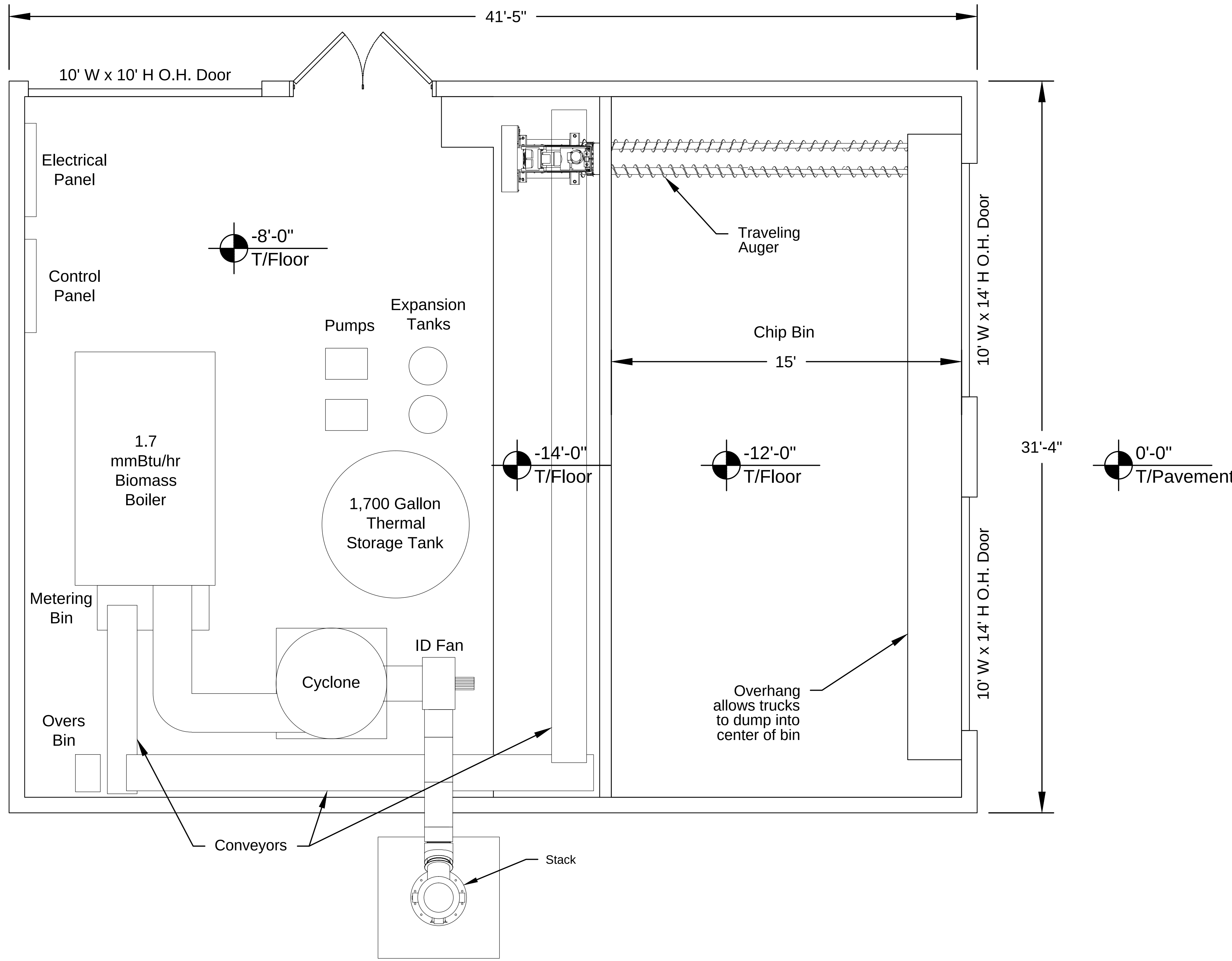
WES

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

REVISIONS

Date	Description	Approved

A.3



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 1 - Wood Chip Boiler Plan View

SCALE 2 0 1 2 Feet

Designed	PFO	7/26/16
Drawn	PFO	7/26/16
Checked	SFK	10/10/16
Approved		Date
Title		Job Class

Ely Bloomenson Community Hospital
Ely, MN

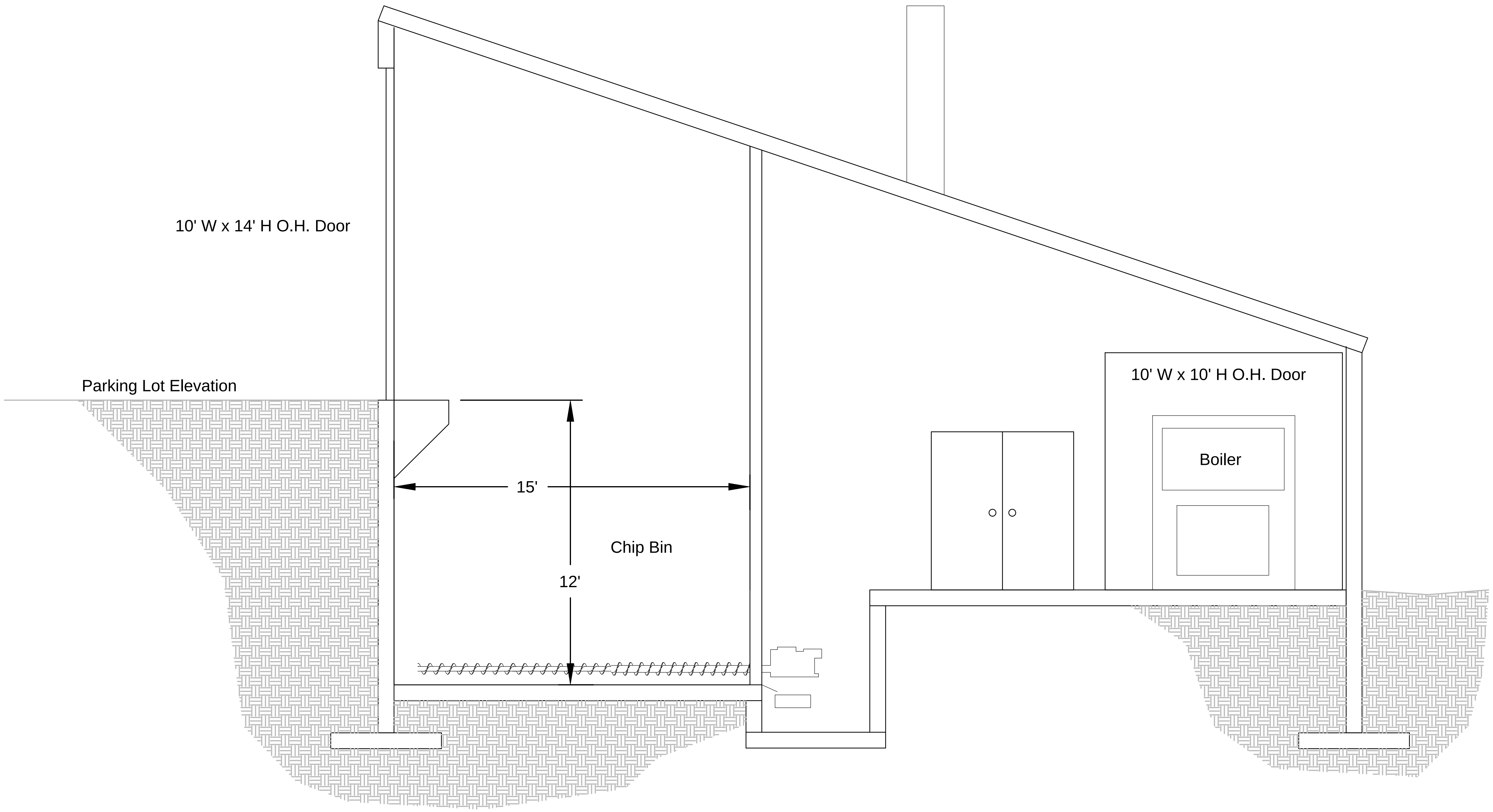
Option 1 Biomass Plant Layout

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

REVISIONS

Date	Description	Approved

A.4



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 1 - Wood Chip Boiler Elevation View (Looking South)

