BIOMASS INTEGRATION STUDY

December 23, 2013

Contents

Executive Summary

Located on the western shore of Lake Bemidji in northern Minnesota, Bemidji State University (BSU) and its nearly 5,000 students are committed to environmental stewardship, community service, and global understanding. As campuses and communities across North America evolve, many have been looking at energy production and consumption as a primary opportunity to advance their respective missions. One of BSU's signature themes is environmental stewardship and as such, it is now pursuing the integration of biomass, a local, renewable, and reliable fuel source into its energy portfolio.

In July, 2013 BSU hired LHB Engineering and Ever-Green Energy to conduct a biomass feasibility study for the campus energy program. This initial assessment has found that biomass is available at a cost that is competitive with fossil fuels and could technically be integrated with BSU's existing energy infrastructure. Moreover, the integration of biomass into BSU's fuel mix would provide the opportunity to reduce greenhouse gas emissions, increase investments into the local economy, broaden the base for environmental education, and diversify its fuel program. These accomplishments would further the BSU sustainability commitment and provide greater resilience from fuel market volatility and more autonomy in providing reliable energy service to the campus.

By extending its fuel mix to include biomass and reducing campus load, it is estimated that BSU could reduce carbon dioxide emissions by nearly 9,600 tons per year from the current energy consumption profile and by approximately 6,400 tons per year when accounting for the reduced campus energy consumption. If the campus energy system were to be integrated with the local community to serve buildings near the campus, those environmental benefits would be even greater.

While shown to be technically and environmentally beneficial, a number of factors need to be investigated further in order to proceed with biomass integration. A major item to address would be the relocation of the primary energy service operations from the south end of the campus to the north end. In addition, certain portions of the distribution system would need to be resized to account for the relocation of the primary campus heating plant. Lastly, BSU would need to conduct a more thorough analysis of the exact location of the new biomass facility and how it would integrate with campus logistics, particularly as it pertains to fuel delivery and ash disposal.

Once all of these factors have been thoroughly investigated and vetted, a more comprehensive plan for biomass integration could be developed, which should include the development of a complete financial model that evaluates the expected economic benefits of the system under several natural gas cost scenarios.

Introduction

Bemidji State's vision is to be "a catalyst for shaping the potential of those it serves, who, in turn, shape the worlds in which they live and work." While BSU has made significant strides to improve the energy efficiency of its campus, natural gas still serves as the primary fuel source for the campus with fuel oil serving as a backup. University students, faculty, and staff have shown an interest in the feasibility of integrating biomass into BSU's fuel mix and displacing a significant portion of its fossil fuel consumption. A biomass fueled system would diversify the fuel options and make it possible to enhance renewable energy and sustainability education with "hands-on" experience for the faculty and students.

BSU Sustainability

As defined on the BSU Sustainability website, "Sustainability involves meeting the needs of the present without compromising the ability of future generations to meet their own needs." BSU views sustainability not only from an environmental perspective, but also from a social, economic, and wellness perspective.

Source: http://www.bemidjistate.edu/sustainability/about/

The Process

In July, 2013, BSU hired LHB Engineering (LHB) and Ever-Green Energy (EGE) to conduct a biomass due-diligence study. The goal of this study is to analyze the technical, operational, environmental, and financial implications of integrating biomass as a fuel source into the existing BSU energy system. To complete this study, building load data and energy production data was collected and analyzed for both the current and the future campus load profiles. The LHB-EGE team (Team) also evaluated the availability of biomass fuel in the Bemidji area and analyzed the technical feasibility of integrating biomass into the existing production facility or elsewhere on the campus. Lastly, the Team broadly evaluated system advancement opportunities that are available to BSU, with a particular focus on the potential for expanding the system into downtown Bemidji.

About LHB

LHB is a multi-disciplinary engineering, architecture, and planning firm known for our design leadership and loyalty to clients. LHB goes beyond good intentions and focuses on measurable performance. We are experts in public works, pipeline, industrial, housing, healthcare, government, education, and commercial design. LHB is dedicated to being environmentally responsible, reducing long term operating costs, and improving the quality of life for our clients.

About Ever-Green Energy

Ever-Green Energy is one of the country's foremost experts on the advancement of community district energy systems, built upon decades of experience with system development, utility ownership and management, and engineering.

For the past 10 years, Ever-Green has owned and operated a biomass-fired combined heat and power facility in downtown Saint Paul, along with a biomass collection and processing business. On an annual basis, these facilities process over 250,000 tons of biomass to generate power and heat. In addition, the operation serves as a research facility for local biomass fuel producers looking to take their fuels to market. EGE's biomass knowledge is recognized internationally and sought after by many campuses and communities looking to develop similar biomass programs.

Heating System Background

BSU has a steam system in place to serve the heating needs of all campus buildings. The steam is generated at a central plant on the south side of the campus through the use of natural gas and fuel oil-fired boilers. Steam is distributed throughout the campus through a series of steam distribution pipes, mainly via an underground tunnel system, although some steam pipe is direct-buried. Once the steam is distributed to the individual campus buildings the heat is transferred to the buildings' hot water and glycol distribution system through an energy transfer station in the individual building's mechanical room. From there, the heat is used for space heating, domestic water heating, and humidification purposes. In the energy transfer station the steam is cooled to condensate, which is pumped back to the central plant through condensate pipes that generally follow the same routing of the steam distribution system. The condensate is reheated to steam for delivery back to the individual buildings. The BSU steam system appears to be well-maintained operates relatively efficiently, and BSU facilities staff continues to make efficiency improvements to the system.

Bemidji State University

Existing Facilities

Figure 1: Existing campus site plan

Consumption

Steam service is used to provide space heating, heating domestic water, and humidification to approximately 1.5 million square feet of office, dormitory, classroom, recreational, and food service on the BSU campus. Each building has a secondary hot water loop that separates the steam distribution network from the building loop through the use of heat exchangers. The heat exchangers transfer the energy from the steam service to the secondary hot water-glycol building loop, which operates at approximately 160°F to 170°F. Utilizing meter data supplied by BSU, Table 1 shows the estimated usage for the campus over the past six years.

Annual Energy Usage	**145,299**	**MMBtu**
Diversified Peak Energy Usage	**55**	**MMBtu/hr**

Table 1: Normalized annual usage using BSU metering data from 2006-2012

Notes:
Normalized data from 2006-2012 metering
2,100 EFL heating hours
80% diversity factor assumed

To estimate the annual and peak energy usage the metering data was normalized, which means it was converted to a nationally common scale that accounts for outside air temperatures. The equivalent full load heating hours, meaning the annual usage divided by the peak capacity used, were assumed to be 2,100 hours based on ASHRAE data. To account for the difference in the time of day that each individual building experiences their peak load, a diversity factor of 80% was applied. These factors are applied to the usage estimations throughout this study.

