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Northeastern Area
State and Private Forestry

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Feasibility Report

UW Stevens Point Biomass CHP Energy Project

Version: Final

Date

February 21, 2011

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Image Source: UWSP Biomass Presentation

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1.0 EXECUTIVE SUMMARY

This feasibility study evaluates options for the installation of a biomass combustion system at the University of Wisconsin – Stevens Point Campus. Unlike coal or natural gas, biomass is a locally grown renewable fuel that keeps energy dollars within the state and provides local markets to support forest management practices. Installation of a biomass boiler CHP system at the UW – Stevens Point Campus is technically feasible, financially viable, and can be supported by local renewable biomass fuel. The project identified meets the following university objectives:

- Replacing coal with biomass for base steam load
- Provides fuel flexibility for a hedge against volatile fossil fuel prices
- Offsets fossil fuel with renewable biomass fuel
- Provides 100% equipment redundancy while taking an aging coal boiler offline
- Saves energy dollars.

The CHP project recommended provides the following benefits:

Economics and Energy Diversification

- Capacity to supply 89% of annual steam demand from biomass
- Hedge against volatility in fossil fuel markets
- First year energy and O&M savings of $791,000 vs. current coal and gas energy costs
- First year energy and O&M savings of $1,141,000 vs. all 100% natural gas firing
- Using 20 year financing at 4.5% interest rate the project provides:
    - $19.5 million, 25 year Net Present Value over current coal and gas fuel use
    - $27.0 million, 25 year Net Present Value over switching to all natural gas
- Using 17 year financing at 1.5% interest rate the project provides:
    - $21.7 million, 25 year Net Present Value over current coal and gas fuel use
    - $29.2 million, 25 year Net Present Value over switching to all natural gas
- Temporary creation or retention of 88 FTE positions; and
- Long-term creation or retention of 14 FTE positions in the local forest products industry.

Environmental Benefits

- Reduction of annual SOx emissions by 74 tons/yr over current coal and natural gas use;
- Offset 24,500 metric tons of CO_2 annually
- Offset 307,000 mmBtu of fossil fuel usage annually
- Generate 3,000 MWh of electricity from renewable fuel annually

Forest Health

- Facilitate the management of forests that are killed or damaged by insect, disease, or weather; and
- Provide a market for fire hazard reduction and other non-harvesting forestry activity materials.

1.1 BIOMASS FUEL SUPPLY

The UW-Stevens Point campus is located in close proximity to national forests and a robust forest products industry. Most of the feedstock will be coming from a 30-60 mile radius of Stevens Point, WI. Utilizing 1% of net annual growth from a 60 mile radius would provide more than enough biomass to meet the annual fuel needs.

There will be the opportunity to determine availability of fuel from a wide variety of sources when the project moves to the fuel procurement phase. A primary emphasis will be put on obtaining logging residue due to it being the most readily available source of woody biomass fuel. Quotes from potential suppliers show that a range from $20 - $50/ton for biomass fuel is available. For this study $35/ton for 40% moisture wood chips is used.

1.2 RECOMMENDED BIOMASS CHP ENERGY PROJECT

The biomass system recommended produces up to 42,000 pounds, 410 psig steam per hour and incorporates a single stage backpressure steam turbine to generate 3,000 Megawatt hours of electricity per year. The system is to be housed in an addition attached to the present boiler room. Below grade storage can hold up to 40 hours of wood chip fuel at maximum boiler output. The system will utilize a new multi-clone in front of the existing bag house and ID fan for particulate removal and allow the current boiler control room to be used for control, monitoring and visual observation. Peak steam demand is 85,000 pounds per hour and can be met by the biomass unit in combination with either of the current coal boilers fired with natural gas or fuel oil. This provides redundancy to the 100,000 pound per hour gas fired boiler.

1.3 ENERGY SAVINGS

The biomass system recommended can supply 89% of the steam load on the central plant. The boiler will modulate effectively between 42,000 pounds per hour and 10,500 pounds per hour capturing 100% of the summer load and the majority of the winter load. 36,593 tons of wood chips will replace 307,000 dekatherms of coal and natural gas and produce 3,000 Megawatt hours of electricity.

Wood chip costs delivered to the site are estimated at $35 per ton with an average net output from the biomass unit estimated at 7.0 mmBtu per ton or approximately $5.00 per 1,000 pounds of steam. This compares favorably to the 2010 average price of $135 per ton of coal or $6.28 per 1,000 pounds of steam and $7.70 per dekatherm for natural gas or $9.63 per 1,000 pounds of steam. Table 1 illustrates annual cash savings based on replacing current fossil fuel use with $35/ton wood chips based on 2010 average prices for coal and natural gas.

Table – 1 Projected Annual Energy Savings

Biomass Fuel Comparison	Annual Energy Savings
Current Use Coal/ Natural Gas	**$791,192**
100% Natural Gas	**$1,141,336**

Factored into the annual energy savings is 3,000 Megawatt hours of electricity that will be generated. This will offset approximately 11% of campus electric purchases from the utility. It is estimated that the average value of electricity generated is $0.052 per kWh based on offsetting electric generation charges and a portion of the demand charge. This results in $158,000 that is part of the annual energy savings from the biomass system.

1.4 Capital Cost Estimate

The estimated total capital cost for the project is $8.13 million with $3.62 million for the boiler contract, $2.7 million for the General Contract and $1.81 million for Engineering and Contingency.

The biomass boiler system and installation is projected to be nearly 60% of the construction cost of the project. Each biomass system is unique in dimensions and material handling components, therefore the biomass boiler manufacturer should be chosen before final design of the facility is completed. As these systems are all unique, generally the installation of the biomass system is completed by the manufacturer. For this reason it is recommended that there be two separate bids and contracts.

1.5 Financial Analysis

Annual O & M costs of the biomass system are estimated at $100,000 per year greater than the installed natural gas system if coal was eliminated from use. When compared to the coal system the biomass system should have reduced operating costs as the coal systems are reaching the end of their useful life and are expected to have increased repairs over the new biomass system. For analysis comparing present energy costs of the coal and gas fired system to a biomass system, operating costs are considered equal. Table 2 summarizes the results of the cash flow analysis using two financing options available to UWSP.

Table 2– Financial Analysis Results

Financing Scenario	Comparison Option	Project Capital Cost	Grants	Year 1 Cash Flow	25-yr Net Present Value
17-yr, 1.5%	100% Natural Gas Operation	$ 8,133,295	$ 250,000	$ 615,528	$ 29,239,607
17-yr, 1.5%	Existing Operation	$ 8,133,295	$ 250,000	$ 262,385	$ 21,754,597
20-yr, 4.5%	100% Natural Gas Operation	$ 8,133,295	$ 250,000	$ 538,300	$ 27,043,894
20-yr, 4.5%	Existing Operation	$ 8,133,295	$ 250,000	$ 185,156	$ 19,558,883

2.0 INTRODUCTION

2.1 WERC PROGRAM

The USDA Forest Service Wood Education and Resource Center (WERC), is providing professional services to promote and support projects utilizing wood energy in a sustainable manner. This is being done through the Wood Energy Utilization Support Program. The goal of the program is to promote the Forest Service's Northeast Area Strategic Plan objective on the sustainable use of forest resources to provide efficient use of renewable energy resources and accomplish greenhouse gas reduction. The services are available to public and private entities (clients) interested in and committed to efficient use of local wood for energy. This report is the result of the feasibility-level study and was developed under the WERC program by Wilson Engineering Services, PC.

2.2 UW STEVENS POINT WOOD UTILIZATION OPPORTUNITY

The State of Wisconsin's existing plan is to replace coal plants over a 15 year period. This policy is subject to review by the current administration. Natural gas is typically available at UWSP and can be used to offset coal use. However, natural gas is subject to significant price volatility. Additionally, UWSP practice is to diversify its fuel sources to allow for potential issues with supply. The UWSP campus uses coal to provide a base load of steam for heating and hot water needs. Natural gas is currently used to supplement coal during the low-use times of the year and for backup. Analysis of the opportunity for biomass is compared to current operations utilizing coal as the base load with natural handling the peaking and summer loads, and comparing biomass to all natural gas firing.

The existing campus boiler plant has a bag house for emission control that is sized for (2) 45,000 pound per hour steam coal boilers. This could be converted to meet the emission standards for the biomass boiler.

UWSP is located in an area of Wisconsin which has a sustainable supply of biomass. There is an existing infrastructure within the region to process and deliver chipped wood, which allows for a competitively priced, long-term biomass supply for energy.

3.0 ENERGY USE AND SYSTEMS

The UWSP campus produces steam at a central plant that is distributed around the campus and to St Michaels Hospital at 110 psig to provide heating and hot water. Natural gas is burned during the summer months for reheat and domestic hot water use. During the heating months the coal boilers are used to cover the base load and natural gas can be burned as back up during an outage. Fuel oil is only used for backup. Average delivered costs for natural gas and coal are $7.70/MCF and $135/ton respectively. The central boiler plant produces 110 psig steam which is distributed throughout the campus and to St. Michaels Hospital. Based on 2009 annual steam demand provided by UWSP, the central heating plant provided 275,196 thousand pounds of steam.

3.1 EXISTING SYSTEM

The UWSP steam plant operates 4 boilers. Two of the boilers are rated at 45,000 pounds per hour. The units are fired with coal but are capable of over firing with natural gas. However that is not currently done because of operational issues. The remaining two boilers are 100,000 and 30,000 pounds per hour. These are fired with natural gas but are capable of burning fuel oil as a backup.

Steam is produced at 110 psig and distributed to the UW Stevens Point Campus and St. Michaels Hospital for heat, hot water, and humidification. A small amount of steam goes through a pressure reducing valve in the plant and supplies low pressure steam for plant heating loads, an adjacent security building, and the condensate and deaerator tanks.

The coal fired units are fed from overhead bins to a vibrating grate combustion unit and are also capable of full fire on natural gas. Each unit is capable of meeting 50% of the peak demand. The small gas boiler is used from mid- March through mid- November when demand is lower. The large gas boiler provides 100% backup. The coal fired units were installed in 1964 and are equipped with a bag house for pollution control. The facility does not have a central chilled water loop.

Coal is delivered via truck and dumped to an underground storage bunker. A drag chain transports the coal to a bucket elevator which delivers the coal to a second belt which feeds hoppers above each combustion unit.