SCALE
2 0 1 2
Feet

Designed	PFO	9/12/16
Drawn	PFO	9/12/16
Checked	SFK	10/10/16

Approved ____ Date ____
Title ____ Job Class ____

Ely Bloomenson Community Hospital
Ely, MN

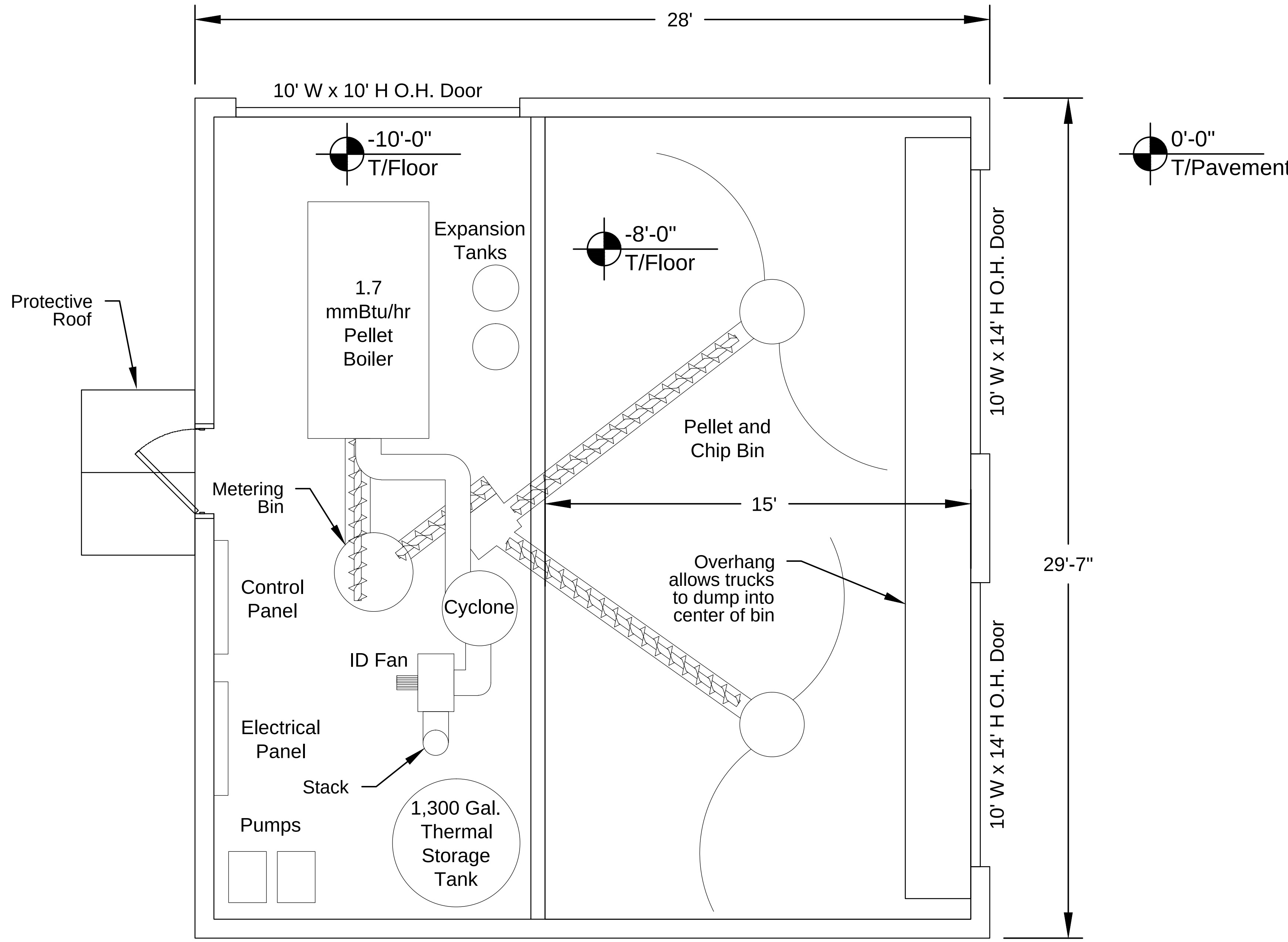
Option 1 Biomass Plant Elevation

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

REVISIONS

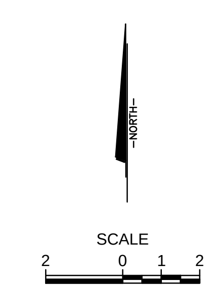
Date	Description	Approved

A.5



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 2 - Pellet and Dry Chip Boiler Plan View



Designed	PFO	9/12/16
Drawn	PFO	9/12/16
Checked	SFK	10/10/16

Approved ____ Date ____
Title ____ Job Class ____

Ely Bloomenson Community Hospital
Ely, MN

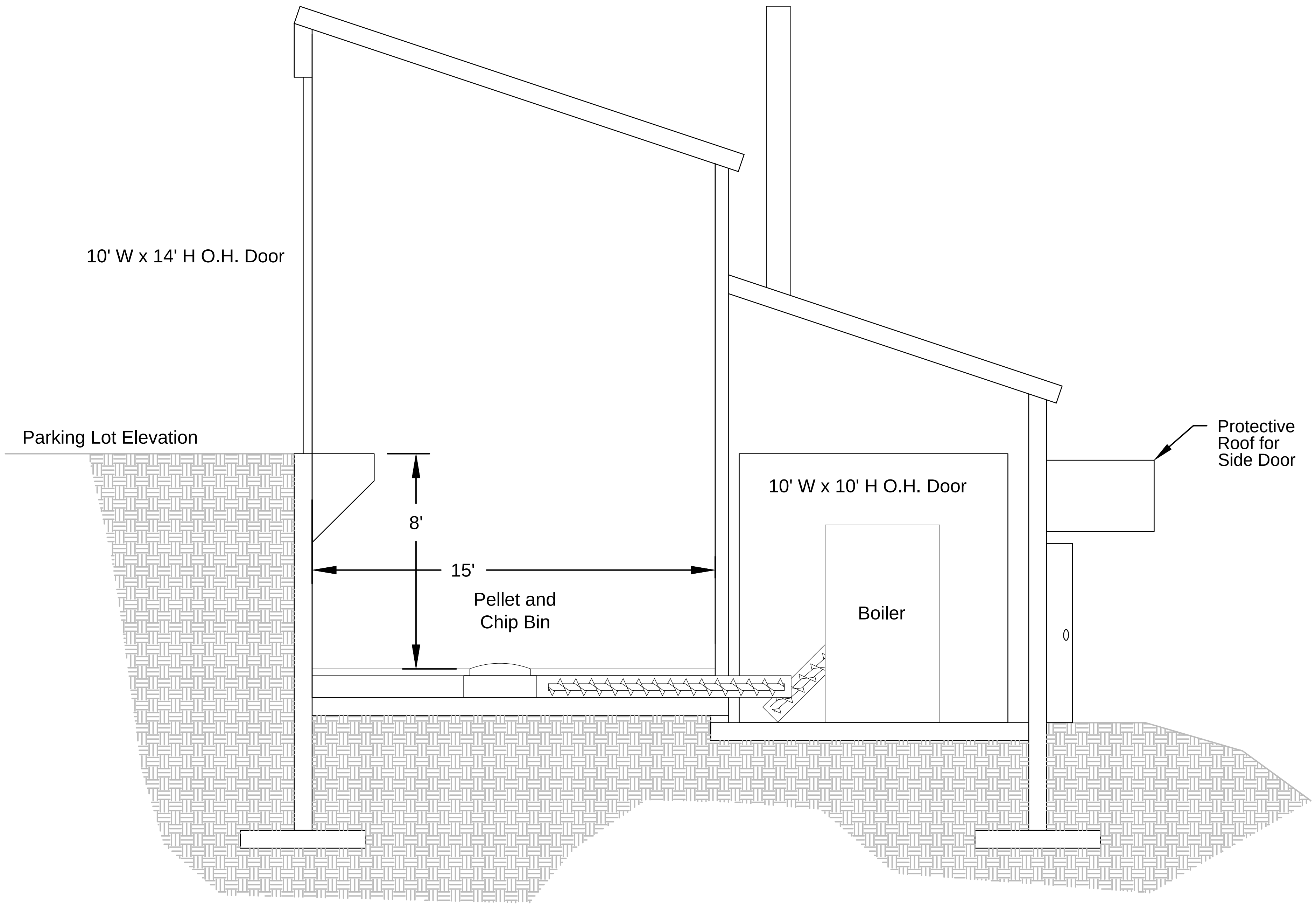
Option 2 Biomass Plant Layout

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

REVISIONS

Date	Description	Approved

A.6



Option 2 - Pellet Boiler Elevation View
(Looking South)

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.