Although Table 1 shows the estimated normalized usage for the campus it is not reflective of the current campus load. Over the last few years BSU has made significant improvements to several buildings, drastically reducing their overall consumption. Table 2 represents modified campus energy consumption after accounting for the energy efficiency improvements made within some of the buildings on the campus. The numbers represented in Table 2 will be used to represent the present consumer load for this report.

Annual Energy Usage	**110,376**	**MMBtu**
Diversified Peak Energy Usage	**42**	**MMBtu/hr**

Table 2: Modified normalized annual and peak usage from metered data
Notes:
Normalized data from 2006-2012 metering
Birch Hall, Bridgeman Hall, Cedar Hall, Hagg-Sauer Hall, Memorial Hall, Oak Hall, and Physical Education Complex metering data modified to 2010-2012 data for energy conservation improvements
Gillett Recreation and Fitness modified metering data to 2009-2011 for usage improvements
2,100 Equivalent full load heating hours
80% diversity factor assumed

Production

Located on the south end of the BSU campus, the current central heating plant houses four steam boilers, with natural gas as their primary fuel and fuel oil as a backup. Three of the boilers provide 100

PSI steam. The fourth unit is a smaller unit producing 11 PSI steam to serve summer loads. The boiler models and capacities are as follows:

- Installed in 2007, boiler #2 is a Cleaver Brooks/Nebraska boiler with 45,000 lb/hr capacity and runs at 100 PSI.
- Installed in 1991, boiler #3 is a Cleaver Brooks boiler with 25,000 lb/hr capacity and runs at 100 PSI.
- Installed in 1991, boiler #4 is a Cleaver Brooks boiler with 25,000 lb/hr capacity and runs at 100 PSI.
- Installed in 1991, boiler #5 is a Cleaver Brooks boiler with 10,000 lb/hr capacity and runs at 11 PSI. This boiler runs to serve domestic hot water load during the summer.

As soon as BSU's system demand reaches 80% capacity of one of the 25,000 lb/hr boilers, BSU fires the second 25,000 lb/hr boiler. When both of these boilers reach 80% capacity, boiler #2 is fired and remains operational until it is more efficient to switch back to the smaller boilers.

Distribution

The campus has a steam distribution network providing steam service to a majority of the campus buildings. The steam is sent out from the central plant at 100 PSI during the heating season and 11 PSI steam is sent out to serve two buildings' domestic hot water needs during the summer months. Condensate is collected from the individual buildings through steam traps and condensate receivers and pumped back to the production facility for reuse. A majority of the steam and condensate distribution piping is installed in pedestrian and utility tunnels. The piping is insulated with a minimum of two inches of fiberglass insulation and was generally found to be in good condition.

A 2001 Stanley Consultants study on the central plant and distribution system recommended that BSU upgrade several sections of the steam distribution network and a majority of the condensate pipe. The condensate network was found to have excessive velocities and was prone to experience periodic incidences of water hammer. Rather than entirely replacing the condensate pipe as recommended in the 2001 study, BSU staff has chosen to replace sections of the condensate system on an as-needed basis. Several of the campus buildings have also undergone significant energy conservation measures, which have reduced the overall load and velocities on the distribution network and extended its useful life.

Future University Energy Consumption

As noted earlier in this report, the current energy consumption for BSU is approximately 110,000 MMBtu per year, with a peak load of approximately 42 MMBtu per hour. BSU has recently completed significant energy conservation projects at several individual campus buildings, which has reduced their overall thermal energy use. As identified in the BSU master plan, the campus will continue to experience some contraction and also will likely be decommissioning several buildings in the future, which will further reduce the overall heating demand of the campus.

Through discussions with BSU and LHB there is indication that Walnut Hall, Tamarak Hall, and Sanford Hall will all be removed from service within the next 10-15 years. In addition, Maple Hall has already been removed from service and Hagg-Sauer Hall is expected to be replaced with a smaller and more energy efficient classroom facility, along with the replacement of Upper and Lower Hobson Hall with a smaller and more energy efficient Student Union. As a result, for the purpose of this report the estimated annual and peak loads in Table 3 will be used to represent the future level of BSU's heating requirements.

Annual Energy Usage	**74,278**	**MMBtu**
Diversified Energy Usage	**28**	**MMBtu/hr**

Table 3: Adjusted ten-year campus load

Notes:
Normalized data from 2006-2012 metering
Birch Hall, Bridgeman Hall, Cedar Hall, Memorial Hall, Oak Hall, and Physical Education Complex metering data modified to 2010-2012 data for usage improvements
Gillett Recreation and Fitness modified metering data to 2009-2011 for usage improvements
Further improvements at Hagg-Sauer Hall to 2/3 its current usage
Sanford Hall, Maple Hall, Tamarak, and Walnut Hall removed
2,100 Equivalent full load heating hours
80% diversity factor assumed

Biomass Options

The type and availability of biomass are key factors in selecting production equipment and modifying plant operations. The Team identified three potential biomass fuel types to be analyzed in this study: pellets, woodchips, and sawdust. The supply of biomass needs to be sustainable, with a stable supply from competing suppliers preferred. Boilers and auxiliary equipment are traditionally optimized for certain types of biomass and fuel moisture content. As such, selecting a fuel type with a single supplier could therefore endanger the continuous operation or adversely affect the price of fuel in the event of an interruption or termination of fuel delivery from that supplier.

Pellets

Biomass pellets, from a technical standpoint, are preferable to other forms of biomass fuels based on higher energy content and uniform sizing. This allows for fewer truck loads, smaller storage requirements, and less complicated fuel handling and combustion equipment. However, the manufacturing process of pellets adds significantly to the cost of fuel, which creates a drawback to this option.

The biomass is normally dried to approximately 10% moisture content in the pellet manufacturing process. The heat content of pellets is therefore higher compared to other biomass fuels, at approximately 16 MMBtu per ton. A high-quality pellet is dry, hard, and durable, with low amounts of ash generated from its combustion. The most common pellets on the market typically have an ash content of less than 1 %, which equates to approximately 60 tons annually from pellets.

Storage and handling of pellets is simpler and easier to automate than woodchips due to their uniform geometry and size. Typically, silo storages would be combined with screw conveyors. Pellets can either be used in a grate-type boiler, or if the pellets are crushed, in a boiler with pellet burners.

About 6,500 tons of pellets would be needed at BSU per year. The current delivered costs are estimated to be $175.00 per ton. This price is reflective of the limited supply and the additional production involved in manufacturing pellets. The closest pellet manufacturer is in Hayward, WI with a distributer in Red Lake Falls, MN.

Other local suppliers, such as Potlatch Corporation (Potlatch), have shown interest in producing pellets near Bemidji. It is unclear at this time if these suppliers will proceed with their plans.

Limited by the legal load capacity of 23 tons per truck load, BSU would require approximately 280 truckloads of pellets annually to meet the energy needs of the campus.