The facility is staffed around the clock. Given the age of the plant it appears very well maintained and clean.

3.2 CURRENT ENERGY USAGE AND COST

UWSP provided 2009 data of the total volume of fuels purchased and minimum, maximum, and total daily steam output from the central heating plant. The facility consumed ~ 340,000 mmBtu of fuel to produce ~ 274,000 Klb of steam in 2009. In 2009, 43% of the energy (146,556 mcf) was provided by natural gas and 57% (7,316 tons) from coal. Since 2009 fuel data only included the total annual cost spent on both natural gas and coal combined, a cost per unit could not be developed. 2009 and 2010 fuel usage and cost per unit are provided in Table 3.

Table 3 – Plant Energy Usage, Cost, and Production CY 2010

Calendar Year	Coal Input, mmBtu/yr	Gas Input, mmBtu/yr	Coal Unit Cost, $/mmBtu	Gas Unit Cost, $/mmBtu	Total Plant Steam Output, mmBtu/yr
2009	196,063	146,556	N/A	N/A	274,095
2010	111,509	205,468	$ 5.09	$ 7.70	263,483

Table 4 presents the campus electricity usage and cost per unit for the past three calendar years.

Table 4 – Campus Electricity Usage CYs 2008-2010

Calendar Year	Electricity Usage, kWh	Electricity Unit Cost, $/kWh
2008	25,706,994	$ 0.0697
2009	24,876,008	$ 0.0700
2010	26,392,513	$ 0.0672

Figure 1 shows the daily average steam demand at the existing central boiler plant for calendar year (CY) 2009. The average shown is based on daily records of steam usage.

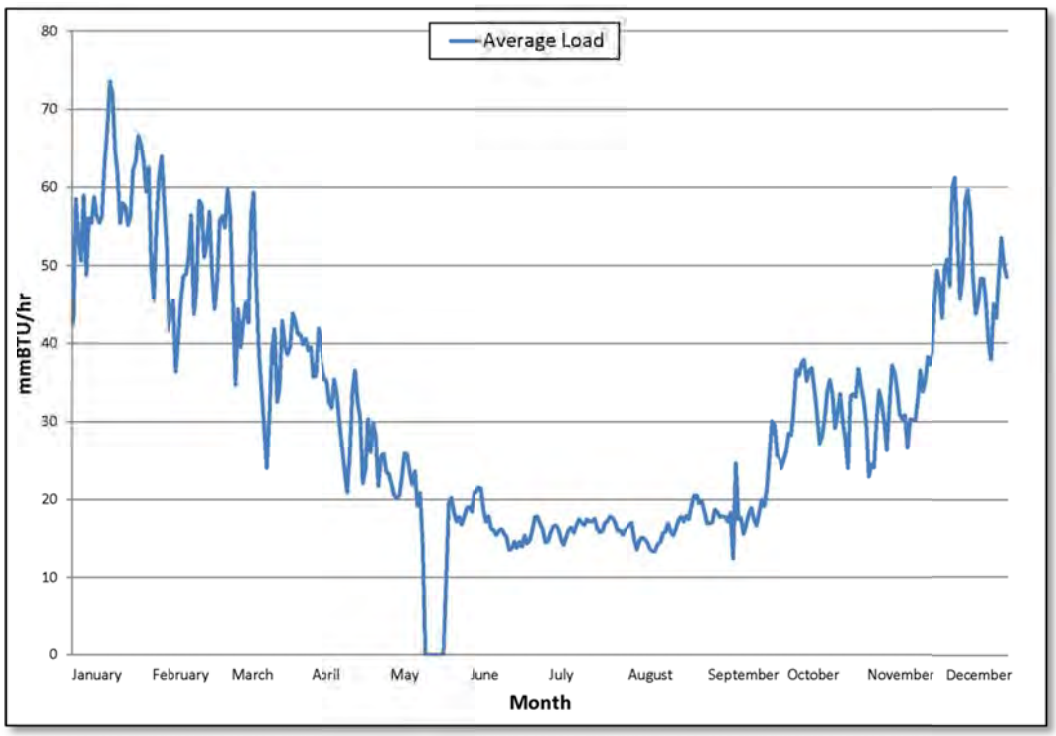


Figure 1 – Daily Average Steam Demand – Central Plant CY 2009 Data

Figure 2 shows how the actual demand can fluctuate significantly during the course of a day. The annual peak average load is estimated at 74 mmBtu/hr with a maximum hourly rate of 85 mmBtu/hr. Minimum recorded summer load is 10 mmBtu/hr when the plant is operational. There are occasional anomalies in the minimum, maximum, and average steam demand that are shown in the graph and are assumed to be recording errors. The purpose of the graph is to illustrate the typical range of daily load fluctuations.

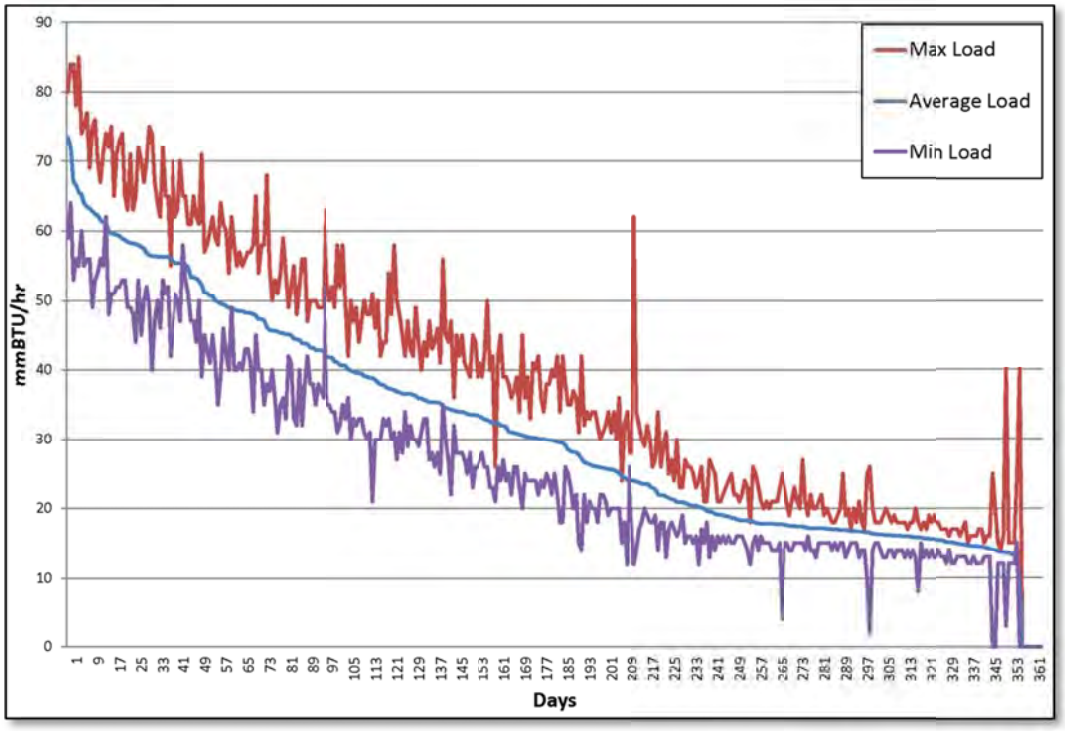


Figure 2 – Load Fluctuation Curve – Central Plant CY 2009 Data

4.0 BIOMASS AVAILABILITY AND PRICE

4.1 BIOMASS AVAILABILITY

The UW-Stevens Point campus is located in close proximity to national forests and a robust forest products industry. Most of the feedstock will be coming from a 30-60 mile radius of Stevens Point, WI. Table 5 shows the forest resource availability at a 30 mile and 60 mile radius from Stevens Point, WI.

Table 5 – Forest Resource Availability

Radius	Net Annual Growth (Tons)	% Required to Meet Plant Demand
30-mile	**856,598**	4.3%
60-mile	**4,165,002**	0.9%

Utilizing 1% of 60 mile radius net annual growth would provide more than enough biomass to meet the annual fuel needs.

4.2 BIOMASS PRICING

There will be the opportunity to determine pricing of fuel from a wide variety of sources when the project moves to the fuel procurement phase. A primary emphasis will be put on obtaining

logging residue since it is the most readily available source of woody biomass fuel. Table 6 shows the price range for several different raw materials. Note that these prices are ranges and vary depending upon a number of variables including: mileage, tree species, etc.

Table 6 – Biomass Pricing

TYPE	PRICE/TON
ROUNDWOOD (MOST SPECIES)	$30-45
BIOMASS CHIPS	$25-45
WASTE FROM FOREST INDUSTRY (BARK, SAWDUST, SHAVINGS, ETC.)	$20-50
WOOD WASTE (URBAN, RIGHT-OF-WAY, SITE CONVERSIONS, ETC.)	$20-30
OTHER ORGANIC WASTE	$31-40

Quotes from potential suppliers show that a range from $20 - $50/ton for biomass fuel is available. For this study $35/ton for 40% moisture wood chips is used.

5.0 EVALUATED BIOMASS SYSTEM OPTIONS

The goal of a biomass system at the UW-Stevens Point campus is to produce the base load steam supply for the campus using a renewable fuel that has a reliable supply. Clean wood chips have been identified as the target fuel source based on fuel availability and cost competitiveness with coal and natural gas. Given the age of the existing plant and space limitations within the plant, retrofit of existing equipment is not considered to be a viable long-term option. Instead, a new storage and handling system with boiler housing in combination with technologies for generating steam from wood chips are evaluated in this report. The following are technologies that were evaluated for use at UW- Stevens Point, but not necessarily recommended for implementation.

5.1 THERMOCHEMICAL CONVERSION OF BIOMASS AND STEAM GENERATION

Thermochemical conversion of biomass, which is a solid fuel, to useful energy for making steam follows a process of several phases. First, water is evaporated from the fuel, then volatiles are driven from the fuel creating several products including a combustible gas (pyrolysis/gasification), and finally, the remaining solid fuel is completely oxidized (combusted). The conversion of biomass to heat requires that drying and pyrolysis/gasification of the solid fuel occur prior to combustion. Once the biomass is converted to heat, the heat is transferred to a working fluid that is used to transport the heat to the point of use. For this application the fluid will be water that is converted to steam within a boiler and then distributed to the UW-Stevens Point campus for use within individual buildings.