SCALE
2 0 1 2
Feet

Designed	PFO	9/12/16
Drawn	PFO	9/12/16
Checked	SFK	10/10/16

Approved ____ Date ____
Title ____ Job Class ____

Ely Bloomenson Community Hospital
Ely, MN

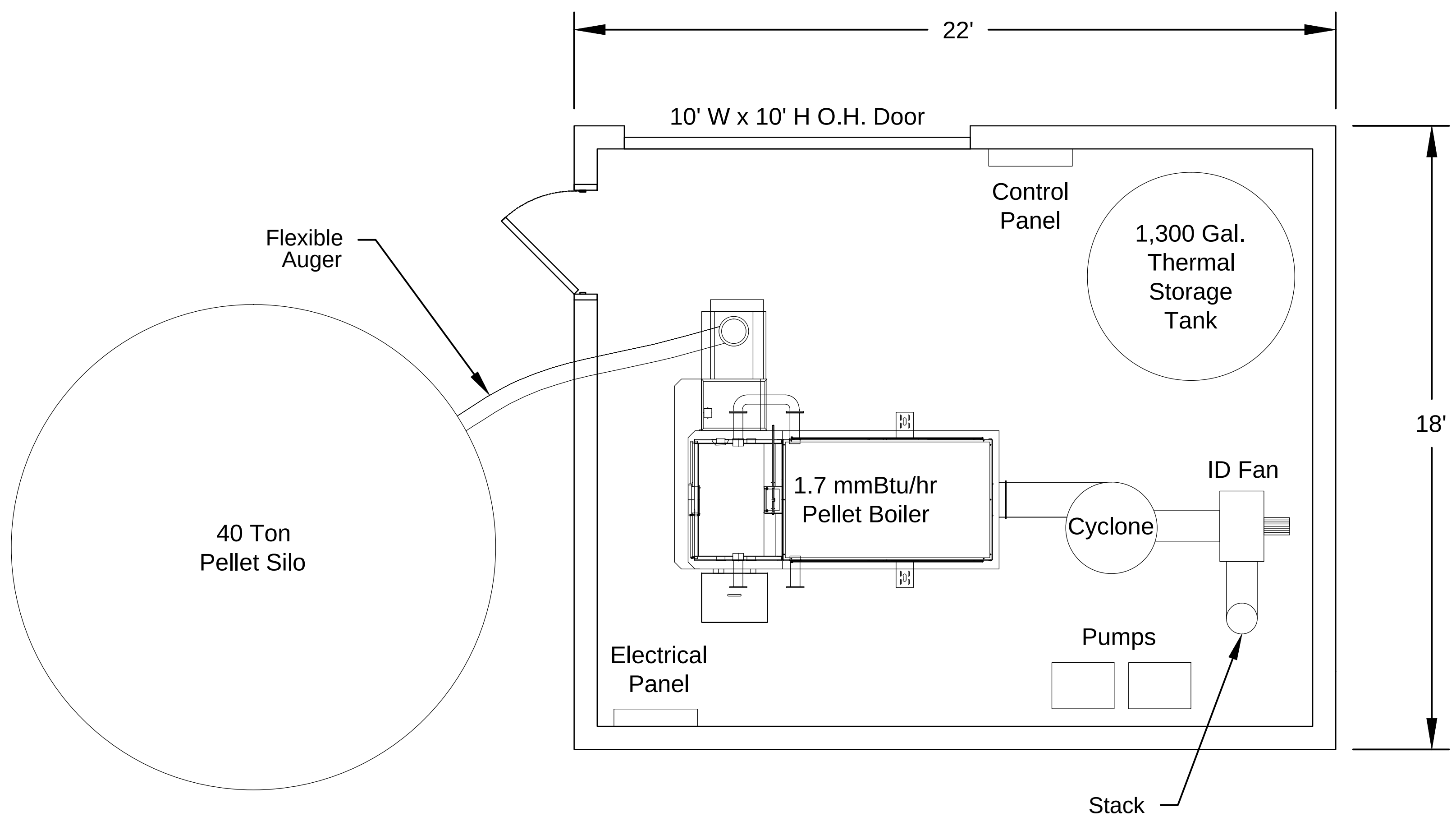
Option 1 Biomass Plant Elevation

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

REVISIONS

Date	Description	Approved

A.7



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 Boiler Plan View

SCALE
2 0 1 2
Feet

Designed PFO 10/6/16
Drawn PFO 10/6/16
Checked SFK 10/10/16
Approved ___ Date ___
Title ___ Job Class ___

Ely Bloomenson Community Hospital
Ely, MN

Option 3 Biomass Plant Layout

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

REVISIONS
Date | Description | Approved

Appendix B – Capital Cost Estimates

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

Option 1 - 1.7 mmBtu/hr Chip Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item	Cost
1.7 mmBtu/hr biomass combustion unit, 60 psig hot water boiler, cyclone, stack, boiler system controls, ash collection	$ 210,000
Fuel reclaim system, fuel handling, screening	$ 75,000
1,700 gallon thermal storage tank(s)	$ 20,000
Installation and startup	$ 65,000
Total Boiler Manufacturer Contract	**$ 370,000**

General Contract

Line Item	Cost
Sitework and grading	$ 100,000
1,300 ft^2 boiler building and fuel storage bunker ($200/sf)	$ 260,000
Electrical service	$ 10,000
Boiler Room Mechanical (pumps, piping, insulation, hydronic specialties)	$ 30,000
Insulated underground PEX piping (203' @ $200/ft)	$ 81,200
Interconnection in main boiler room	$ 20,000
Sub-Total	$ 501,200
Contractor profit, overhead, and insurance 16%	*$ 80,192*
Total General Contract Building and Site[2]	**$ 581,392**

Total Project Cost

Line Item	Cost
Project Sub-Total (Boiler, General Contract, Additional Items)	$ 951,392
Professional Services[3] 10%	*$ 95,139*
Contingency 15%	*$ 142,709*
Total Project Cost	**$ 1,189,240**

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 - 1.7 mmBtu/hr Pellet and Dry Chip Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item	Cost
1.7 mmBtu/hr pellet and dry chip hot water boiler, cyclone, blowers, stack	$ 150,000
Spring agitators and fuel handling system	$ 20,000
Boiler system controls, automatic ignition system, ash collection	$ 15,000
1,300 gallon thermal storage tank(s)	$ 12,000
Installation and startup	$ 50,000
Total Boiler Manufacturer Contract	**$ 247,000**

General Contract

Line Item	Cost
Sitework and grading	$ 100,000
830 ft^2 boiler building and fuel storage bunker ($250/sf)	$ 207,500
Electrical service	$ 10,000
Boiler Room Mechanical (pumps, piping, insulation, hydronic specialties)	$ 30,000
Insulated underground PEX piping, including trenching (203' @ $200/ft)	$ 81,200
Interconnection in main boiler room	$ 20,000
Sub-Total	$ 448,700
Contractor profit, overhead, and insurance 16%	*$ 71,792*
Total General Contract Building and Site[2]	**$ 520,492**

Total Project Cost

Line Item	Cost
Project Sub-Total (Boiler and General Contract)	$ 767,492
Professional Services[3] 10%	*$ 76,749*
Contingency 15%	*$ 115,124*
Total Project Cost	**$ 959,365**

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 - 1.7 mmBtu/hr Pellet Boiler Capital Cost Estimate

Biomass Boiler Manufacturer Contract[1]

Line Item	Cost
1.7 mmBtu/hr pellet boiler, cyclone, blowers, stack	$ 150,000
Boiler system controls, automatic ignition system, ash collection	$ 15,000
1,300 gallon thermal storage tank(s)	$ 15,000
Installation and startup	$ 50,000
Total Boiler Manufacturer Contract	**$ 230,000**

General Contract

Line Item	Cost
Sitework for pellet silo	$ 5,000
40 ton pellet silo and flex auger system	$ 20,000
400 ft^2 boiler building and fuel storage bunker ($200/sf)	$ 80,000
Electrical feeder to boiler room	$ 5,000
Boiler Room Mechanical (pumps, piping, insulation, hydronic specialties)	$ 30,000
Interconnection in main boiler room	$ 20,000
Sub-Total	$ 160,000
Contractor profit, overhead, and insurance 16%	*$ 25,600*
Total General Contract Building and Site[2]	**$ 185,600**

Total Project Cost

Line Item	Cost
Project Sub-Total (Boiler and General Contract)	$ 415,600
Professional Services[3] 10%	*$ 41,560*
Contingency 15%	*$ 62,340*
Total Project Cost	**$ 519,500**

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.