Woodchips

Compared to pellets, woodchip fuel can vary considerably in moisture content and in fuel sizing. It is also common for foreign materials, such as metal objects, tires, etc. to be found in the fuel delivery due to a less controlled fuel processing environment. This provides some challenges in reception, handling, and combustion of wood chips. Screening of the fuel upon reception or sturdy fuel handling and combustion equipment should be used to mitigate this risk.

Energy content of woodchips can also vary depending upon moisture and ash content. Both moisture and ash content can vary depending on the origin, handling, and storage of the raw material. The moisture content of woodchips typically varies between 35% and 55%. Without contamination during the handling of the woodchips, the ash content can be as low as 1%. It is not uncommon to encounter ash content from woodchip in the 5-10% range, due to contamination from soil and sand during logging. With a 5% dry ash content assumption, approximately 360 tons of ash would be generated annually from woodchip combustion.

In extreme cases, the energy content can vary between 7 MMBtu per ton for woodchips with a moisture content of 55% and ash content of 10%; and above 11 MMBtu per ton at 35% moisture content and 1% ash content. For purposes of this report, the energy content of woodchips has been assumed at 9 MMBtu per ton.

Woodchips are considered more energy efficient than pellets when examined across the fuel life-cycle. Less energy is required for manufacturing, processing, and transportation of woodchips, particularly if the woodchips are generated near the biomass-fueled heating production plant. This would be the case for BSU.

A variety of combustion equipment for woodchips is available on the market, such as fluidized bed boilers, vibrating grate boilers, and reciprocating grate boilers. For this size of biomass plant, a reciprocating grate boiler combined with walking-floor storage and a scraper conveyer fuel transport system is a cost-effective solution that will be able to handle uneven fuel quality and size without requiring intensive operator involvement.

Woodchips are available from forest residuals as a byproduct of logging activities and can be comprised of tree tops and limbs, tree trimmings, small diameter trees and stems, dead-standing trees, and downed logs. Woodchips are also a common byproduct from lumber mills. Based upon data received from the Minnesota Department of Natural Resources, the Team has estimated that there are over 462,000 tons of forest residuals available annually within a 100 mile radius of Bemidji. It is estimated that BSU would require about 13,000 tons of woodchips to serve its hot water load. This equates to less than 3% of the wood chips available within a 100 mile radius of Bemidji. Therefore woodchip availability for a BSU biomass facility should not be considered a high risk. Furthermore, the abundant supply of woodchips with above-average competition from logging companies should also provide BSU with competitive supplier pricing.

Woodchip costs usually depend on such factors as the distance from the point of delivery, the type of material, demand, and how the fuel is transported. Based upon the Team's market research, the cost to deliver forest residual wood chips to BSU is estimated between $23.00 and $28.00 per ton. Pricing has been very stable in this area over the last five years with a $2.00 per ton variance based on higher transportation fuel costs. Potlatch has stated that they could provide up to 120,000 tons of woodchips on an annual basis. Potlatch woodchips would be debarked and screened due to their internal processes and their price would be in the range of $40.00 - $45.00 per ton delivered.

Similar to pellets, the amount of woodchips per truck load is limited by the legal load capacity allowed on the roadways (23 tons per truck). Compared to pellets, woodchips have lower fuel content per ton which results in the need for more fuel to be delivered. BSU would require approximately 570 truckloads of woodchips annually for the future load scenario in Table 3.

Sawdust

Sawdust, primarily generated from lumber mill production and logging activities, normally has a uniform sizing with lower moisture content than woodchips, typically in the 35 to 40% range. At 40% moisture content, the energy content is approximately 10 MMBtu per ton.

The handling and combustion of sawdust is less demanding than woodchips due to more uniform properties. Sawdust can be stored in silos and transported pneumatically to a boiler with sawdust burners. However, attention should be paid to eliminating the risk for volatility in the storage and handling system, especially with sawdust with lower moisture content. Sawdust can also be used in grate type boilers, potentially mixed with woodchips depending upon the market availability of the fuel.

Sawdust has limited availability in the area and a dependable supply would need to be developed. The price for logging sawdust is estimated to be at least $30.00 per ton delivered to BSU. Potlatch has indicated that they could provide up to 20,000 tons of sawdust annually in the range of $20.00 to $25.00 per ton delivered. It is estimated that BSU would need approximately 11,500 tons of sawdust annually and operations would produce approximately 70 tons of ash annually with a 1% dry ash content assumption.

Sawdust is less dense than pellets and woodchips and typically will not exceed the 23 tons road weight limitation. Assuming that each truck load contains 20 tons of sawdust, BSU would need approximately 570 truckloads of sawdust annually to serve the future expected load of the campus.

Fuel Cost Analysis

Based upon the findings of the Team, the estimated cost of each fuel type is summarized in Table 4. It should be noted that these are current prices and have not accounted for any market volatility for these fuels.

Fuel Type	$/MMBtu	Historical Price Volatility
Pellets	$ 10.94	High
Woodchips	$ 2.83	Low
Sawdust	$ 3.00	High
Natural Gas	$ 4.93	Med/High

Table 4: Estimated cost of biomass fuels compared to current cost of natural gas

Fuel Handling and Storage

All biomass fuels will require some level of on-site storage. To be adequately prepared for heating demand and weather conditions, a minimum of two days of storage should be maintained on-site. This will reduce the risk of fuel shortages should snow or other major weather events limit delivery truck access to campus. Two days of storage will also minimize the need for fuel transports and fuel reception over weekends.

Pellets and sawdust are the simplest fuels for storage and handling, with pellets requiring the least amount of space for storage. Pellets would typically be stored in silos. Three standardized silos, 10 feet square and 40 feet high, would provide about 8,000 cubic feet of effective storage volume. This would be sufficient for slightly more than two days of storage based upon the quantities discussed in this report. Five similar silos would be needed for sawdust.

Walking-floor storage for woodchips, or a mix of woodchips and sawdust, would occupy approximately 1,500 square feet of the storage and an additional 750 square feet for the hydraulic drive equipment and conveyor systems.

All materials would necessitate a fire suppression system, although sawdust storage would require additional considerations and a more elaborate system.

Biomass Plant Location

Pellets

The pellet boilers and handling equipment could possibly fit in the existing central plant with storage silos erected on the existing coal silo foundations. The challenge with adding pellets at the existing plant site is truck traffic and access. The plant is located on the shores of Lake Bemidji with some limitations for access and fuel delivery. Figure 2 shows a skyway that crosses the expected delivery route of biomass trucks delivering to the central plant. Figure 3 shows the expected exit route for delivery trucks. The exit route would pass through a residential area, which would require additional stakeholder and zoning assessment.

Figure 2 and Figure 3 – Delivery and exit route options for pellet trucks.

It is expected that both the entry and exit routes could be challenging for the campus operations. The plant is also on the lake and adjacent to a city walking path. The addition of a solid fuel at this location may initiate concerns from the local community.