The most commercially viable and environmentally sustainable technology for generating steam from biomass is one that completes the thermochemical conversion within one continuous process. Units that perform this function are typically referred to as advanced biomass combustion units. Advanced biomass combustion units optimize temperature and air flow during the three stages of thermochemical conversion in order to maximize combustion

efficiency. This study focuses on advanced combustion units that optimize the combustion process and have combustion efficiencies exceeding 95%. This means that over 95% of the stored energy in the solid fuel is converted to heat.

The controlled environment that allows for maximizing combustion efficiency also allows for controlling production of nitrogen oxides and carbon monoxide during the combustion process. Ash content of clean wood chips combusted in these units is typically between 1% and 2% of the total dry matter of the wood. Coal ash content currently collected on site is estimated at 8% of coal by weight. Ash from clean wood chips is not considered a hazardous waste and may be applied as a soil amendment. Ash from the biomass system will be equal in volume to the current ash from the coal. In 2009 7,316 tons of coal produced an estimated 585 tons of ash. 36,593 tons of wood replacing all of the coal and ¾ of the natural gas would produce an estimated 549 tons of ash as shown in Table 7.

Table 7 – Ash Production

Fuel	Ton Burned	Ash Content	Tons of Ash
Coal (2009)	7,316	8.0%	585
Biomass	36,593	1.5%	549

Emission controls included in the capital cost for this project are a multi-clone to eliminate larger particulate matter and hot ash. It is assumed that the existing bag house will serve the new biomass unit as it will replace the two coal fired boilers when online.

There are many US and foreign manufacturers of advanced biomass combustion units that can meet the 95% combustion efficiency. Technologies utilized by specific manufacturers can vary, but all units provide control of the combustion stages, which results in high combustion efficiencies.

5.2 Electric Generation (Combined Heat and Power) Options

There are two types of thermal cycles for generating power, closed and open. The closed cycle physically separates the generation of heat from the power generation cycle. The open cycle directly uses the combustion or combustion products to drive a mechanical process and/or power generation cycle. Use of the open cycle, with regard to biomass, provides the opportunity for converting a higher percentage of the biomass energy to power. However, the open cycle requires cleaning or refining of combustion products prior to use in a power generation cycle. Due to the scale of the project being evaluated for UW-Stevens Point, use of an open cycle process is not considered to be economically viable. Thus, this evaluation only looks at closed cycle processes.

Closed cycle power generation processes for combined heat and power (CHP) operations include: steam driven turbines or engines, organic Rankine cycle (ORC) technologies, and

Stirling engines. Given the end goal of producing steam, ORC and Stirling engines are not considered to be applicable technologies for the UW-Stevens Point project.

The UW-Stevens Point goal of distributing steam at one pressure (110 psig) makes back-pressure steam turbine generation the most economically viable CHP process. This process requires generating steam at a higher pressure than is needed for distribution. The high pressure steam is passed through a single-stage backpressure steam turbine that reduces the steam to the desired distribution pressure and generates electricity in the process. The turbine is piped in parallel with a 2 stage pressure reducing (PRV) station as a turbine bypass in case the turbine needs to be shut down for maintenance or repair. A pressure relief valve will be located at the outlet of the turbine and PRV to eliminate the chance or high pressure steam entering the existing distribution system. This method of generation when it is led by a heat demand is 90% thermally efficient and given the cost of biomass, allows electric generation at an added input fuel cost of less than $0.016/kWh.

5.3 Absorption Chilling with Biomass

Absorption chillers use hot water or steam to produce chilled water. The thermal load for cooling with an absorption chiller can provide a summer base load for a biomass boiler allowing effective year round operation. Absorption chillers are designed as single effect or double effect with the thermal input efficiency to chilled water output efficiency at 0.8 for a single effect and 1.2 for a double effect chiller. Single effect chillers can operate with hot water temperatures as low as 180°F while double effect chillers require steam at pressures above 65 psig to operate.

Economic opportunities for absorption chillers occur when there are high electric costs or very low heat costs. A typical application for absorption chillers would be where high summer peak electrical demand charges can be avoided or where there is a need to dissipate a heat load.

There is not a central chilled water loop on the UWSP Campus, however there are chilled water plants serving areas of the campus. Steam could be provided through the current distribution system to these areas and absorption chillers installed at the various plants; however current electric costs and biomass steam costs do not justify offsetting electric chillers with steam chillers. Current electric costs with demand and generation charges average less than $0.07 per kWh putting the cost per ton of cooling with electric chillers at approximately $0.04 per ton cooling. Steam costs from biomass at $5.00 per 1,000 pounds yields a ton of cooling from absorption chillers at $0.063. Under current conditions energy costs for absorption chillers are 160% more expensive than conventional chillers.

At present adding absorption chilling to this project is not recommended. The addition of absorption chilling may be worth evaluating in the future as commodity prices change relative to one another and existing chiller equipment reaches the end of its useful life. Excess summer capacity from the biomass system will allow future addition of absorption chillers without changes to the recommended biomass boiler installation.

6.0 RECOMMENDED BIOMASS SYSTEM SIZING

This study considered the options of replacing the current fuel usage of coal and natural gas, and replacing the potential future usage of 100% natural gas. Appendix A includes a schematic showing the biomass system configuration. The project will be located adjacent to the existing boiler plant on University owned land. The area has sufficient room for a biomass boiler housing and storage building, and has sufficient access for trucks and fuel delivery. The location also has convenient access to necessary utilities and the steam distribution system. Appendix A provides a site plan for the proposed biomass system, and this section provides a discussion of the system sizing and component selection.

6.1 BOILER COMBUSTION UNIT SIZING

Various biomass combustion sizes were evaluated relative to the current steam load and considering the current equipment capabilities. A single 1250 hp (42,000 pounds per hour steam) biomass boiler was selected for this study for the following reasons.

- A 1,250 hp boiler is the largest single boiler that can modulate down to capture the summer load and still operate effectively. Biomass units can operate effectively between 25% and 100% of rated capacity. While boilers will modulate below 25% sustained operation below this level is not recommended.
- A 1,250 hp boiler would displace an estimated 89% of the annual fuel used for steam generation. The unit will operate effectively between 10,500 and 42,000 pounds per hour, displacing nearly all the load for 9 months of the year and between 60-90% of the load during the three coldest months with the existing gas fired units supplying the remainder.
- Coal could be completely eliminated as a fuel while decreasing current fuel costs.
- 100% load equipment redundancy can be achieved by the biomass unit in combination with one of the coal units firing natural gas.

The peak steam demand for 2009 was 85,000 pounds per hour. As seen in Table 8 below, the proposed biomass boiler in combination with either of the Coal/Gas boilers can meet the peak demand.

Table 8 - Proposed Boiler Sizes for UW Stevens Point

Boiler	Fuel	Size (lb/hr)
1	Biomass	42,000
2	Gas/Oil	30,000
3	Gas/Oil	100,000
4	Coal/Gas	45,000
5	Coal/Gas	45,000

6.2 PRIME MOVER (BACKPRESSURE STEAM TURBINE) SIZING

Section 5.2 discusses the selection of a single-stage backpressure steam turbine as the appropriate prime mover for this thermally-led CHP project. Single-stage backpressure steam turbines can modulate from 100 – 25% of their rated capacity. The system will be designed to produce electricity at a rate determined by the steam demand of the campus heating systems. Thus, the turbine will operate at a rate that ensures 100% of the steam output from the turbine is utilized in the campus heating system. Given the biomass fuel input cost of $3.50/mmBtu and steam utilization, the turbine will provide electricity at an effective fuel cost of $0.016/kWh.

The turbine is sized to have a maximum output of 500kW using the following assumptions:

- Isentropic efficiency of 45%
- 1250 hp biomass boiler producing 410 psig steam, saturated
- Feed water temperature of 227°F
- Turbine output of 110 psig steam, saturated

The operating range of the single stage turbine is similar to the biomass units, so for this evaluation a single stage turbine was selected to match the 42,000-10,500lb/hr steam output. Table 9 shows the electricity that would be generated based on the 2009 steam demand.

Table 9 - Estimated Value of Annual Electric Offset by CHP

Electric Generated	$/kWh	Annual Electric Cost Offset
3,043,334	$ 0.052	$158,253

The value of $0.052/kWh is used for the value of electricity generated, which is less than the ~$0.07/kWh blended rate charged to UWSP as shown in section 3.2. This is because the kWh generated would only be able to offset a portion of the demand charge for electricity.

7.0 ANALYSIS OF BIOMASS SYSTEM BENEFITS

The recommended system is a biomass combustion unit producing 42,000 pounds steam per hour at 410 psig. Appendix A contains a schematic of a one line diagram showing the described system. Pressure will be reduced to 110 psig through a single stage turbine and supplied to the main steam distribution header. The turbine will drive a generator capable of producing 500 kW at maximum steam output from the boiler. A below grade facility capable of storing 1,000 yards of wood chips will automatically transfer fuel to the biomass unit.

The biomass system will utilize wood chips to offset the use of natural gas and coal at the UW-Stevens Point campus while also generating a portion of the campus electrical demand.

Calendar year 2009 daily steam demand and energy usage data is used in this report to model the base-load biomass system's ability to meet steam demand in the central boiler plant.

Coal is currently used to provide base load heating at the UW Stevens Point central boiler plant. The University has a goal to eventually eliminate the use of coal. The design of the biomass system will allow 100% of the coal to be replaced by biomass allowing the plant to phase out the use of coal.

7.1 Wood Utilization and Fossil Fuel Replacement

Table 10 presents the steam demand for calendar year 2009, the actual fossil fuel input used in 2009, the estimated requirement for 100% natural gas fuel input based on an overall recorded system efficiency of 80%, and the estimated biomass input to cover the base load based on 70% system efficiency and the additional natural gas required to catch the peak loads at 80% system efficiency.

Currently an average of 2 loads of coal per day are delivered during the peak heating system. Coal has 3 times the heating value of biomass by weight (Ton_{Coal} vs. $Ton_{Biomass}$) and 6 times the heating value by volume (Ft^3_{Coal} vs. $Ft^3_{Biomass}$). Since the chip storage was sized based on required biomass weight (tons), wood will require an average of 6 loads per day during peak usage. Pedestrian traffic restrictions may be required on the timing of the biomass deliveries to avoid congestion. Sufficient biomass storage is planned to allow flexibility in delivery.