Appendix C – Financial and Fuel Cost Analyses

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

Appendix C

Option 1 - Wood Chip Boiler
25-year Cash Flow Analysis

Input Variables	Value	Units
Project Costs Financed	$1,189,240	$
Grant Amount	$0	$
Project Costs Financed	$1,189,240	$
Annual Propane Usage	81,373	gal
Average Propane Price	$1.15	$/gal
Wood Chip Usage (green chips)	776	tons/yr
Year 1 Wood Chip Price	$40	$/ton
Annual Propane Usage w/ Wood System	12,206	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	$11,005	$/year
Thermal Production Incentive	$27,176	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (1,189,240)	$ (1,189,240)
1	$ 93,756	$ (31,058)	$ (14,063)	$ (11,005)	$ 37,629	$ 27,176	$ 64,805	$ 64,164
2	$ 95,162	$ (31,214)	$ (14,274)	$ (11,005)	$ 38,670	$ 26,462	$ 65,131	$ 63,848
3	$ 96,590	$ (31,370)	$ (14,488)	$ (11,005)	$ 39,727	$ 25,766	$ 65,493	$ 63,566
4	$ 98,039	$ (31,526)	$ (14,706)	$ (11,005)	$ 40,801	$ 25,088	$ 65,890	$ 63,319
5	$ 99,509	$ (31,684)	$ (14,926)	$ (11,005)	$ 41,894	$ 24,429	$ 66,323	$ 63,104
6	$ 101,002	$ (31,843)	$ (15,150)	$ (11,005)	$ 43,004	$ 23,787	$ 66,791	$ 62,920
7	$ 102,517	$ (32,002)	$ (15,378)	$ (11,005)	$ 44,133	$ 23,161	$ 67,294	$ 62,766
8	$ 104,055	$ (32,162)	$ (15,608)	$ (11,005)	$ 45,280	$ 22,552	$ 67,832	$ 62,642
9	$ 105,616	$ (32,323)	$ (15,842)	$ (11,005)	$ 46,446	$ 21,959	$ 68,405	$ 62,546
10	$ 107,200	$ (32,484)	$ (16,080)	$ (11,005)	$ 47,631	$ 21,382	$ 69,013	$ 62,476
11	$ 108,808	$ (32,647)	$ (16,321)	$ (11,005)	$ 48,835		$ 48,835	$ 43,772
12	$ 110,440	$ (32,810)	$ (16,566)	$ (11,005)	$ 50,059		$ 50,059	$ 44,425
13	$ 112,096	$ (32,974)	$ (16,814)	$ (11,005)	$ 51,303		$ 51,303	$ 45,078
14	$ 113,778	$ (33,139)	$ (17,067)	$ (11,005)	$ 52,568		$ 52,568	$ 45,732
15	$ 115,485	$ (33,304)	$ (17,323)	$ (11,005)	$ 53,852		$ 53,852	$ 46,386
16	$ 117,217	$ (33,471)	$ (17,583)	$ (11,005)	$ 55,158		$ 55,158	$ 47,040
17	$ 118,975	$ (33,638)	$ (17,846)	$ (11,005)	$ 56,486		$ 56,486	$ 47,695
18	$ 120,760	$ (33,807)	$ (18,114)	$ (11,005)	$ 57,834		$ 57,834	$ 48,350
19	$ 122,571	$ (33,976)	$ (18,386)	$ (11,005)	$ 59,205		$ 59,205	$ 49,006
20	$ 124,410	$ (34,145)	$ (18,661)	$ (11,005)	$ 60,598		$ 60,598	$ 49,663
21	$ 126,276	$ (34,316)	$ (18,941)	$ (11,005)	$ 62,013		$ 62,013	$ 50,320
22	$ 128,170	$ (34,488)	$ (19,226)	$ (11,005)	$ 63,452		$ 63,452	$ 50,977
23	$ 130,093	$ (34,660)	$ (19,514)	$ (11,005)	$ 64,914		$ 64,914	$ 51,635
24	$ 132,044	$ (34,833)	$ (19,807)	$ (11,005)	$ 66,399		$ 66,399	$ 52,294
25	$ 134,025	$ (35,008)	$ (20,104)	$ (11,005)	$ 67,908		$ 67,908	$ 52,953
							25-year Net Present Value	**$ 167,436**

Note: All values are in real dollars.

Appendix C

Option 1 - Wood Chip Boiler
25-year Cash Flow Analysis with 25% Grant

Input Variables	Value	Units
Project Costs Financed	$1,189,240	$
Grant Amount	$297,310	$
Project Costs Financed	$891,930	$
Annual Propane Usage	81,373	gal
Average Propane Price	$1.15	$/gal
Wood Chip Usage (green chips)	776	tons/yr
Year 1 Wood Chip Price	$40	$/ton
Annual Propane Usage w/ Wood System	12,206	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	$11,005	$/year
Thermal Production Incentive	$27,176	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (891,930)	$ (891,930)
1	$ 93,756	$ (31,058)	$ (14,063)	$ (11,005)	$ 37,629	$ 27,176	$ 64,805	$ 64,164
2	$ 95,162	$ (31,214)	$ (14,274)	$ (11,005)	$ 38,670	$ 26,462	$ 65,131	$ 63,848
3	$ 96,590	$ (31,370)	$ (14,488)	$ (11,005)	$ 39,727	$ 25,766	$ 65,493	$ 63,566
4	$ 98,039	$ (31,526)	$ (14,706)	$ (11,005)	$ 40,801	$ 25,088	$ 65,890	$ 63,319
5	$ 99,509	$ (31,684)	$ (14,926)	$ (11,005)	$ 41,894	$ 24,429	$ 66,323	$ 63,104
6	$ 101,002	$ (31,843)	$ (15,150)	$ (11,005)	$ 43,004	$ 23,787	$ 66,791	$ 62,920
7	$ 102,517	$ (32,002)	$ (15,378)	$ (11,005)	$ 44,133	$ 23,161	$ 67,294	$ 62,766
8	$ 104,055	$ (32,162)	$ (15,608)	$ (11,005)	$ 45,280	$ 22,552	$ 67,832	$ 62,642
9	$ 105,616	$ (32,323)	$ (15,842)	$ (11,005)	$ 46,446	$ 21,959	$ 68,405	$ 62,546
10	$ 107,200	$ (32,484)	$ (16,080)	$ (11,005)	$ 47,631	$ 21,382	$ 69,013	$ 62,476
11	$ 108,808	$ (32,647)	$ (16,321)	$ (11,005)	$ 48,835		$ 48,835	$ 43,772
12	$ 110,440	$ (32,810)	$ (16,566)	$ (11,005)	$ 50,059		$ 50,059	$ 44,425
13	$ 112,096	$ (32,974)	$ (16,814)	$ (11,005)	$ 51,303		$ 51,303	$ 45,078
14	$ 113,778	$ (33,139)	$ (17,067)	$ (11,005)	$ 52,568		$ 52,568	$ 45,732
15	$ 115,485	$ (33,304)	$ (17,323)	$ (11,005)	$ 53,852		$ 53,852	$ 46,386
16	$ 117,217	$ (33,471)	$ (17,583)	$ (11,005)	$ 55,158		$ 55,158	$ 47,040
17	$ 118,975	$ (33,638)	$ (17,846)	$ (11,005)	$ 56,486		$ 56,486	$ 47,695
18	$ 120,760	$ (33,807)	$ (18,114)	$ (11,005)	$ 57,834		$ 57,834	$ 48,350
19	$ 122,571	$ (33,976)	$ (18,386)	$ (11,005)	$ 59,205		$ 59,205	$ 49,006
20	$ 124,410	$ (34,145)	$ (18,661)	$ (11,005)	$ 60,598		$ 60,598	$ 49,663
21	$ 126,276	$ (34,316)	$ (18,941)	$ (11,005)	$ 62,013		$ 62,013	$ 50,320
22	$ 128,170	$ (34,488)	$ (19,226)	$ (11,005)	$ 63,452		$ 63,452	$ 50,977
23	$ 130,093	$ (34,660)	$ (19,514)	$ (11,005)	$ 64,914		$ 64,914	$ 51,635
24	$ 132,044	$ (34,833)	$ (19,807)	$ (11,005)	$ 66,399		$ 66,399	$ 52,294
25	$ 134,025	$ (35,008)	$ (20,104)	$ (11,005)	$ 67,908		$ 67,908	$ 52,953
							25-year Net Present Value	**$ 464,746**

Note: All values are in real dollars.