Woodchips and Sawdust

Unlike pellets, boilers and fuel handling for woodchips and sawdust could not be physically located at the existing central plant. The size of that equipment exceeds the capacity of the existing operational footprint. Several locations on the campus have been identified as potential alternative locations for a new plant. The biomass facility could be located on the north side of the campus near Maple Hall and Oak Hall. As Maple Hall has already been removed from service, this site is a preferred option for a new facility. Walnut Hall serves as another potential location, with this building possibly being repurposed as the new biomass facility. Repurposing would also allow the new biomass facility to architecturally integrate with the campus. Walnut Hall has loading docks and the walking-floor could most likely be housed inside the building. Another location discussed with BSU staff is near the Otter Tail substation, adjacent to the fitness and recreation building. This site may prove to be more advantageous if combined heat and power were added on campus in the future.

Fuel Recommendation

For purposes of this report, the Team has assumed that woodchips would be the selected biomass fuel. While pellets could also be a compelling fuel, the price of the fuel and the uncertainty of suppliers add a level of risk that may be difficult to overcome. Woodchip supply in the Bemidji area is abundant and the price of woodchips has been stable over the past few years. Compared to the volatility of natural gas prices, woodchips would provide BSU with a very stable, locally produced fuel source.

With the integration of woodchips, the Team has also assumed that the new central plant would be located in Walnut Hall. This location was selected due to the preferred logistics of delivering fuel to the campus and removing ash from the campus. Given the other options for locations, a more comprehensive site evaluation should be performed if woodchip biomass fuels are pursued for the campus.

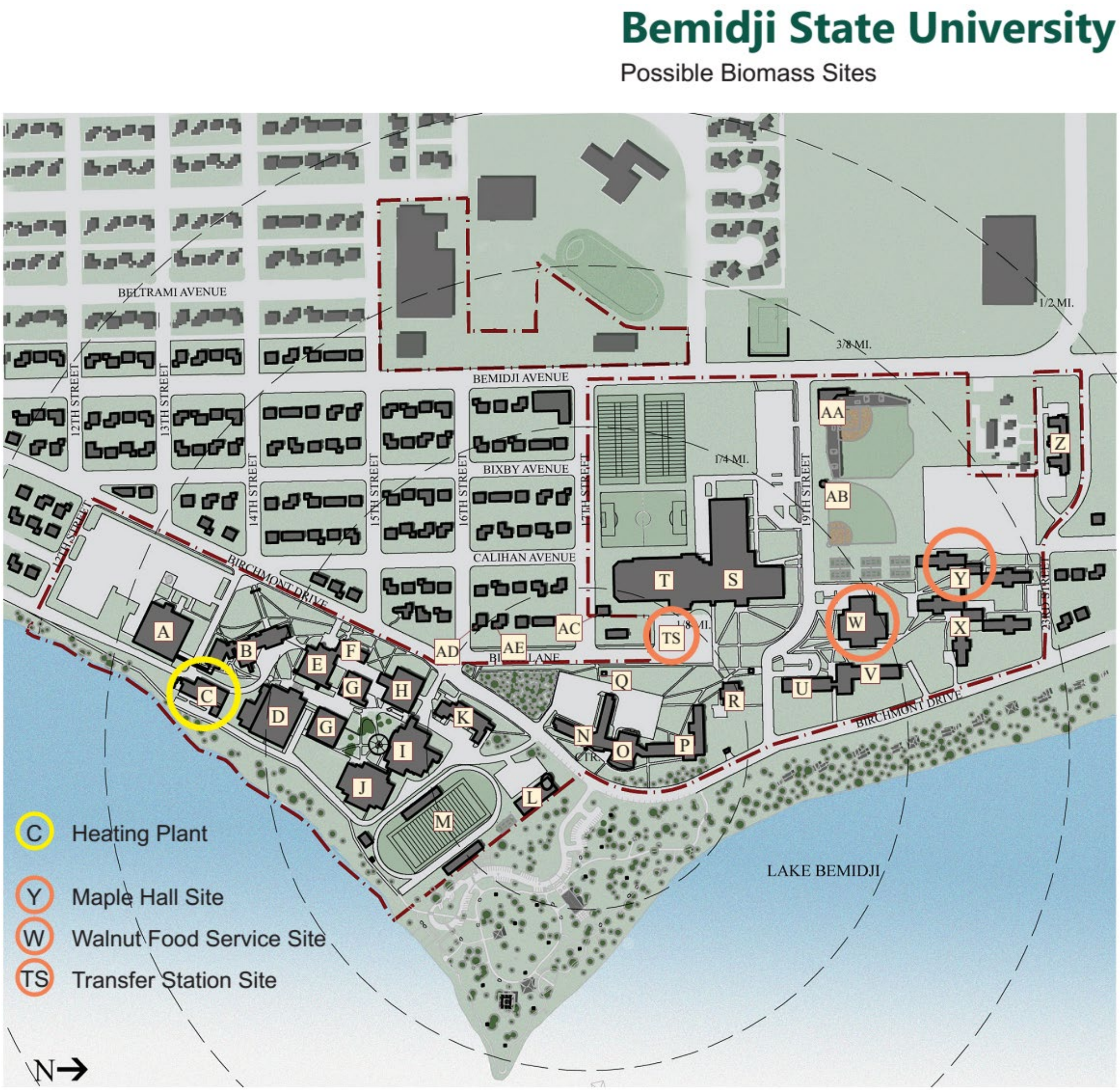


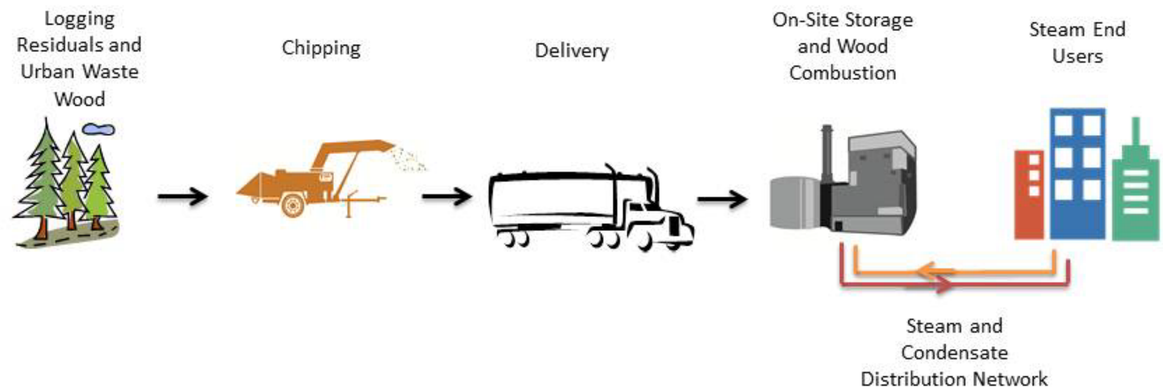
Figure 4: Possible biomass plant locations

EVER-GREEN ENERGY™ LHB

Production

Based upon the findings of the Team and an understanding of the current biomass market, woodchips have been identified as the preferred fuel for implementation. This preference is based upon current market conditions, both from a supply and cost perspective. In the event that market conditions change prior to BSU making a decision to proceed, this preference should be revisited to determine the most prudent fuel source.