Table 10 – CY 2009 Reported Energy Usage and Biomass CHP System Energy Usage

Steam Demand, mmBtu/yr	Current Fossil Fuel Usage, mmBtu/yr		100% Natural Gas Usage, mmBtu/yr	Biomass CHP System Fuel Usage, mmBtu/yr	
	Coal Input	Natural Gas Input	Natural Gas Input	Wood Input	Natural Gas Input
274,095	196,063	146,556	342,619	365,920	35,241

Figure 3 shows the steam demand coverage with biomass. The portion of the load duration shaded in red shows where demand is covered by the biomass system. The remainder of the area under the curve represents demand covered by natural gas. The graph shows that the biomass CHP system will cover over 89% of the annual steam demand.

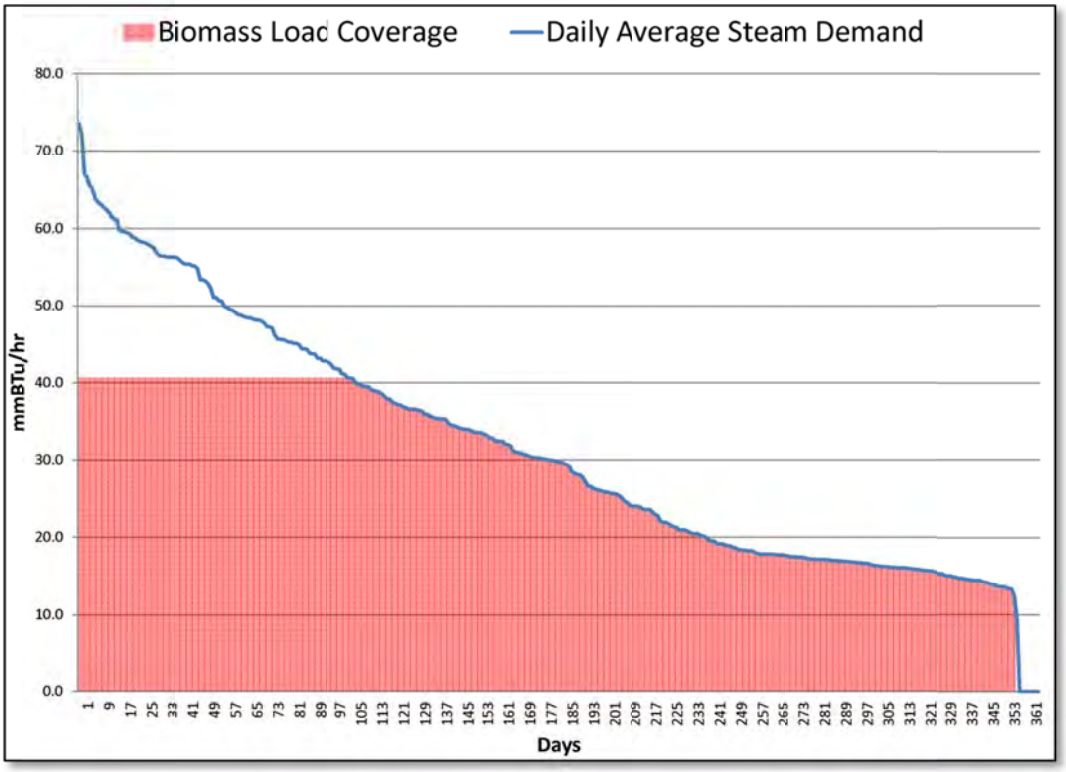


Figure 3 – CY 2009 Modeled Biomass System Coverage of Steam Demand

7.2 CAPITAL COST ESTIMATE

Biomass boiler projects require a manufacturer to be chosen before final building design can be completed as each system is unique in dimensions and method for handling fuel and ash. For this project over 60% of the building and construction costs are in the biomass unit and its assembly. We would recommend that two separate prime contracts be awarded which will reduce overall project costs and simplify engineering design and permitting.

7.2.1 Biomass Building and Chip Storage

The biomass unit will be housed in a building interconnected to the existing steam plant and make use of space in the existing facility for components of the system. This will allow all of the boilers to be observed and monitored from the present boiler operators' station. Because of somewhat limited site requirements, storage for the biomass will be limited to 40 hours of peak operation. Delivery of biomass will be through a contract to supply woodchips on a set delivery schedule. This keeps the responsibility on the fuel supplier. Wood chip supply contracts will require daily deliveries at peak steam demand with redundancy of natural gas or fuel oil as backup if required. Fuel handling of wood chips from on campus chip storage to the combustion unit will be fully automated and not require any effort from the plant operators. Below grade storage vs. silos was chosen to better fit with the surrounding campus use. A minimum of 1,000 cubic yards of chip storage is recommended. A site drawing and building layout are contained in Appendix A.

7.2.2 Capital Cost Estimate

The estimated capital cost for developing the system and interconnecting it with existing university facilities is $8,133,295. Appendix B provides the line item capital cost estimate. An installed quote was obtained for the biomass boiler and used as the basis for the project cost, and is anticipated to be accurate to plus or minus 10% of the final cost of the project in today's dollars.

7.3 Financial Analysis and UW Economics

The UW system will be gradually eliminating the use of coal at its facilities. This can currently be done with the existing natural gas capacity at the UW Stevens Point Campus. However, natural gas has the drawbacks of interruptible service and future price volatility as electric generation and usage in fleet vehicles in the US expands. Thus, it is necessary for UW to diversify its fuel sources. The biomass project provides a hedge against future gas price volatility and the ability to shoulder the majority of the campus load incase access to gas becomes temporarily limited. In conjunction with these and environmental benefits, the biomass project must be able to show a substantial financial benefit to UW for it to be viable in the current funding climate. Table 11 presents the economic benefits to the UW campus provided by the biomass project. The economics of the projects are shown as a cash flow analysis for the CHP biomass project. Appendix C presents the cash flow analysis given the assumptions presented in Table 13.

Table 11– Financial Analysis Results

Financing Scenario	Comparison Option	Project Capital Cost	Grants	Year 1 Cash Flow	25-yr Net Present Value
17-yr, 1.5%	100% Natural Gas Operation	$ 8,133,295	$ 250,000	$ 615,528	$ 29,239,607
17-yr, 1.5%	Existing Operation	$ 8,133,295	$ 250,000	$ 262,385	$ 21,754,597
20-yr, 4.5%	100% Natural Gas Operation	$ 8,133,295	$ 250,000	$ 538,300	$ 27,043,894
20-yr, 4.5%	Existing Operation	$ 8,133,295	$ 250,000	$ 185,156	$ 19,558,883

Table 12 shows a fuel sensitivity analysis of 1st year fuel savings based on price fluctuations of natural gas and biomass. It is assumed that 100% of the fuel replaced by biomass is natural gas for the purposes of this table.

Table 12– Year 1 Operation & Maintenance Savings Sensitivity to Gas and Wood Chip Price Assumptions

Price of Wood Chips - per Ton	Price of Natural Gas per MCF							
	$5.00	$6.00	$7.00	$8.00	$9.00	$10.00	$11.00	$12.00
$10.00	$ 1,229,218	$ 1,536,595	$ 1,843,972	$ 2,151,349	$ 2,458,726	$ 2,766,103	$ 3,073,480	$ 3,380,857
$15.00	$ 1,046,258	$ 1,353,635	$ 1,661,012	$ 1,968,389	$ 2,275,766	$ 2,583,143	$ 2,890,520	$ 3,197,897
$20.00	$ 863,298	$ 1,170,675	$ 1,478,052	$ 1,785,429	$ 2,092,806	$ 2,400,183	$ 2,707,560	$ 3,014,937
$25.00	$ 680,338	$ 987,715	$ 1,295,092	$ 1,602,469	$ 1,909,846	$ 2,217,223	$ 2,524,600	$ 2,831,977
$30.00	$ 497,378	$ 804,755	$ 1,112,132	$ 1,419,509	$ 1,726,886	$ 2,034,263	$ 2,341,640	$ 2,649,017
$35.00	$ 314,418	$ 621,795	$ 929,172	$ 1,236,549	$ 1,543,926	$ 1,851,303	$ 2,158,680	$ 2,466,057
$40.00	$ 131,458	$ 438,835	$ 746,212	$ 1,053,589	$ 1,360,966	$ 1,668,343	$ 1,975,720	$ 2,283,097
$45.00	$ (51,502)	$ 255,875	$ 563,252	$ 870,629	$ 1,178,006	$ 1,485,383	$ 1,792,760	$ 2,100,137
$50.00	$ (234,462)	$ 72,915	$ 380,292	$ 687,669	$ 995,046	$ 1,302,423	$ 1,609,800	$ 1,917,177
$55.00	$ (417,422)	$ (110,045)	$ 197,332	$ 504,709	$ 812,086	$ 1,119,463	$ 1,426,840	$ 1,734,217
$60.00	$ (600,382)	$ (293,005)	$ 14,372	$ 321,749	$ 629,126	$ 936,503	$ 1,243,880	$ 1,551,257
$65.00	$ (783,342)	$ (475,965)	$ (168,588)	$ 138,789	$ 446,166	$ 753,543	$ 1,060,920	$ 1,368,297
$70.00	$ (966,302)	$ (658,925)	$ (351,548)	$ (44,171)	$ 263,206	$ 570,583	$ 877,960	$ 1,185,337

Table 13 contains all of the assumptions used for the financial analysis. While the life of the system would be expected to match the expected life of the coal boilers of >40 years, NPV was calculated over 25 years.

Table 13 – Assumptions Utilized in Financial Analysis

Item	Value and Units	Data Sourced
Project costs financed	100%	WERC Assumption
Financing Term 1	17 years	UW Current Rate
Financing Rate 1 (apr)	1.5%	UW Current Rate
Financing Term 2	20 years	UW Current Rate
Financing Rate 2 (apr)	4.5%	UW Current Rate
Annual Natural Gas Replaced	307,377 DTh	CY 2009 Model
Year 1 natural gas purchase price	$7.70/DTh	CY 2010 Avg
Year 1 wood chip purchase price	$35/ton	Quoted Value
Generated Electric Value (assumes partial offset of demand)	$0.052/kwh	WERC Assumption
Natural gas inflation rate (apr)	3.7%	WERC Assumption
Wood chip inflation rate (apr)	2.7%	WERC Assumption
Electric inflation rate (apr)	3.7%	WERC Assumption
General inflation rate (apr)	2.7%	WERC Assumption
Wood chip heating value	10,000,000 Btu/ton	WERC Assumption
Existing system thermal efficiency	80%	CY 2009 Reported

Biomass system thermal efficiency	70%	WERC Assumption
Cost to replace 1 existing dual fuel coal/natural gas boilers in 2019	$3,430,0000	WERC Assumption

Table 14 shows the additional operating costs when compared to 100% natural gas firing. Operating costs for the biomass boiler are considered to be similar to current coal system operating costs with reductions in annual repairs and maintenance due to the age of the coal boilers.