Option 1 - Wood Chip Boiler
Fuel Cost Sensitivity Analysis

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

Price of Wood Chips - $/ton	Fossil Fuel Price, $/gal: $0.75	$1.00	$1.15	$1.25	$1.50	$1.75	$2.00
$10	$33,106	$50,397	$60,923	$67,689	$84,981	$102,273	$119,564
$15	$29,223	$46,515	$57,041	$63,807	$81,099	$98,390	$115,682
$20	$25,341	$42,633	$53,159	$59,925	$77,216	$94,508	$111,800
$25	$21,459	$38,751	$49,276	$56,042	$73,334	$90,626	$107,917
$30	$17,576	$34,868	$45,394	$52,160	$69,452	$86,743	$104,035
$35	$13,694	$30,986	$41,512	$48,278	$65,569	$82,861	$100,153
$40	$9,812	$27,104	$37,629	$44,395	$61,687	$78,979	$96,271
$45	$5,930	$23,221	$33,747	$40,513	$57,805	$75,097	$92,388
$50	$2,047	$19,339	$29,865	$36,631	$53,923	$71,214	$88,506
$55	($1,835)	$15,457	$25,983	$32,749	$50,040	$67,332	$84,624
$60	($5,717)	$11,575	$22,100	$28,866	$46,158	$63,450	$80,741
$65	($9,599)	$7,692	$18,218	$24,984	$42,276	$59,567	$76,859
$70	($13,482)	$3,810	$14,336	$21,102	$38,393	$55,685	$72,977
$75	($17,364)	($72)	$10,453	$17,219	$34,511	$51,803	$69,095

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

Appendix C

Option 2 - Pellet Boiler
25-year Cash Flow Analysis

Input Variables	Value	Units	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
Project Costs Financed	$959,365	$	0	$ -	$ -	$ -	$ -	$ -	$ -	$ (959,365)	$ (959,365)
Grant Amount	$0	$	1	$ 93,756	$ (95,516)	$ (4,688)	$ (5,251)	$ (11,698)	$ 30,380	$ 18,681	$ 18,496
Project Costs Financed	$959,365	$	2	$ 95,162	$ (95,993)	$ (4,758)	$ (5,251)	$ (10,840)	$ 29,581	$ 18,741	$ 18,372
Annual Propane Usage	81,373	gal	3	$ 96,590	$ (96,473)	$ (4,829)	$ (5,251)	$ (9,964)	$ 28,803	$ 18,839	$ 18,285
Average Propane Price	$1.15	$/gal	4	$ 98,039	$ (96,956)	$ (4,902)	$ (5,251)	$ (9,070)	$ 28,046	$ 18,976	$ 18,236
Pellet Usage	463	tons/yr	5	$ 99,509	$ (97,440)	$ (4,975)	$ (5,251)	$ (8,158)	$ 27,309	$ 19,151	$ 18,222
Year 1 Pellet Price	$206	$/ton	6	$ 101,002	$ (97,928)	$ (5,050)	$ (5,251)	$ (7,227)	$ 26,591	$ 19,364	$ 18,242
Annual Propane Usage w/ Wood System	4,069	gal	7	$ 102,517	$ (98,417)	$ (5,126)	$ (5,251)	$ (6,277)	$ 25,892	$ 19,615	$ 18,295
Fossil Fuel Escalation Rate (apr)	1.5%	Percent	8	$ 104,055	$ (98,909)	$ (5,203)	$ (5,251)	$ (5,308)	$ 25,211	$ 19,903	$ 18,380
Wood Fuel Escalation Rate (apr)	0.5%	Percent	9	$ 105,616	$ (99,404)	$ (5,281)	$ (5,251)	$ (4,320)	$ 24,548	$ 20,228	$ 18,495
Real Discount Rate (apr)	1.0%	Percent	10	$ 107,200	$ (99,901)	$ (5,360)	$ (5,251)	$ (3,312)	$ 23,903	$ 20,591	$ 18,641
Inflation Rate (apr)	2.7%	Percent	11	$ 108,808	$ (100,400)	$ (5,440)	$ (5,251)	$ (2,284)		$ (2,284)	$ (2,047)
Added Annual O&M Costs for Biomass Plant	$5,251	$/year	12	$ 110,440	$ (100,902)	$ (5,522)	$ (5,251)	$ (1,236)		$ (1,236)	$ (1,097)
Thermal Production Incentive	$30,380	$/year	13	$ 112,096	$ (101,407)	$ (5,605)	$ (5,251)	$ (166)		$ (166)	$ (146)
			14	$ 113,778	$ (101,914)	$ (5,689)	$ (5,251)	$ 924		$ 924	$ 804
			15	$ 115,485	$ (102,424)	$ (5,774)	$ (5,251)	$ 2,036		$ 2,036	$ 1,754
			16	$ 117,217	$ (102,936)	$ (5,861)	$ (5,251)	$ 3,169		$ 3,169	$ 2,703
			17	$ 118,975	$ (103,450)	$ (5,949)	$ (5,251)	$ 4,325		$ 4,325	$ 3,652
			18	$ 120,760	$ (103,968)	$ (6,038)	$ (5,251)	$ 5,503		$ 5,503	$ 4,601
			19	$ 122,571	$ (104,487)	$ (6,129)	$ (5,251)	$ 6,704		$ 6,704	$ 5,549
			20	$ 124,410	$ (105,010)	$ (6,220)	$ (5,251)	$ 7,928		$ 7,928	$ 6,498
			21	$ 126,276	$ (105,535)	$ (6,314)	$ (5,251)	$ 9,176		$ 9,176	$ 7,446
			22	$ 128,170	$ (106,063)	$ (6,409)	$ (5,251)	$ 10,448		$ 10,448	$ 8,394
			23	$ 130,093	$ (106,593)	$ (6,505)	$ (5,251)	$ 11,744		$ 11,744	$ 9,342
			24	$ 132,044	$ (107,126)	$ (6,602)	$ (5,251)	$ 13,065		$ 13,065	$ 10,289
			25	$ 134,025	$ (107,662)	$ (6,701)	$ (5,251)	$ 14,411		$ 14,411	$ 11,237
										25-year Net Present Value	**$ (706,724)**

Note: All values are in real dollars.