Figure 5: Proposed biomass flow process



Once woodchips were identified as the preferred fuel, the Team then determined the preferred technical solution for the new energy center. Technology selection presented in this section is based upon the future load projection identified in Table 3. It should be noted that with a projected campus load of 74,278 MMBtu, additional fuel input will be required to account for boiler efficiencies and distribution system losses. In this study an annual distribution heat loss of 15% has been used.

Woodchip Biomass Plant

For this size of the recommended equipment, the most cost-effective biomass-fired plant would be built around packaged units, with two (2) 8.5 MMBtu/hr biomass boilers, including auxiliaries, installed in pre-manufactured boiler houses. However, the availability of packaged biomass boilers on the North American market is currently limited. With a field erected solution, the most cost-efficient option would utilize only one (1) 16 MMBtu/hr biomass boiler. In Table 5, the 2 x 8.5 MMBtu/hr option has been used to portray how much of the heating generation can be provided with different sizing of boilers. With only one (1) 16 MMBtu/hr boiler, the energy provided from biomass will be slightly lower compared to the 2 X 8.5 MMBtu/hr option, while gas boilers would need to be used during the summer when the biomass boiler would be shut-down for seasonal maintenance.

The plant would also include gas boilers with sufficient capacity to cover the system peak for the entire campus, as well as to provide adequate redundancy in the event that biomass operations are interrupted. This would provide BSU with maximum fuel flexibility and effective use of operations staff while providing BSU with the ability to repurpose the existing central plant. Table 5 provides a description of how much of the campus load would be served by the different boilers, based on an estimated load duration curve for the campus shown in Figure 6.

	Peak Capacity	Energy Production		Energy Price		Boiler Efficiency
	MMBtu/hr	MMBtu	%	$/MMBtu	$/yr	%
Biomass boiler #1	8.5	59,749	70%	4.0	$241,841	70%
Biomass boiler #2	8.5	22,867	27%	4.0	$92,557	70%
Peaking boilers	11.3	2,804	3%	6.6	$18,432	75%
Total	28.3	85,420		4.1	$352,830	
Current Operations Fuel Costs					$579,906	

Table 5: Estimated energy production from different boiler units at the woodchip biomass plant

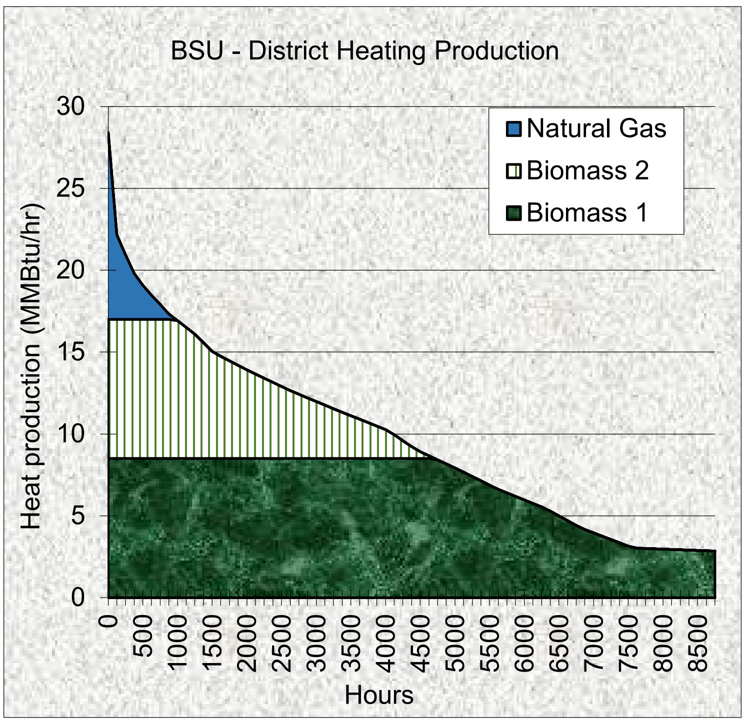


Figure 6: Campus load duration curve showing estimated boiler dispatch for the woodchip biomass plant

Biomass Plant Space Requirements

As noted earlier in this report, the existing central plant location does not provide sufficient space for a new woodchip boiler plant. As such, a new location would need to be identified for this facility.

A plant built around two packaged reciprocating grate boilers with walking-floor fuel storage, gas peaking boilers and a control room would need a minimum area of about 5,500 square feet. Additional space would be needed for fuel delivery and ash handling truck accessibility. An existing building, such as Walnut Hall, could be utilized for the plant if space allows and BSU would prefer to repurpose an existing building. The packaged units are very compact and a field erected plant would require significantly more space. In the event that a field erected plant was preferred, it is estimated that the footprint would be increased to approximately 9,500 square feet.

Opinion of Probable Cost

Based upon the findings in this report, the Team identified the expected equipment that would be needed for the new biomass operations. Contained within Table 6 is the Team's opinion of probable cost for that equipment. It should be noted that this estimate is for the energy center equipment only. In subsequent sections of this report, the Team addresses expected distribution system modifications. Also, if this option is viewed favorably by BSU, a comprehensive evaluation of plant location options should occur, which should include an estimate of structural and architectural costs for the new central plant location. It should also be noted that the probable cost is based on packaged boiler units. However, by going to one field erected 16 MMBtu/hr biomass boiler in lieu of two packaged 8.5 MMBtu/hr units, the cost should be comparable. Lastly, it should be noted that the projected costs below do not include other system development costs or air permit modification costs.