Table 14– Biomass System Annual O&M Costs

Item #	Item	Price
1	Electricity Usage	$ 51,400
2	Ash Removal	$ 15,600
3	Annual Service	$ 25,000
4	Hearth Grates & Ash Screw	$ 3,000
5	Stoker Screw & Furnace Screw	$ 2,000
6	410psig Turbine	$ 3,000
Total Operating Costs for 1200HP CHP		**$ 100,000**

The steam produced utilizing wood chip fuel will be used on the UW Stevens Point campus and St Michaels Hospital. It is not necessary to conduct a market analysis for utilization of steam from the wood chip system since campus consumption is sufficient to justify system economics. All electricity generated by the wood plant will be utilized only by the campus.

7.4 LOCAL ECONOMIC IMPACT

The project will require an investment of $8,133,295 in UW Stevens Point infrastructure. These funds will provide for 88 full time equivalent (FTE) positions in the following sectors:

- Professional services – 9 FTE
- Construction – 48 FTE
- Manufacturing – 31 FTE

FTEs were calculated using the project schedule, cost estimate, and the Council of Economic Advisor's number of $92,000/job-year. These positions would be temporary.

The purchase of local wood will result in the creation or retention of jobs in the forest products industry. UW would purchase $1,280,720 in wood chips (1,466 truckloads) in the first year of operation. It is assumed that this will support 14 FTE jobs in the forest products industry annually.

The existing plant currently has one operator around the clock and two additional staff during the day shift on most weekdays. The biomass plant would require that the same level of staff continue to be maintained by UW Stevens Point. Since staff will be unchanged from the

existing plant requirements, the labor force wages and availability are known and considered to remain constant through the switch to wood energy.

7.5 ENVIRONMENTAL IMPACTS

Modern wood energy systems are automated, clean, and efficient. Air quality permitting requires the use of particulate emission controls to meet emission levels. The cost estimate for the system proposed in this report includes a multi-clone that will be installed before the existing bag house to reduce PM and hot ash. These advanced systems are considered CO_2 neutral and qualify for voluntary carbon credits.

The projected changes in emissions by switching to a biomass system from a mixture of 30% coal and 70% natural gas are as follows:

- NOx increase by 16 tons/yr
- CO increase by 39 tons/yr
- PM increase by 9 tons/yr
- SO2 **decrease** by 74 tons/yr

There are several air permitting issues that are currently in a state of flux. These include new federal regulations establishing new emission limits for CO, PM, and additional air pollutants that are anticipated to be released by the end of February 2011. These also include a state review of whether modification projects completed in the past were required to follow Prevention of Significant Deterioration (PSD) rules. The state has received an EPA Section 114 letter and is in the process of evaluating how its coal boilers will be treated regarding PSD and actions that must be taken. These issues are currently being resolved, and thus potential scenarios regarding requirements for emission controls are beyond the scope of this feasibility study. Standard requirements for new wood boilers are used for the purposes of this report.

8.0 PROJECT IMPLEMENTATION

The UW Department of Administration (DOA) has a current plan committing to the replacement of 15 coal boilers from its fleet over the next 15 years. This plan is subject to review by the current administration. Natural gas will be a major component in the fleet replacement. It is anticipated that several of the initial replacements will utilize advanced biomass CHP systems. The initial projects utilizing wood chips will serve as models for the remaining fleet replacements. The UW system will use the initial projects to gain experience with operation of the technology, procurement of the fuel, and implementation costs. These experiences will determine whether wood is a suitable fuel for use at the remaining 10-13 facilities.

8.1 PROJECT SCHEDULE

The initial scope of work to be completed is to obtain a detailed level of project design and cost estimation. This will allow UWSP to seek funding for the wood project in the state's 2013 budget. Completion of the detailed level of design is not in the state's 2011 or 2012 budget, and will require a grant in order to allow completion in time to seek SFY 2013 funding. UW is seeking a US Forest Service Woody Biomass Utilization Grant at the time of this feasibility study

to provide funding to allow the project completion in early 2014. Figure 4 shows the schedule for the project.

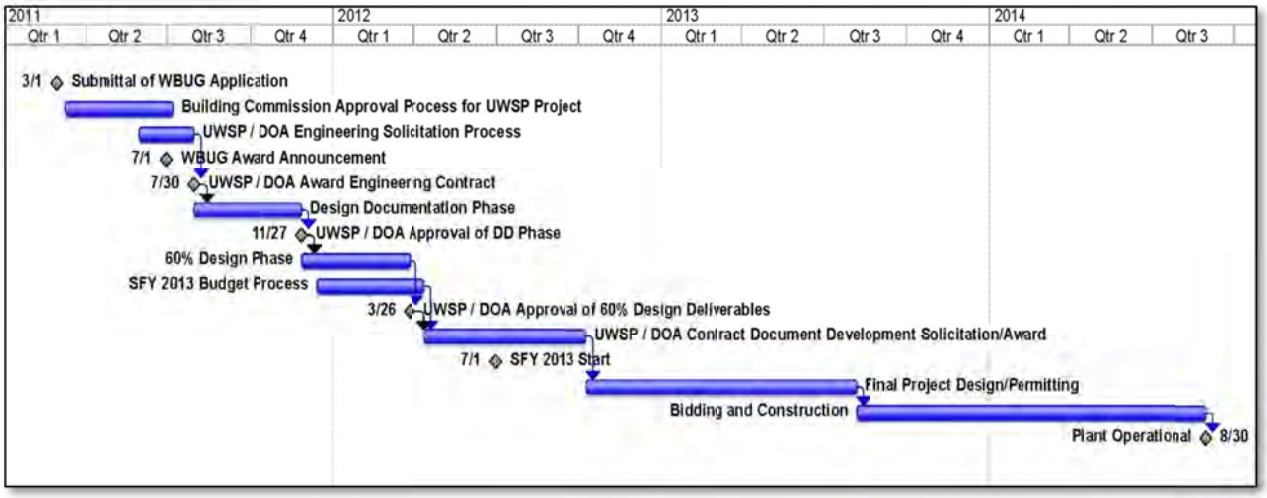


Figure 4 – UW Stevens Point Project Implementation Schedule

The project will be financed through the state's budget process. Once the project is constructed, the annual operating budget of the UW campus will provide funds for the operational phase.

8.2 KEY STAFF

The DOA's Division of State Facilities will be in charge of selecting and managing an A/E firm for the design, and will be responsible overall for the design and implementation of the biomass CHP project. Multiple bureaus of the Division of State Facilities have committed high-level staff to oversee this project. This includes the Heating Plant Engineering Team Leader from the Division's Bureau of Architecture and Engineering. The Bureau's functions are to plan, manage, and provide technical advice for construction projects; administer the state building program; and provide commissioning, sustainability quality control, building engineering services, energy conservation planning, and fuel procurement. The Bureau has over 2,200 active projects valued at over $2 Billion. The Team Leader has extensive experience in implementation of boiler plant projects and management of A/E firms for boiler plant project design.

8.3 TRACKING OF ENERGY AND FINANCIAL PERFORMANCE DURING OPERATIONS

DOA has detailed reporting practices and requirements for energy usage and cost at their existing boiler systems and university campuses. Currently boiler plant superintendents and facility managers track gas, coal, fuel oil, and electricity usage and cost on a daily or monthly basis. The current system for tracking usage and cost will remain in place following implementation of the wood energy project. This will provide an easy mechanism for tracking performance of the wood system and provide detailed information for DOA to evaluate the merits of implementing similar systems at other facilities.

9.0 SUMMARY OF PROJECT BENEFITS

Implementation of a biomass CHP energy system at the UW Stevens Point central plant will have the following benefits:

Economics and Energy Diversification

- Capacity to supply 89% of annual steam demand from biomass
- Hedge against volatility in fossil fuel markets
- First year energy savings of $791,000 vs. current coal and gas energy costs
- First year energy savings of $1,141,000 vs. all 100% natural gas firing
- Using 20 year financing at 4.5% interest rate the project provides:
    - $19.5 million, 25 year Net Present Value over current coal and gas fuel use
    - $27.0 million, 25 year Net Present Value over switching to all natural gas
- Using 17 year financing at 1.5% interest rate the project provides:
    - $21.7 million, 25 year Net Present Value over current coal and gas fuel use
    - $29.2 million, 25 year Net Present Value over switching to all natural gas
- Temporary creation or retention of 88 FTE positions; and
- Long-term creation or retention of 14 FTE positions in the local forest products industry.