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

Input Variables	Value	Units	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
Project Costs Financed	$959,365	$	0	$ -	$ -	$ -	$ -	$ -	$ -	$ (719,524)	$ (719,524)
Grant Amount	$239,841	$	1	$ 93,756	$ (95,516)	$ (4,688)	$ (5,251)	$ (11,698)	$ 30,380	$ 18,681	$ 18,496
Project Costs Financed	$719,524	$	2	$ 95,162	$ (95,993)	$ (4,758)	$ (5,251)	$ (10,840)	$ 29,581	$ 18,741	$ 18,372
Annual Propane Usage	81,373	gal	3	$ 96,590	$ (96,473)	$ (4,829)	$ (5,251)	$ (9,964)	$ 28,803	$ 18,839	$ 18,285
Average Propane Price	$1.15	$/gal	4	$ 98,039	$ (96,956)	$ (4,902)	$ (5,251)	$ (9,070)	$ 28,046	$ 18,976	$ 18,236
Pellet Usage	463	tons/yr	5	$ 99,509	$ (97,440)	$ (4,975)	$ (5,251)	$ (8,158)	$ 27,309	$ 19,151	$ 18,222
Year 1 Pellet Price	$206	$/ton	6	$ 101,002	$ (97,928)	$ (5,050)	$ (5,251)	$ (7,227)	$ 26,591	$ 19,364	$ 18,242
Annual Propane Usage w/ Wood System	4,069	gal	7	$ 102,517	$ (98,417)	$ (5,126)	$ (5,251)	$ (6,277)	$ 25,892	$ 19,615	$ 18,295
Fossil Fuel Escalation Rate (apr)	1.5%	Percent	8	$ 104,055	$ (98,909)	$ (5,203)	$ (5,251)	$ (5,308)	$ 25,211	$ 19,903	$ 18,380
Wood Fuel Escalation Rate (apr)	0.5%	Percent	9	$ 105,616	$ (99,404)	$ (5,281)	$ (5,251)	$ (4,320)	$ 24,548	$ 20,228	$ 18,495
Real Discount Rate (apr)	1.0%	Percent	10	$ 107,200	$ (99,901)	$ (5,360)	$ (5,251)	$ (3,312)	$ 23,903	$ 20,591	$ 18,641
Inflation Rate (apr)	2.7%	Percent	11	$ 108,808	$ (100,400)	$ (5,440)	$ (5,251)	$ (2,284)		$ (2,284)	$ (2,047)
Added Annual O&M Costs for Biomass Plant	$5,251	$/year	12	$ 110,440	$ (100,902)	$ (5,522)	$ (5,251)	$ (1,236)		$ (1,236)	$ (1,097)
Thermal Production Incentive	$30,380	$/year	13	$ 112,096	$ (101,407)	$ (5,605)	$ (5,251)	$ (166)		$ (166)	$ (146)
			14	$ 113,778	$ (101,914)	$ (5,689)	$ (5,251)	$ 924		$ 924	$ 804
			15	$ 115,485	$ (102,424)	$ (5,774)	$ (5,251)	$ 2,036		$ 2,036	$ 1,754
			16	$ 117,217	$ (102,936)	$ (5,861)	$ (5,251)	$ 3,169		$ 3,169	$ 2,703
			17	$ 118,975	$ (103,450)	$ (5,949)	$ (5,251)	$ 4,325		$ 4,325	$ 3,652
			18	$ 120,760	$ (103,968)	$ (6,038)	$ (5,251)	$ 5,503		$ 5,503	$ 4,601
			19	$ 122,571	$ (104,487)	$ (6,129)	$ (5,251)	$ 6,704		$ 6,704	$ 5,549
			20	$ 124,410	$ (105,010)	$ (6,220)	$ (5,251)	$ 7,928		$ 7,928	$ 6,498
			21	$ 126,276	$ (105,535)	$ (6,314)	$ (5,251)	$ 9,176		$ 9,176	$ 7,446
			22	$ 128,170	$ (106,063)	$ (6,409)	$ (5,251)	$ 10,448		$ 10,448	$ 8,394
			23	$ 130,093	$ (106,593)	$ (6,505)	$ (5,251)	$ 11,744		$ 11,744	$ 9,342
			24	$ 132,044	$ (107,126)	$ (6,602)	$ (5,251)	$ 13,065		$ 13,065	$ 10,289
			25	$ 134,025	$ (107,662)	$ (6,701)	$ (5,251)	$ 14,411		$ 14,411	$ 11,237
										25-year Net Present Value	**$ (466,883)**

Note: All values are in real dollars.

Option 2 - 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**	**$1.15**	**$1.25**	**$1.50**	**$1.75**	**$2.00**
$170	($26,001)	($6,675)	$5,089	$12,651	$31,977	$51,303	$70,629
$175	($28,317)	($8,990)	$2,774	$10,336	$29,662	$48,988	$68,314
$180	($30,632)	($11,306)	$458	$8,020	$27,346	$46,672	$65,998
$185	($32,948)	($13,622)	($1,857)	$5,704	$25,031	$44,357	$63,683
$190	($35,263)	($15,937)	($4,173)	$3,389	$22,715	$42,041	$61,367
$195	($37,579)	($18,253)	($6,489)	$1,073	$20,399	$39,726	$59,052
$200	($39,894)	($20,568)	($8,804)	($1,242)	$18,084	$37,410	$56,736
$206	($42,789)	($23,463)	($11,698)	($4,137)	$15,190	$34,516	$53,842
$210	($44,525)	($25,199)	($13,435)	($5,873)	$13,453	$32,779	$52,105
$215	($46,841)	($27,515)	($15,751)	($8,189)	$11,137	$30,463	$49,789
$220	($49,156)	($29,830)	($18,066)	($10,504)	$8,822	$28,148	$47,474
$225	($51,472)	($32,146)	($20,382)	($12,820)	$6,506	$25,832	$45,158
$230	($53,787)	($34,461)	($22,697)	($15,135)	$4,191	$23,517	$42,843
$235	($56,103)	($36,777)	($25,013)	($17,451)	$1,875	$21,201	$40,527

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

Appendix C

Option 2 - Pellet Boiler using Dry Chips
25-year Cash Flow Analysis

Input Variables	Value	Units
Project Costs Financed	$959,365	$
Grant Amount	$0	$
Project Costs Financed	$959,365	$
Annual Propane Usage	81,373	gal
Average Propane Price	$1.15	$/gal
Dry Wood Chip Usage	675	tons/yr
Year 1 Dry Wood Chip Price	$80	$/ton
Annual Propane Usage w/ Wood System	4,069	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	$5,251	$/year
Thermal Production Incentive	$30,380	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (959,365)	$ (959,365)
1	$ 93,756	$ (54,009)	$ (4,688)	$ (5,251)	$ 29,809	$ 30,380	$ 60,189	$ 59,593
2	$ 95,162	$ (54,279)	$ (4,758)	$ (5,251)	$ 30,875	$ 29,581	$ 60,456	$ 59,265
3	$ 96,590	$ (54,550)	$ (4,829)	$ (5,251)	$ 31,959	$ 28,803	$ 60,763	$ 58,976
4	$ 98,039	$ (54,823)	$ (4,902)	$ (5,251)	$ 33,063	$ 28,046	$ 61,109	$ 58,725
5	$ 99,509	$ (55,097)	$ (4,975)	$ (5,251)	$ 34,186	$ 27,309	$ 61,495	$ 58,510
6	$ 101,002	$ (55,372)	$ (5,050)	$ (5,251)	$ 35,329	$ 26,591	$ 61,919	$ 58,331
7	$ 102,517	$ (55,649)	$ (5,126)	$ (5,251)	$ 36,491	$ 25,892	$ 62,383	$ 58,186
8	$ 104,055	$ (55,927)	$ (5,203)	$ (5,251)	$ 37,674	$ 25,211	$ 62,885	$ 58,073
9	$ 105,616	$ (56,207)	$ (5,281)	$ (5,251)	$ 38,877	$ 24,548	$ 63,425	$ 57,992
10	$ 107,200	$ (56,488)	$ (5,360)	$ (5,251)	$ 40,101	$ 23,903	$ 64,004	$ 57,942
11	$ 108,808	$ (56,771)	$ (5,440)	$ (5,251)	$ 41,346		$ 41,346	$ 37,059
12	$ 110,440	$ (57,054)	$ (5,522)	$ (5,251)	$ 42,612		$ 42,612	$ 37,816
13	$ 112,096	$ (57,340)	$ (5,605)	$ (5,251)	$ 43,901		$ 43,901	$ 38,574
14	$ 113,778	$ (57,626)	$ (5,689)	$ (5,251)	$ 45,212		$ 45,212	$ 39,332
15	$ 115,485	$ (57,915)	$ (5,774)	$ (5,251)	$ 46,545		$ 46,545	$ 40,091
16	$ 117,217	$ (58,204)	$ (5,861)	$ (5,251)	$ 47,901		$ 47,901	$ 40,851
17	$ 118,975	$ (58,495)	$ (5,949)	$ (5,251)	$ 49,280		$ 49,280	$ 41,611
18	$ 120,760	$ (58,788)	$ (6,038)	$ (5,251)	$ 50,683		$ 50,683	$ 42,372
19	$ 122,571	$ (59,082)	$ (6,129)	$ (5,251)	$ 52,110		$ 52,110	$ 43,134
20	$ 124,410	$ (59,377)	$ (6,220)	$ (5,251)	$ 53,561		$ 53,561	$ 43,896
21	$ 126,276	$ (59,674)	$ (6,314)	$ (5,251)	$ 55,037		$ 55,037	$ 44,659
22	$ 128,170	$ (59,972)	$ (6,409)	$ (5,251)	$ 56,538		$ 56,538	$ 45,423
23	$ 130,093	$ (60,272)	$ (6,505)	$ (5,251)	$ 58,065		$ 58,065	$ 46,187
24	$ 132,044	$ (60,573)	$ (6,602)	$ (5,251)	$ 59,617		$ 59,617	$ 46,953
25	$ 134,025	$ (60,876)	$ (6,701)	$ (5,251)	$ 61,196		$ 61,196	$ 47,719
							25-year Net Present Value	**$ 261,904**

Note: All values are in real dollars.