	Size		Units	Unit price	Total
Package biomass boiler *1	8.5	MMBtu/hr	2	1,670,000	$3,340,000
Electrostatic precipitator			0	450,000	0
Package gas boilers *2	8.5	MMBtu/hr	3	360,000	$1,080,000
Balance of plant *3			1	240,000	$240,000
Civil works *4			1	120,000	$120,000
Civil works - below ground fuel storage *5	15,000	cu.ft	15,000	30	$450,000
Mechanical installation *6			1	230,000	$230,000
Electrical installation *6			1	230,000	$230,000
Controls *6			1	60,000	$60,000
Building *7	1,000	sq.ft	1,000	200	$200,000
Subtotal					$5,950,000
Engineering	10%				$595,000
Contingency	25%				$1,636,250
TOTAL					**$8,181,250**
**1 Complete installation with container type boiler house and walking floor storage equipment*					
**2 Complete installation with container type boiler house*					
**3 Softener, chemical feed, deaerator, etc.*					
**4 Foundations for the boiler houses, etc.*					
**5 Fuel storage (128 tons, 1,151 MMBtu, 47 hours)*					
**6 External connections, internal work included in the package price above*					
**7 Building for balance of plant equipment and control room*					

Table 6: Opinion of probable cost for a woodchip biomass plant

Operations

BSU operates its existing district energy system with four boiler operators, one relief operator, and three plant maintenance engineers for maintenance in the buildings. Biomass-fired systems similar to what is proposed in this report do not typically require any further staffing than a similar sized natural gas-fired plant. Therefore, the staffing needs of the new biomass plant should be consistent with how the campus system is staffed today. The equipment in the new plant has been sized to meet the entire load of the campus, so it is assumed that all boiler plant operations staff would shift to the new biomass plant. In the event that biomass operations are disrupted, redundancy has been incorporated into the new plant so that the campus may be served by natural gas.

In order to maintain current staffing levels, the Team has included walking-floor storage with a scraper conveyer fuel transport system and reciprocating grate boilers. That configuration is very sturdy and can handle uneven fuel quality and size, and is therefore not as operator intensive. This configuration, however, does include equipment that requires higher levels of maintenance and repair. The Team estimates that annual maintenance and repair costs would be approximately $150,000 per year greater than the current annual maintenance and repair costs.

Shifting all of the campus load management to the new biomass plant would also allow BSU to repurpose the existing central plant. For purposes of this analysis, the Team has not included any costs for that repurposing, nor has it assumed any revenue for selling the existing assets within the existing plant.

Distribution System Resizing

In the event that the biomass facility is located on the north side of the campus, a more detailed assessment of the distribution system sizing should be completed. The Team performed an initial analysis of the system and found that the system is adequately sized to meet the projected load, although some steam and condensate pipe near the proposed plant would need to be upgraded. Preliminary estimates indicate that this upgrade would cost between $500,000 and $1 million, however a more thorough analysis should be conducted to refine that estimate.

In the event that the preferred plant location changes, the projected campus load changes, or the decommissioning plan for the buildings identified in this report changes, the distribution system would need to be reevaluated to verify its capacity.

Air Permits

BSU currently burns natural gas in its plant and operates under an Option D Air Emission Permit. If biomass were introduced into its fuel mix, BSU would need to apply for a Title V air permit to account for a new emission source. If biomass is found to be of interest, this new permit would need to be secured prior to construction commencement. The pursuit of this permit should occur in conjunction with design-development of the new system. The activities and timeline related to this permit are unknown at this time, as it will depend upon MPCA requirements and interpretations. In the event that biomass is pursued, an environmental engineer should be engaged to identify the scope of obtaining the permit, the cost to obtain the permit, and the schedule for obtaining it. The costs for this permit are not included in Table 6.

Typical environmental performance that can be expected from a woodchip-fired boiler is approximately 0.2 lb/MMBtu for CO and NOx and 0.1 lb/MMBtu for particulates. The particulate emissions are based on the use of multicyclone equipment. Further reductions can be achieved with an electrostatic precipitator, but at a significant cost increase. An electrostatic precipitator is normally not required for this size of production equipment.

BSU Previous Biomass Boiler Installation

Approximately 30 years ago, BSU installed a biomass boiler at the central plant to feed the steam distribution network. The boiler was intended to operate 24 hours a day as the base load boiler and multiple biomass fuels were tested, including briquettes, pucks, and pellets. The fuel was stored within the central plant to supply the operations. Through discussions with one of the operators of this biomass boiler, it suffered from severe reliability issues, consistently requiring a natural gas backup boiler to come online. The operator interviewed recalled significant problems with the fuel handling system and the installed auger. As a result, the biomass plant was removed the following summer after one season of operation. A natural gas boiler was installed in its place. The root cause of the past problems is not known and EGE's recent positive experience with biomass in Saint Paul should be considered as more applicable to the solutions presented in this report.

Environmental Benefits

The combustion of biomass at Bemidji State University will provide substantial environmental benefits to the campus and local community. Although natural gas, which is considered one of the cleanest fossil fuels, is currently the primary fuel source for the central plant, it still releases pollutants such as carbon dioxide (CO_2) into the atmosphere. By replacing fossil fuels with a local, renewable resource in biomass, the calculated emissions of CO_2 would be drastically reduced. A comparison of emissions between natural gas and biomass for the future load are shown in Table 7. The future campus load with biomass combustion reduces the present CO_2 emissions by approximately 9,600 tons per year through load reduction, biomass combustion, and the elimination of fuel oil as a back-up fuel. When comparing natural gas and biomass under the future expected load, biomass is estimated to provide BSU with CO_2 emission reductions of approximately 6,400 tons annually. These improvements are estimated to reduce BSU's Scope 1 greenhouse gas emissions by over 90% and its overall greenhouse gas emissions by approximately 44%, and set BSU well on its way to meet its greenhouse gas emission reduction commitments as part of the American College & University Presidents' Climate Commitment.

	Gas Today			Gas Under Future Load			With Biomass Under Future Load			
	Fuel Usage	CO_2 *1	SO_2 *2	Fuel Usage	CO_2 *1	SO_2 *2	Fuel Usage	CO_2 *1	SO_2 *2	PM *3
	MMBtu/yr	tons/year		MMBtu/yr	tons/year		MMBtu/yr	tons/year		
Gas Usage	169,243	9,816	-	113,893	6,606	-	3,739	217	-	-
Biomass Usage	-	-	-	-	-	-	118,023	-	0.6	6.2
TOTAL	169,243	9,816	-	113,893	6,606	-	121,762	217	0.6	6.2

NOTES:

****1 lb/MMBtu Gas: 116 Biomass: 0***

****2 lb/MMBtu Gas: 0 Biomass: 0.01***

****3 lb/MMBtu Gas: 0 Biomass: 0.10***

Table 7: Emission comparison between natural gas and biomass under the future campus load

System Advancement

In additional to utilizing biomass to offset natural gas and fossil fuel use for the steam distribution network, several other system advancements have been identified to further reduce energy use on the campus and within the surrounding community. Advancement options include combined heat and power, converting the steam network to hot water, solar thermal, solar PV, and capturing waste heat. Additionally, the expansion of the distribution network to serve the local community would offer efficiency and sustainability benefits.

In addition to improving the overall system, the integration of these technologies, fuels, and system enhancements offers a unique opportunity for the academic offerings of BSU. These applications can be used for experiential educational opportunities for students, faculty, staff, industry affiliates, and the greater community. This will elevate BSU's overall academic profile, while simultaneously improving sustainability efforts.