Environmental Benefits

- Reduction of annual SOx emissions by 74 tons/yr over current coal and natural gas use;
- Offset 24,500 metric tons of CO_2 annually
- Offset 307,000 mmBtu of fossil fuel usage annually
- Generate 3,000 MWh of electricity from renewable fuel annually

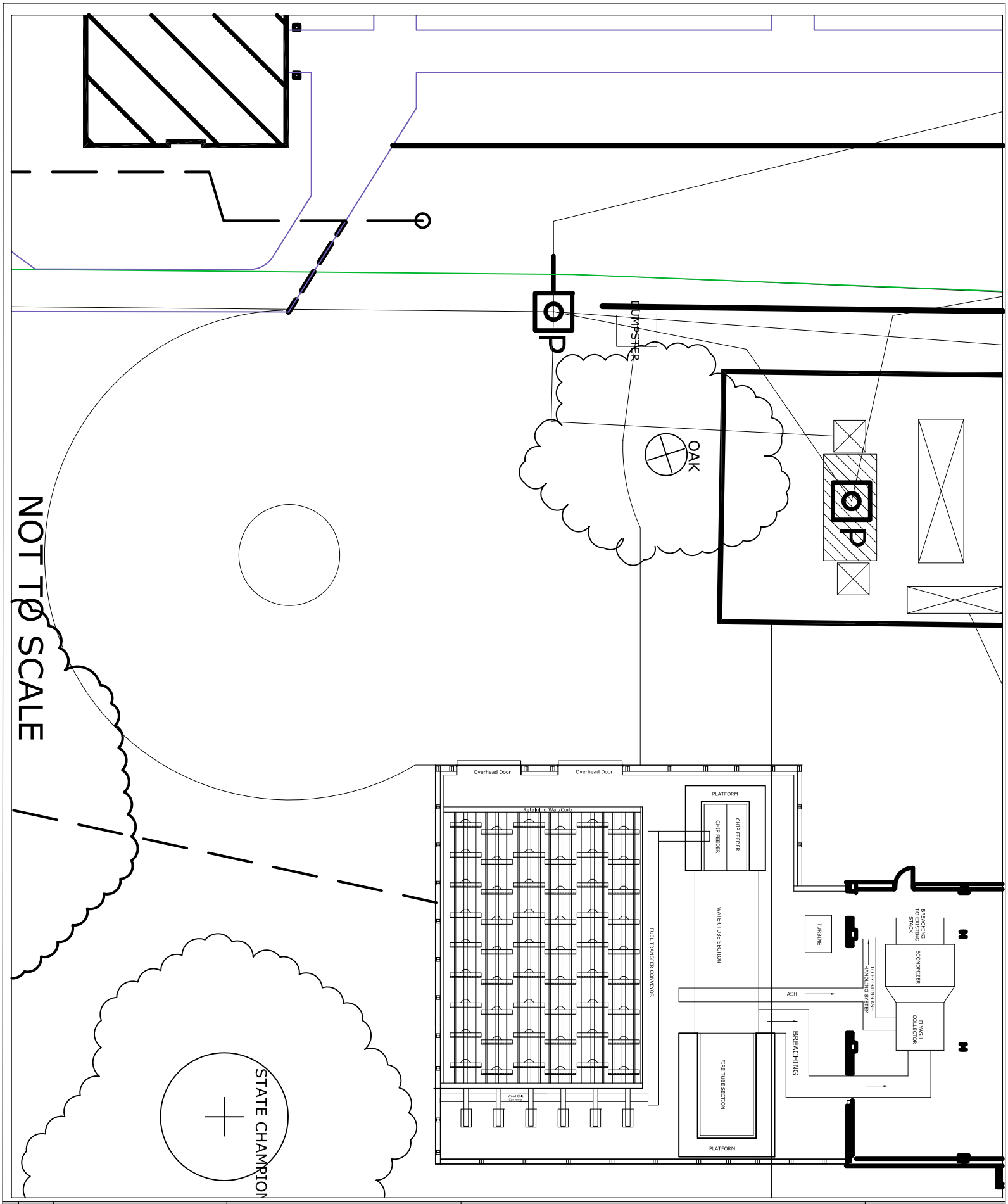
Forest Health

- Facilitate the management of forests that are killed or damaged by insect, disease, or weather; and
- Provide a market for fire hazard reduction and other non-harvesting forestry activity materials.

In addition to the above listed benefits, the project will also serve as one of the initial biomass CHP energy projects for the UW system. The scale of this project allows for initial evaluation of biomass CHP with minimal capital investment. The project will allow the evaluation of the operational requirements, capital requirements, and implementation efforts required for replacement of large coal systems with biomass energy systems.

Appendix A

Site Layout, Plan View, and Biomass System Schematic



REVISIONS		
Date	Description	Approved

WERC

Wood Education and Resource Center
United States Forest Service
United States Department of Agriculture

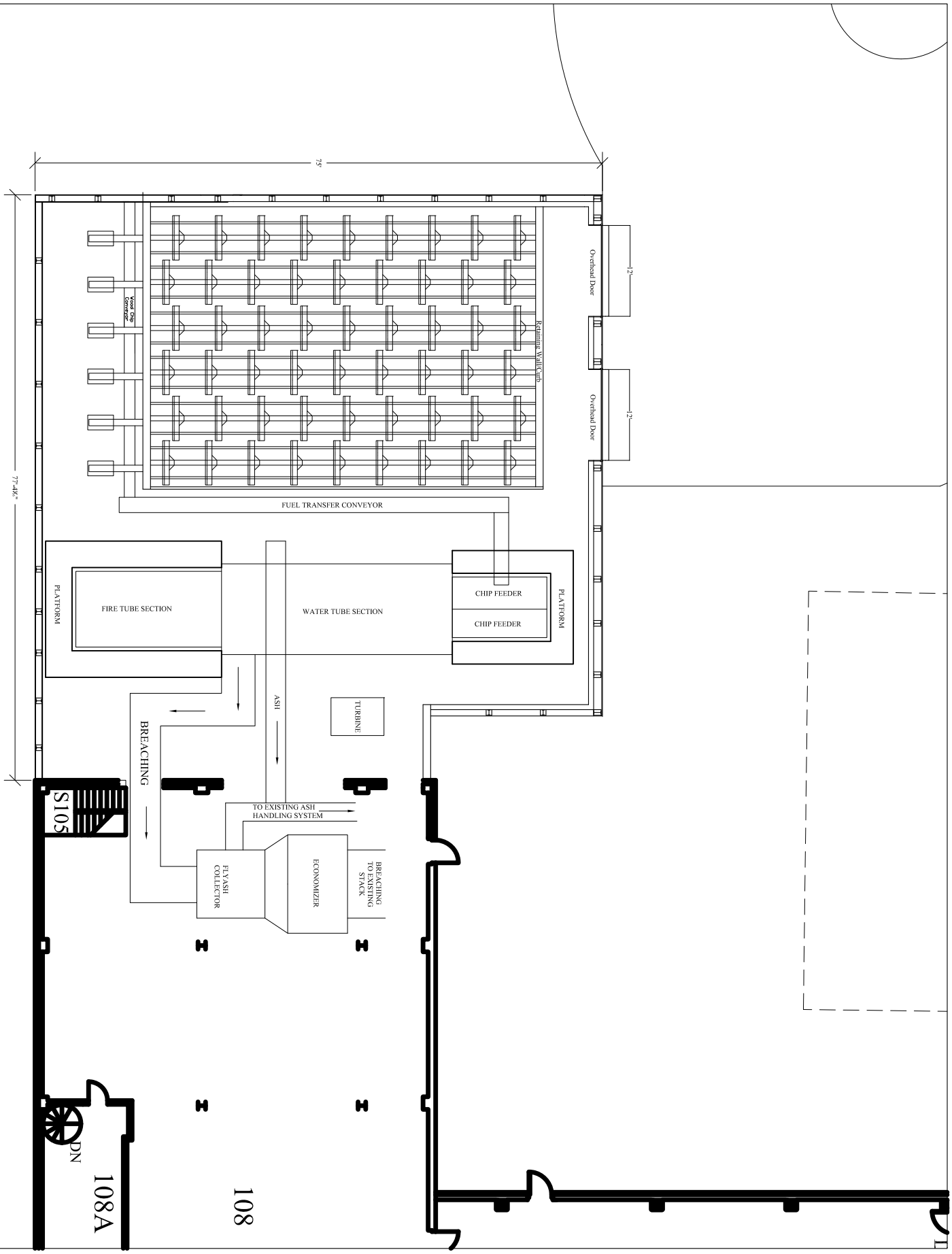
University of Wisconsin Stevens Point

Site Layout

Designed	GJF	2-11-11
Drawn	GJF	2-11-11
Checked	DAW	2-11-11

Approved _____ Date _____
Title _____ Job Class _____

Appendix A.1



NOT TO SCALE

REVISIONS		
Date	Description	Approved

Appendix A.2

WERC

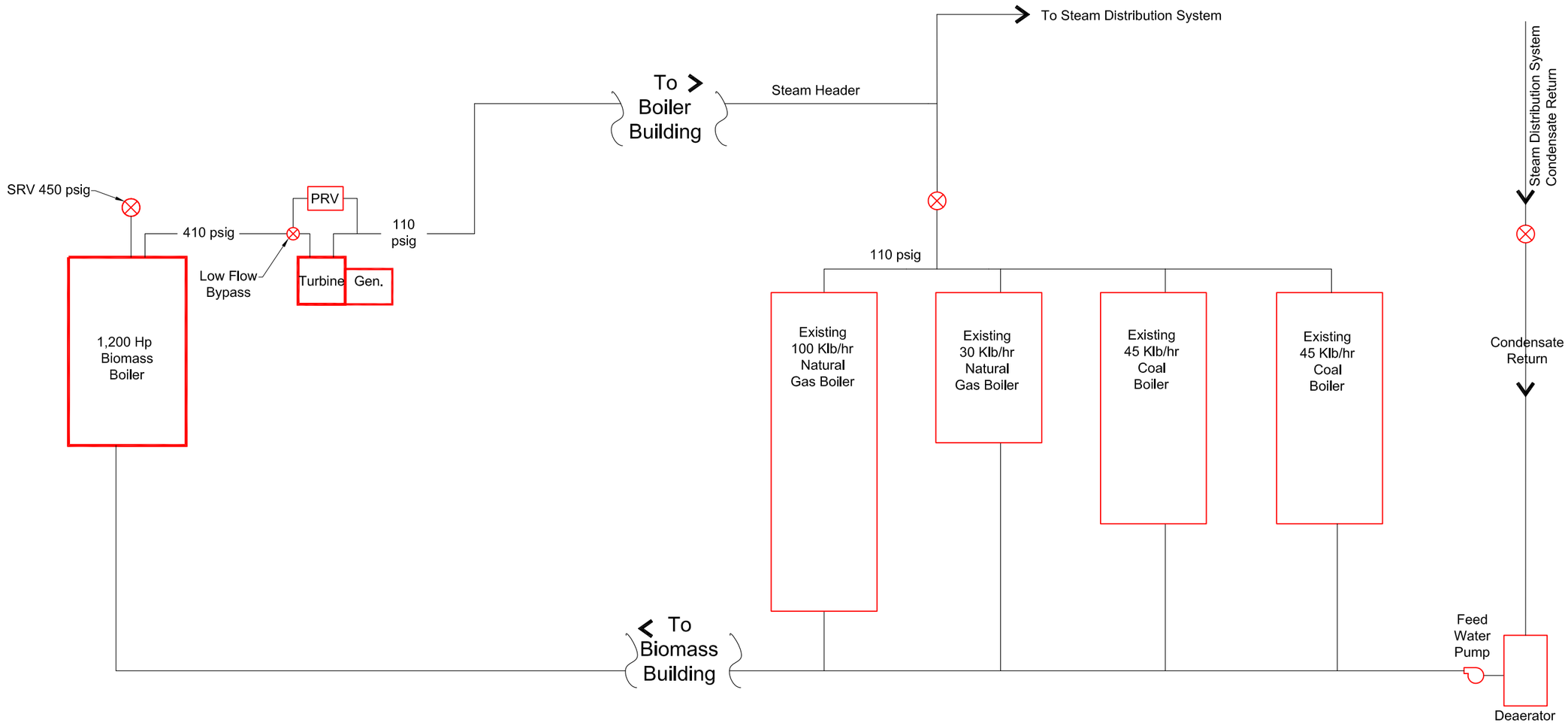
Wood Education and Resource Center
United States Forest Service
United States Department of Agriculture