Appendix C

Option 2 - Pellet Boiler using Dry Chips
25-year Cash Flow Analysis with 25% Grant

Input Variables	Value	Units
Project Costs Financed	$959,365	$
Grant Amount	$239,841	$
Project Costs Financed	$719,524	$
Annual Propane Usage	81,373	gal
Average Propane Price	$1.15	$/gal
Dry Wood Chip Usage	675	tons/yr
Year 1 Dry Wood Chip Price	$80	$/ton
Annual Propane Usage w/ Wood System	4,069	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	$5,251	$/year
Thermal Production Incentive	$30,380	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (719,524)	$ (719,524)
1	$ 93,756	$ (54,009)	$ (4,688)	$ (5,251)	$ 29,809	$ 30,380	$ 60,189	$ 59,593
2	$ 95,162	$ (54,279)	$ (4,758)	$ (5,251)	$ 30,875	$ 29,581	$ 60,456	$ 59,265
3	$ 96,590	$ (54,550)	$ (4,829)	$ (5,251)	$ 31,959	$ 28,803	$ 60,763	$ 58,976
4	$ 98,039	$ (54,823)	$ (4,902)	$ (5,251)	$ 33,063	$ 28,046	$ 61,109	$ 58,725
5	$ 99,509	$ (55,097)	$ (4,975)	$ (5,251)	$ 34,186	$ 27,309	$ 61,495	$ 58,510
6	$ 101,002	$ (55,372)	$ (5,050)	$ (5,251)	$ 35,329	$ 26,591	$ 61,919	$ 58,331
7	$ 102,517	$ (55,649)	$ (5,126)	$ (5,251)	$ 36,491	$ 25,892	$ 62,383	$ 58,186
8	$ 104,055	$ (55,927)	$ (5,203)	$ (5,251)	$ 37,674	$ 25,211	$ 62,885	$ 58,073
9	$ 105,616	$ (56,207)	$ (5,281)	$ (5,251)	$ 38,877	$ 24,548	$ 63,425	$ 57,992
10	$ 107,200	$ (56,488)	$ (5,360)	$ (5,251)	$ 40,101	$ 23,903	$ 64,004	$ 57,942
11	$ 108,808	$ (56,771)	$ (5,440)	$ (5,251)	$ 41,346		$ 41,346	$ 37,059
12	$ 110,440	$ (57,054)	$ (5,522)	$ (5,251)	$ 42,612		$ 42,612	$ 37,816
13	$ 112,096	$ (57,340)	$ (5,605)	$ (5,251)	$ 43,901		$ 43,901	$ 38,574
14	$ 113,778	$ (57,626)	$ (5,689)	$ (5,251)	$ 45,212		$ 45,212	$ 39,332
15	$ 115,485	$ (57,915)	$ (5,774)	$ (5,251)	$ 46,545		$ 46,545	$ 40,091
16	$ 117,217	$ (58,204)	$ (5,861)	$ (5,251)	$ 47,901		$ 47,901	$ 40,851
17	$ 118,975	$ (58,495)	$ (5,949)	$ (5,251)	$ 49,280		$ 49,280	$ 41,611
18	$ 120,760	$ (58,788)	$ (6,038)	$ (5,251)	$ 50,683		$ 50,683	$ 42,372
19	$ 122,571	$ (59,082)	$ (6,129)	$ (5,251)	$ 52,110		$ 52,110	$ 43,134
20	$ 124,410	$ (59,377)	$ (6,220)	$ (5,251)	$ 53,561		$ 53,561	$ 43,896
21	$ 126,276	$ (59,674)	$ (6,314)	$ (5,251)	$ 55,037		$ 55,037	$ 44,659
22	$ 128,170	$ (59,972)	$ (6,409)	$ (5,251)	$ 56,538		$ 56,538	$ 45,423
23	$ 130,093	$ (60,272)	$ (6,505)	$ (5,251)	$ 58,065		$ 58,065	$ 46,187
24	$ 132,044	$ (60,573)	$ (6,602)	$ (5,251)	$ 59,617		$ 59,617	$ 46,953
25	$ 134,025	$ (60,876)	$ (6,701)	$ (5,251)	$ 61,196		$ 61,196	$ 47,719
							25-year Net Present Value	**$ 501,745**

Note: All values are in real dollars.

Option 2 - Pellet Boiler using Dry Chips
Fuel Cost Sensitivity Analysis

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

Price of Dry Wood Chips - $/ton	Fossil Fuel Price, $/gal						
	$0.75	**$1.00**	**$1.15**	**$1.25**	**$1.50**	**$1.75**	**$2.00**
$20	$39,225	$58,551	$70,315	$77,877	$97,203	$116,529	$135,855
$30	$32,474	$51,800	$63,564	$71,126	$90,452	$109,778	$129,104
$40	$25,723	$45,049	$56,813	$64,375	$83,701	$103,027	$122,353
$50	$18,972	$38,298	$50,062	$57,624	$76,950	$96,276	$115,602
$60	$12,221	$31,547	$43,311	$50,873	$70,199	$89,525	$108,851
$70	$5,470	$24,796	$36,560	$44,122	$63,448	$82,774	$102,100
$80	($1,281)	$18,045	$29,809	$37,371	$56,697	$76,023	$95,349
$90	($8,032)	$11,294	$23,058	$30,620	$49,946	$69,272	$88,598
$100	($14,784)	$4,543	$16,307	$23,869	$43,195	$62,521	$81,847
$110	($21,535)	($2,209)	$9,556	$17,118	$36,444	$55,770	$75,096
$120	($28,286)	($8,960)	$2,804	$10,366	$29,692	$49,019	$68,345
$130	($35,037)	($15,711)	($3,947)	$3,615	$22,941	$42,267	$61,594
$140	($41,788)	($22,462)	($10,698)	($3,136)	$16,190	$35,516	$54,842
$150	($48,539)	($29,213)	($17,449)	($9,887)	$9,439	$28,765	$48,091

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

Appendix C

Option 3 - Pellet Boiler
25-year Cash Flow Analysis

Input Variables	Value	Units
Project Costs Financed	$519,500	$
Grant Amount	$0	$
Project Costs Financed	$519,500	$
Annual Propane Usage	81,373	gal
Average Propane Price	$1.15	$/gal
Pellet Usage	457	tons/yr
Year 1 Pellet Price	$206	$/ton
Annual Propane Usage w/ Wood System	4,069	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	$3,764	$/year
Thermal Production Incentive	$30,007	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (519,500)	$ (519,500)
1	$ 93,756	$ (94,343)	$ (4,688)	$ (3,764)	$ (9,039)	$ 30,007	$ 20,968	$ 20,760
2	$ 95,162	$ (94,815)	$ (4,758)	$ (3,764)	$ (8,174)	$ 29,218	$ 21,043	$ 20,629
3	$ 96,590	$ (95,289)	$ (4,829)	$ (3,764)	$ (7,292)	$ 28,450	$ 21,157	$ 20,535
4	$ 98,039	$ (95,765)	$ (4,902)	$ (3,764)	$ (6,392)	$ 27,702	$ 21,309	$ 20,478
5	$ 99,509	$ (96,244)	$ (4,975)	$ (3,764)	$ (5,474)	$ 26,974	$ 21,499	$ 20,456
6	$ 101,002	$ (96,725)	$ (5,050)	$ (3,764)	$ (4,537)	$ 26,264	$ 21,727	$ 20,468
7	$ 102,517	$ (97,209)	$ (5,126)	$ (3,764)	$ (3,582)	$ 25,574	$ 21,992	$ 20,512
8	$ 104,055	$ (97,695)	$ (5,203)	$ (3,764)	$ (2,607)	$ 24,902	$ 22,295	$ 20,589
9	$ 105,616	$ (98,183)	$ (5,281)	$ (3,764)	$ (1,613)	$ 24,247	$ 22,634	$ 20,695
10	$ 107,200	$ (98,674)	$ (5,360)	$ (3,764)	$ (599)	$ 23,609	$ 23,011	$ 20,831
11	$ 108,808	$ (99,168)	$ (5,440)	$ (3,764)	$ 436		$ 436	$ 390
12	$ 110,440	$ (99,664)	$ (5,522)	$ (3,764)	$ 1,490		$ 1,490	$ 1,323
13	$ 112,096	$ (100,162)	$ (5,605)	$ (3,764)	$ 2,566		$ 2,566	$ 2,254
14	$ 113,778	$ (100,663)	$ (5,689)	$ (3,764)	$ 3,662		$ 3,662	$ 3,186
15	$ 115,485	$ (101,166)	$ (5,774)	$ (3,764)	$ 4,780		$ 4,780	$ 4,118
16	$ 117,217	$ (101,672)	$ (5,861)	$ (3,764)	$ 5,920		$ 5,920	$ 5,049
17	$ 118,975	$ (102,180)	$ (5,949)	$ (3,764)	$ 7,082		$ 7,082	$ 5,980
18	$ 120,760	$ (102,691)	$ (6,038)	$ (3,764)	$ 8,267		$ 8,267	$ 6,911
19	$ 122,571	$ (103,205)	$ (6,129)	$ (3,764)	$ 9,474		$ 9,474	$ 7,842
20	$ 124,410	$ (103,721)	$ (6,220)	$ (3,764)	$ 10,705		$ 10,705	$ 8,773
21	$ 126,276	$ (104,239)	$ (6,314)	$ (3,764)	$ 11,959		$ 11,959	$ 9,704
22	$ 128,170	$ (104,760)	$ (6,409)	$ (3,764)	$ 13,237		$ 13,237	$ 10,635
23	$ 130,093	$ (105,284)	$ (6,505)	$ (3,764)	$ 14,540		$ 14,540	$ 11,565
24	$ 132,044	$ (105,811)	$ (6,602)	$ (3,764)	$ 15,867		$ 15,867	$ 12,496
25	$ 134,025	$ (106,340)	$ (6,701)	$ (3,764)	$ 17,220		$ 17,220	$ 13,427
							25-year Net Present Value	**$ (209,893)**