Combined Heat and Power (CHP)

Combined heat and power (CHP) is an internationally recognized solution to address aging infrastructure, maximize renewable fuel integration, and maintain versatility and resilience in a volatile energy market and policy realm. By capturing heat from the production of electricity, plants and systems can use less fuel to generate more energy while also reducing the amount of pollutants released to the environment. CHP opens doors for communities to incorporate biomass and other renewables more effectively and create affordable, stable price structures for customers. CHP systems also improve the stability of the local electric grid, increasing energy security and reliability for users.

Due to the relatively low electric prices in the area and the relatively high capital cost of a CHP installation, this option is not addressed in this study. It is recommended as an option for exploration in the future.

Hot Water Conversion

All campus buildings currently connected to the central plant's steam distribution network have hot water or glycol internal systems, which utilize steam to hot water heat exchangers in their mechanical rooms. The buildings already receive the benefits of a hot water mechanical system such as ease of control, increased safety and comfort, decreased energy usage, and reduced maintenance. Additional benefits can be realized by converting the steam distribution network to hot water.

Hot water networks also allow for the integration of other technologies such as solar thermal, utilizing waste heat, and other low grade or lower temperature hot water sources.

This option is not included in the study since the steam system is well maintained and conversion would require relatively high upfront costs. This option should be studied when additional integration of energy sources is considered.

Solar Thermal

Solar thermal collectors could be integrated on campus to capture the sun's energy and would supplement the needs of domestic hot water and building space heat. A solar thermal system could be installed on an individual building to supplement the needs of a building with consistent hot water and heating needs (ex. athletic center, residential halls, and cafeterias).   If the system converts to a hot water distribution system, an installation could be placed anywhere within the campus to feed to system. Through the use of solar thermal the district heating system can lower its carbon footprint and further diversify the campus's fuel mix. Solar installations also serve as a helpful teaching mechanism for physics, engineering, and other science education.

Waste Heat

Low-grade waste heat could be captured and integrated from sources such as boiler flue gas, production and manufacturing processes, sewage heat recovery, and other streams of thermal energy. This integration is more viable with hot water distribution systems. Although nearby waste heat sources have not been identified in this report, sources may present themselves in the future and should be considered as a future benefit of converting to a hot water distribution system.

Community Integration

Currently, the majority of non-university buildings in Bemidji serve their heating needs by fossil fuel-based combustion on-site. The environmental benefits of a BSU biomass plant could be further increased by integrating some of these surrounding buildings into the system, replacing fossil fuel use at those buildings with a locally derived renewable source of fuel. By connecting those buildings onto the district heating network, the greenhouse gas emissions profile for the entire Bemidji community could be reduced. Buildings served by the district heating network will also realize the benefits of reliable service and reduced maintenance costs that come with being connected to district energy. For Bemidji State University, an expanded network and customer base could serve as a source of revenue for the central plant that can lead to more opportunities to further improve the district heating system. In some cases, production assets already installed in the private buildings can provide backup, redundancy, and summertime or peaking capabilities to the network as well. Buildings recognized as potential candidates for service connections to BSU's district heating network include:

- Sanford Senior Behavioral Health Clinic
- St. Philips
- First Lutheran Church
- Central Elementary School
- JW Smith Elementary School
- Boys & Girls Club
- Possible residential expansion near the Boys and Girls Club

A survey was sent out to these buildings to learn more about their building heating and cooling requirements, and how these needs are currently met. The survey was used to get a better understanding of the buildings' thermal demand and the level of difficulty for each building to connect to a district energy system. Based on the survey responses received, it is estimated that the buildings listed above could add an additional 4 to 5 MMBtu/hr of load to the BSU campus network (approximately 15%). Most of the buildings did appear to be compatible with a district energy system.

Solar PV

Several factors play into the feasibility of campus photovoltaic (PV) power. This study reviews the geographical solar potential and the economy of an installation. In addition, future opportunities are summarized for current and upcoming regulation changes in Minnesota.

The BSU campus heating plant converts natural gas and electricity to campus steam and chilled water. The 2012 annual electrical consumption totaled 11,803,408 kilowatt-hours (kWh). As the campus operates continuously, the total annual campus consumption equals 1.3 megawatts (MW). The cost of campus electricity is $0.07/kWh where, according to the U.S. Energy Information Administration, the national average for commercial electrical retail rates is $0.1016/kWh.

Reviewing the National Renewable Energy Laboratory (NREL) annual solar capacity in the United States, Minnesota falls into a “Good – Fair” category of 4.0-4.5 kWh/m2/Day. Actual PV production depends on specific site limitations. Derating factors include soiling (debris, snow, pollution films), shading, sun-tracking, and age. Snow derating would be a significant factor for BSU installations. Small PV array tilts prevent snow from sliding off the assembly. Once a specific site is located, LHB recommends a site specific analysis to optimize the array tilt and minimize the array shading and spacing requirements.

NREL also maintains an Open PV Project where PV installation cost data is averaged in the United States. While the site is not intended to be comprehensive PV installation data for the entire United States, it does give a good indication of the range of prices based on geographic location. Minnesota’s average 2012 installation costs were $4.69/Watt while the cost recorded in Beltrami was significantly higher at $10.82/Watt.

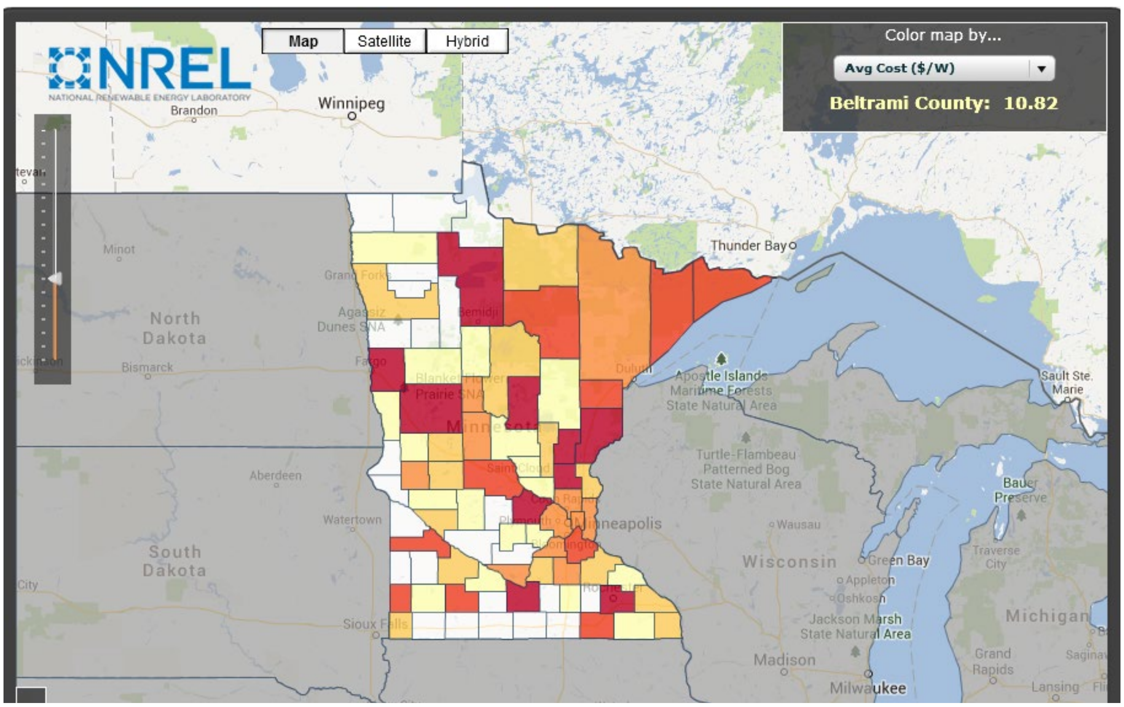


Figure 7: Open PV Project, average cost of installation for Minnesota; National Renewable Energy Laboratory; http://openpv.nrel.gov/visualization.