University of Wisconsin
Stevens Point

Biomass Building Plan View

Designed	GJF	2-11-11
Drawn	GJF	2-11-11
Checked	DAW	2-11-11

Approved _____ Date _____
Title _____ Job Class _____



Designed TW 2-11-11
Drawn GJF 2-11-11
Checked TW 2-11-11

Approved
Title
Date
Job Class

University of Wisconsin - Stevens Point
Biomass Project

Biomass System Schematic

WERC
Wood Education and Resource Center
United States Forest Service
United States Department of Agriculture

REVISIONS

Date	Description	Approved

Apprndix A.3

Appendix B

Capital Cost Estimate

Capital Cost Estimate - Biomass Boiler

Line Item			Cost
Biomass boiler 450 psig (42,000 lb/hr steam output), Installed		$	2,878,800
Fuel Bunker Receiving, storage, material transfer, Installed		$	606,400
Boiler platform, stairs, and ladders installed		$	43,800
Additional Breaching to connect to present flue system		$	22,000
Sub-total		$	3,551,000
Boiler Manufacturer Bid Bond and Insurance	*2%*	$	71,020
Total Boiler Manufacturer Contract		$	3,622,020
General Contract			
Biomass Boiler Building and Chip Storage Pit ($225 per ft^2)		$	1,316,250
Site work		$	270,000
Steam Turbine/Generator with controls		$	270,000
Steam Specialties and Interconnection to Steam Header		$	150,000
Location and Isolation of existing campus power feed		$	55,000
Electrical		$	150,000
Mechanical		$	110,000
Sub-Total		$	2,321,250
Contractor Profit overhead and insurance	*16%*	*$*	*371,400*
Total General Contract Building and Site		*$*	*2,692,650*
Sub-Total Boiler Manufacturer and General Contractor		*$*	*6,314,670*
Contingency	*15%*	*$*	*947,201*
Sub-Total		*$*	*7,261,871*
Professional Services[1]	*12%*	*$*	*871,424*
Total[2]		**$**	**8,133,295**
US Forest Service Wood Biomass Utilization Grant		**$**	**250,000**
Amount to Finance		**$**	**7,883,295**

Notes:
1 - Professional Services includes engineering and project management
2 - Assumes that biomass boiler and general contract are bid seperately

Appendix C

Cash Flow Analysis

Cash Flow Analysis

17 Year Term at 1.5%

(Biomass vs. Existing Operation)

Input Variables	Value	Units
Financed Amount	7,883,282	$
Finance Period	17	# years
Interest Rate	1.5%	Percent
Existing Fuel Usage Offset	307,377	DTh
Coal Steam Production	57%	Percent
Nat. Gas Steam Production	43%	Percent
Coal Price	135	$/Ton
Natural Gas Price	7.70	$/MCF
Wood Chip Usage	36,592	tons/yr
Wood Chip Price	35	$/ton
Gas & Coal Inflation Rate	3.7%	Percent
Chip Inflation Rate	2.7%	Percent
General Inflation Rate	2.7%	Percent
O&M Costs	$ -	$/yr
Electric Unit Value	$ 0.052	$/kWh
Electric Production	3,043,334	kWh
Electric Inflation	3.7%	Percent

Year	Existing Fuel Cost Offset by Biomass System	Value of Electricity	Avoided Cost (New Gas Capacilty)	Wood Chip Cost	Added O&M Costs	Annual Financing Payments	Net Cash Flow	Present Value of Cash Flow
1	$ 1,913,659	$ 158,253		$ 1,280,720	$ -	$ 528,808	$ 262,385	$ 262,385
2	$ 1,984,465	$ 164,109		$ 1,315,299	$ -	$ 528,808	$ 304,466	$ 296,461
3	$ 2,057,890	$ 170,181		$ 1,350,813	$ -	$ 528,808	$ 348,450	$ 330,369
4	$ 2,134,032	$ 176,477		$ 1,387,284	$ -	$ 528,808	$ 394,417	$ 364,119
5	$ 2,212,991	$ 183,007		$ 1,424,741	$ -	$ 528,808	$ 442,449	$ 397,723
6	$ 2,294,872	$ 189,778		$ 1,463,209	$ -	$ 528,808	$ 492,633	$ 431,192
7	$ 2,379,782	$ 196,800		$ 1,502,716	$ -	$ 528,808	$ 545,058	$ 464,536
8	$ 2,467,834	$ 204,082		$ 1,543,289	$ -	$ 528,808	$ 599,819	$ 497,767
9	$ 2,559,144	$ 211,633	$ 3,430,000	$ 1,584,958	$ -	$ 528,808	$ 4,087,011	$ 3,302,494
10	$ 2,653,832	$ 219,463		$ 1,627,752	$ -	$ 528,808	$ 716,736	$ 563,929
11	$ 2,752,024	$ 227,583		$ 1,671,701	$ -	$ 528,808	$ 779,098	$ 596,880
12	$ 2,853,849	$ 236,004		$ 1,716,837	$ -	$ 528,808	$ 844,208	$ 629,758
13	$ 2,959,441	$ 244,736		$ 1,763,192	$ -	$ 528,808	$ 912,178	$ 662,573
14	$ 3,068,940	$ 253,791		$ 1,810,798	$ -	$ 528,808	$ 983,126	$ 695,333
15	$ 3,182,491	$ 263,182		$ 1,859,689	$ -	$ 528,808	$ 1,057,176	$ 728,049
16	$ 3,300,243	$ 272,919		$ 1,909,901	$ -	$ 528,808	$ 1,134,454	$ 760,728
17	$ 3,422,352	$ 283,017		$ 1,961,468	$ -	$ 528,808	$ 1,215,094	$ 793,382
18	$ 3,548,979	$ 293,489		$ 2,014,428	$ -		$ 1,828,041	$ 1,162,219
19	$ 3,680,292	$ 304,348		$ 2,068,817	$ -		$ 1,915,822	$ 1,186,006
20	$ 3,816,463	$ 315,609		$ 2,124,676	$ -		$ 2,007,396	$ 1,210,025
21	$ 3,957,672	$ 327,286		$ 2,182,042	$ -		$ 2,102,916	$ 1,234,277
22	$ 4,104,105	$ 339,396		$ 2,240,957	$ -		$ 2,202,545	$ 1,258,766
23	$ 4,255,957	$ 351,954		$ 2,301,463	$ -		$ 2,306,448	$ 1,283,493
24	$ 4,413,428	$ 364,976		$ 2,363,602	$ -		$ 2,414,802	$ 1,308,461
25	$ 4,576,725	$ 378,480		$ 2,427,420	$ -		$ 2,527,785	$ 1,333,673
							Net Present Value	**$ 21,754,597**

Cash Flow Analysis

17 Year Term at 1.5%

(Biomass vs. 100% Natural Gas)

Project Cost	7,883,282	$
Finance Period	17	# years
Interest Rate	1.5%	Percent
Nat. Gas Usage Offset	307,377	DTh
Nat. Gas Price	7.70	$/MCF
Wood Chip Usage	36,592	tons/yr
Wood Chip Price	35	$/ton
Gas Inflation Rate	3.7%	Percent
Chip Inflation Rate	2.7%	Percent
General Inflation Rate	2.7%	Percent
O&M Costs	$ 100,000	$/yr
Electric Unit Value	$ 0.052	$/kWh
Electric Production	3,043,334	kWh
Electric Inflation	3.7%	Percent

	Natural Gas Cost Offset by Biomass System	Value of Electricity	Wood Chip Cost	Added O&M Costs	Annual Financing Payments	Net Cash Flow	Present Value of Cash Flow
1	$ 2,366,803	$ 158,253	$ 1,280,720	$ 100,000	$ 528,808	$ 615,528	$ 615,528
2	$ 2,454,375	$ 164,109	$ 1,315,299	$ 102,700	$ 528,808	$ 671,676	$ 654,017
3	$ 2,545,186	$ 170,181	$ 1,350,813	$ 105,473	$ 528,808	$ 730,274	$ 692,380
4	$ 2,639,358	$ 176,477	$ 1,387,284	$ 108,321	$ 528,808	$ 791,423	$ 730,629
5	$ 2,737,015	$ 183,007	$ 1,424,741	$ 111,245	$ 528,808	$ 855,227	$ 768,775
6	$ 2,838,284	$ 189,778	$ 1,463,209	$ 114,249	$ 528,808	$ 921,797	$ 806,831
7	$ 2,943,301	$ 196,800	$ 1,502,716	$ 117,334	$ 528,808	$ 991,244	$ 844,806
8	$ 3,052,203	$ 204,082	$ 1,543,289	$ 120,502	$ 528,808	$ 1,063,686	$ 882,714
9	$ 3,165,134	$ 211,633	$ 1,584,958	$ 123,755	$ 528,808	$ 1,139,246	$ 920,563
10	$ 3,282,244	$ 219,463	$ 1,627,752	$ 127,097	$ 528,808	$ 1,218,051	$ 958,365
11	$ 3,403,687	$ 227,583	$ 1,671,701	$ 130,528	$ 528,808	$ 1,300,234	$ 996,131
12	$ 3,529,624	$ 236,004	$ 1,716,837	$ 134,052	$ 528,808	$ 1,385,930	$ 1,033,870
13	$ 3,660,220	$ 244,736	$ 1,763,192	$ 137,672	$ 528,808	$ 1,475,285	$ 1,071,593
14	$ 3,795,648	$ 253,791	$ 1,810,798	$ 141,389	$ 528,808	$ 1,568,445	$ 1,109,310
15	$ 3,936,087	$ 263,182	$ 1,859,689	$ 145,207	$ 528,808	$ 1,665,565	$ 1,147,030
16	$ 4,081,722	$ 272,919	$ 1,909,901	$ 149,127	$ 528,808	$ 1,766,806	$ 1,184,764
17	$ 4,232,746	$ 283,017	$ 1,961,468	$ 153,154	$ 528,808	$ 1,872,334	$ 1,222,519
18	$ 4,389,357	$ 293,489	$ 2,014,428	$ 157,289		$ 2,511,130	$ 1,596,509
19	$ 4,551,764	$ 304,348	$ 2,068,817	$ 161,536		$ 2,625,759	$ 1,625,499
20	$ 4,720,179	$ 315,609	$ 2,124,676	$ 165,897		$ 2,745,215	$ 1,654,770
21	$ 4,894,826	$ 327,286	$ 2,182,042	$ 170,376		$ 2,869,694	$ 1,684,327
22	$ 5,075,934	$ 339,396	$ 2,240,957	$ 174,976		$ 2,999,397	$ 1,714,172
23	$ 5,263,744	$ 351,954	$ 2,301,463	$ 179,701		$ 3,134,534	$ 1,744,307
24	$ 5,458,502	$ 364,976	$ 2,363,602	$ 184,553		$ 3,275,323	$ 1,774,736
25	$ 5,660,467	$ 378,480	$ 2,427,420	$ 189,536		$ 3,421,992	$ 1,805,461
						Net Present Value	**$ 29,239,607**