Note: All values are in real dollars.

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

Input Variables	Value	Units
Project Costs Financed	$519,500	$
Grant Amount	$129,875	$
Project Costs Financed	$389,625	$
Annual Propane Usage	81,373	gal
Average Propane Price	$1.15	$/gal
Pellet Usage	457	tons/yr
Year 1 Pellet Price	$206	$/ton
Annual Propane Usage w/ Wood System	4,069	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	$3,764	$/year
Thermal Production Incentive	$30,007	$/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	$ -	$ -	$ -	$ -	$ -	$ -	$ (389,625)	$ (389,625)
1	$ 93,756	$ (94,343)	$ (4,688)	$ (3,764)	$ (9,039)	$ 30,007	$ 20,968	$ 20,760
2	$ 95,162	$ (94,815)	$ (4,758)	$ (3,764)	$ (8,174)	$ 29,218	$ 21,043	$ 20,629
3	$ 96,590	$ (95,289)	$ (4,829)	$ (3,764)	$ (7,292)	$ 28,450	$ 21,157	$ 20,535
4	$ 98,039	$ (95,765)	$ (4,902)	$ (3,764)	$ (6,392)	$ 27,702	$ 21,309	$ 20,478
5	$ 99,509	$ (96,244)	$ (4,975)	$ (3,764)	$ (5,474)	$ 26,974	$ 21,499	$ 20,456
6	$ 101,002	$ (96,725)	$ (5,050)	$ (3,764)	$ (4,537)	$ 26,264	$ 21,727	$ 20,468
7	$ 102,517	$ (97,209)	$ (5,126)	$ (3,764)	$ (3,582)	$ 25,574	$ 21,992	$ 20,512
8	$ 104,055	$ (97,695)	$ (5,203)	$ (3,764)	$ (2,607)	$ 24,902	$ 22,295	$ 20,589
9	$ 105,616	$ (98,183)	$ (5,281)	$ (3,764)	$ (1,613)	$ 24,247	$ 22,634	$ 20,695
10	$ 107,200	$ (98,674)	$ (5,360)	$ (3,764)	$ (599)	$ 23,609	$ 23,011	$ 20,831
11	$ 108,808	$ (99,168)	$ (5,440)	$ (3,764)	$ 436		$ 436	$ 390
12	$ 110,440	$ (99,664)	$ (5,522)	$ (3,764)	$ 1,490		$ 1,490	$ 1,323
13	$ 112,096	$ (100,162)	$ (5,605)	$ (3,764)	$ 2,566		$ 2,566	$ 2,254
14	$ 113,778	$ (100,663)	$ (5,689)	$ (3,764)	$ 3,662		$ 3,662	$ 3,186
15	$ 115,485	$ (101,166)	$ (5,774)	$ (3,764)	$ 4,780		$ 4,780	$ 4,118
16	$ 117,217	$ (101,672)	$ (5,861)	$ (3,764)	$ 5,920		$ 5,920	$ 5,049
17	$ 118,975	$ (102,180)	$ (5,949)	$ (3,764)	$ 7,082		$ 7,082	$ 5,980
18	$ 120,760	$ (102,691)	$ (6,038)	$ (3,764)	$ 8,267		$ 8,267	$ 6,911
19	$ 122,571	$ (103,205)	$ (6,129)	$ (3,764)	$ 9,474		$ 9,474	$ 7,842
20	$ 124,410	$ (103,721)	$ (6,220)	$ (3,764)	$ 10,705		$ 10,705	$ 8,773
21	$ 126,276	$ (104,239)	$ (6,314)	$ (3,764)	$ 11,959		$ 11,959	$ 9,704
22	$ 128,170	$ (104,760)	$ (6,409)	$ (3,764)	$ 13,237		$ 13,237	$ 10,635
23	$ 130,093	$ (105,284)	$ (6,505)	$ (3,764)	$ 14,540		$ 14,540	$ 11,565
24	$ 132,044	$ (105,811)	$ (6,602)	$ (3,764)	$ 15,867		$ 15,867	$ 12,496
25	$ 134,025	$ (106,340)	$ (6,701)	$ (3,764)	$ 17,220		$ 17,220	$ 13,427
							25-year Net Present Value	**$ (80,018)**

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**	**$1.15**	**$1.25**	**$1.50**	**$1.75**	**$2.00**
$170	($23,547)	($4,221)	$7,543	$15,105	$34,431	$53,757	$73,083
$175	($25,834)	($6,508)	$5,256	$12,818	$32,144	$51,470	$70,796
$180	($28,122)	($8,796)	$2,969	$10,531	$29,857	$49,183	$68,509
$185	($30,409)	($11,083)	$681	$8,243	$27,569	$46,896	$66,222
$190	($32,696)	($13,370)	($1,606)	$5,956	$25,282	$44,608	$63,934
$195	($34,983)	($15,657)	($3,893)	$3,669	$22,995	$42,321	$61,647
$200	($37,270)	($17,944)	($6,180)	$1,382	$20,708	$40,034	$59,360
$206	($40,129)	($20,803)	($9,039)	($1,477)	$17,849	$37,175	$56,501
$210	($41,844)	($22,518)	($10,754)	($3,192)	$16,134	$35,460	$54,786
$215	($44,131)	($24,805)	($13,041)	($5,479)	$13,847	$33,173	$52,499
$220	($46,418)	($27,092)	($15,328)	($7,766)	$11,560	$30,886	$50,212
$225	($48,706)	($29,379)	($17,615)	($10,053)	$9,273	$28,599	$47,925
$230	($50,993)	($31,667)	($19,903)	($12,341)	$6,986	$26,312	$45,638
$235	($53,280)	($33,954)	($22,190)	($14,628)	$4,698	$24,024	$43,351

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

Appendix D – UMN Extension By-Products Program Brochure

Why Recycle?

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

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

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

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

University of Minnesota
Extension
SERVICE

Carlton County

By-products Program

By-products Program

Wood Ash
Bio-Solids
Lime

By-product Program Resources

Troy Salzer
Extension Educator, Agriculture

Dr. Carl Rosen
Soil Scientist – Fertility

Dr. Tom Halbach
Water quality & Waste Mgmt

Russ Mathison
Forage Specialist

Bob Olen
Extension Educator, Horticulture

Dr. George Rehm
U of M Soil Scientist

Paul Peterson
Forage Specialist

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

Wood Ash

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

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

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

Bio-Solids

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

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

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

Lime

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

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

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

Benefits to participating in the By-products Program:

- Proven track record with over a decade of beneficial reuse of by-products
- University research used for application recommendations
- Education programs and field days for both industries and producers to share current research data and cropping improvement technologies
- Unbiased 3rd party involvement
- Provide educational programming to local decision makers/residents describing the research on the reuse 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.