Minnesota State Colleges and Universities (MnSCU) maintains strict guidelines for roof installations on campus buildings. The PV installations need to be set 36” above the roof membrane with the pipe box curbs set 24” above the roof to accommodate the future reroofing. The costs for the system supports often exceed project budgets. Given the MnSCU guidelines, a ground installation or roof installation on a non-MnSCU building is recommended.

To balance the space requirements with the need for production, LHB analyzed a PV system that would generate 10% of the current campus electrical needs. While the actual space requirements for a PV system are site specific, the system would roughly require 10 acres.

Using PVsyst, a photovoltaic analysis software program, LHB created a feasibility model for Bemidji State University. The program model assumes a ground-based, stationary and 30° tilted PV array system. Given the solar potential in Bemidji, the estimated costs of installation and electrical savings, LHB determined that the straight payback of installing a 1 MW system ranged between 50 and 120 years. The payback range accounts for the 2012 average installation costs in Minnesota as a whole and Beltrami County, respectively.

Potential Financial Resources:

- Xcel Energy – Renewable Development Fund Grants.
- Otter Tail Power Company – Community-Based Energy Development (C-Bed) Tariff.
- Made in MN incentive *for systems < 4 kW.*
- By January 31, 2014, the Minnesota Department of Commerce (DOC) will develop a distributed methodology to price the value of solar energy.

Potential Partnerships for the future Community-Based Energy Development Tariff:

- Beltrami County HRA – Managed by HRDC (), and holds several properties in town. One of these is Conifer Estates, a transitional housing development near HWY 2 and the off-ramp for HWY 71 north. They own some other land and have experience as developers. They are a highly viable partner.
- Lueken's Foods –The company president is very interested in renewable energy. The company has two buildings, one on the north end of town and one on the south end. It's an employee owned company and real cornerstone of the community.
- The Boys and Girls Club located on 15th between Irvine and HWY 197. - This location is visible from campus and has a strong presence in the community.
- The BSU foundation - This foundation owns an empty lot at the Northwest Corner of HWY 197 and 15th St next to the Boys and Girls Club.
- Beltrami County –The county campus is located in downtown Bemidji. The county owns and manages the Courthouse, law enforcement center, and administrative buildings. All of these properties are highly visible and compelling buildings.
- The City of Bemidji – The city owns the Sanford Center, which was originally planned to include solar energy. There is some likelihood that this building might have prepared for solar installations. The city just had an audit completed, so they are in the midst of a focus on energy issues.

1. Sanford Hospital - This might be a good organization to contact directly. They have been expanding their campus and have further expansion plans.
2. Bemidji high school and middle school
3. There are two malls and a number of big box stores that could serve as viable options.

Recommendations and Next Steps

This study has found that generating steam through biomass combustion at Bemidji State University is technically feasible and environmentally beneficial. Biomass fuel in Bemidji and the surrounding area is plentiful, with woodchips as the most abundant and stable fuel source. Biomass would provide BSU with greater fuel flexibility, a stable fuel cost, and an opportunity to reinvest in the local community.

While the cost of biomass is stable and less expensive than natural gas today, and natural gas prices have been historically volatile, a number of factors should be further investigated before it is determined that biomass integration is the right decision for Bemidji State University. Primary among those factors are:

- Verify the expected future campus load through the completion of the master plan process.
- Identify the preferred biomass fuel and potential fuel suppliers.
- Site the biomass plant and develop a conceptual design for the boiler facility, fuel handling, and storage.
- Develop a staffing and operations strategy.
- Determine the best environmental and economic option for managing summer load.
- Decide upon a community integration strategy, if it is found to be of interest.
- Determine if the existing central plant should be maintained for system redundancy or if redundancy should be added at the new biomass plant.
- Build an economic model for the preferred option to verify the financial feasibility of biomass integration.

Once these steps are taken, BSU can make an informed decision on the most appropriate and viable direction for their future energy program.

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We appreciate the contributions of these and other stakeholders as we worked toward the completion of this study. We recognize the value of each of these contributions and understand that the success of this endeavor will be predicated upon the ongoing support of these parties.

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Appendix 1: Building Consumption

Building Name	Area	2006-2012 Normalized Consumption	Modified Normalized Consumption	Future Consumption
	ft²	kBtu	kBtu	kBtu
Bangsberg Hall	86,878	4,523,242	4,523,242	4,523,242
Birch Hall	62,184	4,174,733	5,009,679	5,009,679
Bridgeman Hall	33,772	10,553,590	3,835,895	3,835,895
Cedar Hall	39,133	7,507,482	2,717,236	2,717,236
Clark Library	71,462	2,327,802	2,327,802	2,327,802
Decker/Hickory Hall	29,424	1,074,972	1,074,972	1,074,972
Deputy Hall	78,656	3,253,463	3,253,463	3,253,463
Education/Art	53,342	3,260,968	3,260,968	3,260,968
Gillett Rec/Fitness	85,765	3,644,788	2,819,792	2,819,792
Hagg-Sauer Hall	82,478	7,194,665	4,141,310	2,760,873
Hobson Memorial Union	76,756	6,959,633	6,959,633	6,959,633
Linden Hall	67,565	1,653,527	1,653,527	1,653,527
Maple Hall	94,635	8,491,441	8,491,441	-
Memorial Hall	53,893	4,860,150	2,722,209	2,722,209
Oak Hall	128,550	15,146,532	10,063,055	10,063,055
Physical Education Complex	121,586	21,756,939	8,606,482	8,606,482
Pine Hall	50,264	4,598,661	4,598,661	4,598,661
Sanford Hall	17,012	408,135	408,135	-
Sattgast Hall	107,598	8,090,656	8,090,656	8,090,656
Tamarack Hall	88,410	16,681,204	16,681,204	-
Walnut Hall	57,167	9,136,659	9,136,659	-
TOTAL	1,486,530	145,299,242	110,376,020	74,278,145