Cash Flow Analysis

20 Year Term at 4.5%

(Biomass vs. Existing Operation)

Input Variables	Value	Units
Financed Amount	7,883,282	$
Finance Period	20	# years
Interest Rate	4.5%	Percent
Existing Fuel Usage Offset	307,377	DTh
Coal Steam Production	57%	Percent
Nat. Gas Steam Production	43%	Percent
Coal Price	135	$/Ton
Natural Gas Price	7.70	$/MCF
Wood Chip Usage	36,592	tons/yr
Wood Chip Price	35	$/ton
Gas & Coal Inflation Rate	3.7%	Percent
Chip Inflation Rate	2.7%	Percent
General Inflation Rate	2.7%	Percent
O&M Costs	$ -	$/yr
Electric Unit Value	$ 0.052	$/kWh
Electric Production	3,043,334	kWh
Electric Inflation	3.7%	Percent

Year	Existing Fuel Cost Offset by Biomass System	Value of Electricity	Avoided Cost (New Gas Capacilty)	Wood Chip Cost	Added O&M Costs	Annual Financing Payments	Net Cash Flow	Present Value of Cash Flow
1	$ 1,913,659	$ 158,253		$ 1,280,720	$ -	$ 606,036	$ 185,156	$ 185,156
2	$ 1,984,465	$ 164,109		$ 1,315,299	$ -	$ 606,036	$ 227,238	$ 221,263
3	$ 2,057,890	$ 170,181		$ 1,350,813	$ -	$ 606,036	$ 271,222	$ 257,147
4	$ 2,134,032	$ 176,477		$ 1,387,284	$ -	$ 606,036	$ 317,189	$ 292,823
5	$ 2,212,991	$ 183,007		$ 1,424,741	$ -	$ 606,036	$ 365,221	$ 328,301
6	$ 2,294,872	$ 189,778		$ 1,463,209	$ -	$ 606,036	$ 415,405	$ 363,595
7	$ 2,379,782	$ 196,800		$ 1,502,716	$ -	$ 606,036	$ 467,830	$ 398,717
8	$ 2,467,834	$ 204,082		$ 1,543,289	$ -	$ 606,036	$ 522,590	$ 433,678
9	$ 2,559,144	$ 211,633	$ 3,430,000	$ 1,584,958	$ -	$ 606,036	$ 4,009,782	$ 3,240,090
10	$ 2,653,832	$ 219,463		$ 1,627,752	$ -	$ 606,036	$ 639,507	$ 503,165
11	$ 2,752,024	$ 227,583		$ 1,671,701	$ -	$ 606,036	$ 701,870	$ 537,714
12	$ 2,853,849	$ 236,004		$ 1,716,837	$ -	$ 606,036	$ 766,979	$ 572,148
13	$ 2,959,441	$ 244,736		$ 1,763,192	$ -	$ 606,036	$ 834,949	$ 606,477
14	$ 3,068,940	$ 253,791		$ 1,810,798	$ -	$ 606,036	$ 905,898	$ 640,712
15	$ 3,182,491	$ 263,182		$ 1,859,689	$ -	$ 606,036	$ 979,947	$ 674,863
16	$ 3,300,243	$ 272,919		$ 1,909,901	$ -	$ 606,036	$ 1,057,225	$ 708,941
17	$ 3,422,352	$ 283,017		$ 1,961,468	$ -	$ 606,036	$ 1,137,865	$ 742,956
18	$ 3,548,979	$ 293,489		$ 2,014,428	$ -	$ 606,036	$ 1,222,004	$ 776,917
19	$ 3,680,292	$ 304,348		$ 2,068,817	$ -	$ 606,036	$ 1,309,786	$ 810,834
20	$ 3,816,463	$ 315,609		$ 2,124,676	$ -	$ 606,036	$ 1,401,360	$ 844,716
21	$ 3,957,672	$ 327,286		$ 2,182,042	$ -		$ 2,102,916	$ 1,234,277
22	$ 4,104,105	$ 339,396		$ 2,240,957	$ -		$ 2,202,545	$ 1,258,766
23	$ 4,255,957	$ 351,954		$ 2,301,463	$ -		$ 2,306,448	$ 1,283,493
24	$ 4,413,428	$ 364,976		$ 2,363,602	$ -		$ 2,414,802	$ 1,308,461
25	$ 4,576,725	$ 378,480		$ 2,427,420	$ -		$ 2,527,785	$ 1,333,673
							Net Present Value	**$ 19,558,883**

Cash Flow Analysis

20 Year Term at 4.5%

(Biomass vs. 100% Natural Gas)

Project Cost	7,883,282	$
Finance Period	20	# years
Interest Rate	4.5%	Percent
Nat. Gas Usage Offset	307,377	DTh
Nat. Gas Price	7.70	$/MCF
Wood Chip Usage	36,592	tons/yr
Wood Chip Price	35	$/ton
Gas Inflation Rate	3.7%	Percent
Chip Inflation Rate	2.7%	Percent
General Inflation Rate	2.7%	Percent
O&M Costs	$ 100,000	$/yr
Electric Unit Value	$ 0.052	$/kWh
Electric Production	3,043,334	kWh
Electric Inflation	3.7%	Percent

	Natural Gas Cost Offset by Biomass System	Value of Electricity	Wood Chip Cost	Added O&M Costs	Annual Financing Payments	Net Cash Flow	Present Value of Cash Flow
1	$ 2,366,803	$ 158,253	$ 1,280,720	$ 100,000	$ 606,036	$ 538,300	$ 538,300
2	$ 2,454,375	$ 164,109	$ 1,315,299	$ 102,700	$ 606,036	$ 594,448	$ 578,818
3	$ 2,545,186	$ 170,181	$ 1,350,813	$ 105,473	$ 606,036	$ 653,045	$ 619,159
4	$ 2,639,358	$ 176,477	$ 1,387,284	$ 108,321	$ 606,036	$ 714,194	$ 659,332
5	$ 2,737,015	$ 183,007	$ 1,424,741	$ 111,245	$ 606,036	$ 777,999	$ 699,353
6	$ 2,838,284	$ 189,778	$ 1,463,209	$ 114,249	$ 606,036	$ 844,568	$ 739,234
7	$ 2,943,301	$ 196,800	$ 1,502,716	$ 117,334	$ 606,036	$ 914,015	$ 778,987
8	$ 3,052,203	$ 204,082	$ 1,543,289	$ 120,502	$ 606,036	$ 986,457	$ 818,624
9	$ 3,165,134	$ 211,633	$ 1,584,958	$ 123,755	$ 606,036	$ 1,062,018	$ 858,159
10	$ 3,282,244	$ 219,463	$ 1,627,752	$ 127,097	$ 606,036	$ 1,140,823	$ 897,602
11	$ 3,403,687	$ 227,583	$ 1,671,701	$ 130,528	$ 606,036	$ 1,223,005	$ 936,965
12	$ 3,529,624	$ 236,004	$ 1,716,837	$ 134,052	$ 606,036	$ 1,308,702	$ 976,260
13	$ 3,660,220	$ 244,736	$ 1,763,192	$ 137,672	$ 606,036	$ 1,398,056	$ 1,015,497
14	$ 3,795,648	$ 253,791	$ 1,810,798	$ 141,389	$ 606,036	$ 1,491,216	$ 1,054,689
15	$ 3,936,087	$ 263,182	$ 1,859,689	$ 145,207	$ 606,036	$ 1,588,336	$ 1,093,845
16	$ 4,081,722	$ 272,919	$ 1,909,901	$ 149,127	$ 606,036	$ 1,689,577	$ 1,132,977
17	$ 4,232,746	$ 283,017	$ 1,961,468	$ 153,154	$ 606,036	$ 1,795,105	$ 1,172,094
18	$ 4,389,357	$ 293,489	$ 2,014,428	$ 157,289	$ 606,036	$ 1,905,094	$ 1,211,207
19	$ 4,551,764	$ 304,348	$ 2,068,817	$ 161,536	$ 606,036	$ 2,019,722	$ 1,250,326
20	$ 4,720,179	$ 315,609	$ 2,124,676	$ 165,897	$ 606,036	$ 2,139,179	$ 1,289,461
21	$ 4,894,826	$ 327,286	$ 2,182,042	$ 170,376		$ 2,869,694	$ 1,684,327
22	$ 5,075,934	$ 339,396	$ 2,240,957	$ 174,976		$ 2,999,397	$ 1,714,172
23	$ 5,263,744	$ 351,954	$ 2,301,463	$ 179,701		$ 3,134,534	$ 1,744,307
24	$ 5,458,502	$ 364,976	$ 2,363,602	$ 184,553		$ 3,275,323	$ 1,774,736
25	$ 5,660,467	$ 378,480	$ 2,427,420	$ 189,536		$ 3,421,992	$ 1,805,461
						Net Present Value	**$ 27,043,894**