Campus Energy & Sustainability Master Plan Study

BOWLING GREEN STATE UNIVERSITY

Final Report

November 23, 2016

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I. Introduction

Project Scope:

On January 7, 2016, Bowling Green State University retained SHP Leading Design and CMTA Inc to perform a Campus Energy and Sustainability Master Plan study. The master plan study is to be centered around three main topics with those being Policy and Behavior, Renewable Energy Systems and Energy Conservation Measures. The study is a combined effort of SHP Leading Design and CMTA and included engagement from Bowling Green State University stakeholders including Staff, Faculty, Students and other state and local entities. The study will help inform the University on the best plan to move forward in achieving the goals outline in BGSU's Climate Action Plan as well as Dr. Mary Ellen Mazey's signing of the President's Climate Commitment. Fundamentally this study will help inform the University on strategies to reduce carbon production through energy conservation measures in conjunction with renewable energy systems. Once implemented, the results will be championed by the student groups dedicated to providing a more sustainable future for them, the University and those to follow.

The study will cover each of the three main topics but will start with discussing the relationship and existing pricing issues between Bowling Green Municipal Utilities and Bowling Green State University.

After the Utility discussion, Policy and Behavior will be discussed including such topics as Carbon Sequestration along with Carbon and Renewable Energy offsets/credits.

The second topic covered will center around Renewable Energy systems and will include Photovoltaic systems, CHP, Geothermal (Green ECM), Wind and Biomass systems.

The final topic covered will center around Energy Conservation Measures (ECM's) and will include LED Lighting replacements, HVAC/Demand control strategies, power factor correction, distributed energy storage systems, thermal storage systems, and decentralized boilers.

The study will conclude with SHP and CMTA's recommendations for a plan of action for moving forward. The goal of the study is to provide the University with information that can be used the help make good decisions on future policy, renewable energy projects and energy conservation measures that will lead them towards both a highly energy efficient campus and carbon neutrality.

II. Executive Summary

This Campus Energy and Sustainability Master Study is the result of a collaboration between Bowling Green State University, SHP Leading Design and CMTA, Inc, that started on January 7, 2016. Over the past 10 months this team has worked with University planners, staff, faculty, students, architects, energy analysts, utility providers and engineers to investigate and analyze how the University is currently operating in terms of energy and sustainable practices. Construction standards, university policies, site existing conditions and energy operating data from the physical plant have been analyzed.

The goal is to create a road map to a Carbon Neutral Campus by the year 2040 per Dr. Mary Ellen Mazey's signing of the President's Climate Commitment. To achieve this goal, the study focused on three main themes.

- Policy and Behavior
- Renewable Energy Systems
- Energy Conservation Measures

The results of these three main themes are contained within the body of this study and are organized by theme. A summary of these findings along with recommendations are included below. There is one overarching topic that affects the entire study and that is the existing relationship and challenges between Bowling Green Municipal Utilities (BGMU) and the University.

Existing Utility Considerations:

There are several utility factors that have an impact on the recommendations contained within this report. First, it would be extremely difficult to sever the relationship with BGMU without a significant investment by BGSU to basically become its own utility provider. In doing this, the effect on the surrounding community would be extremely costly since the community would have to pick up the remainder of the debt obligation associated with decisions that BGMU made related to the Prairie State Power Plant. With that said, it could ultimately be an option that BGSU wants to pursue, but in terms of this report, it is not a recommendation at this time. Therefore, the study is centered around looking for strategies that could help BGMU and BGSU. That being win – win scenarios for both organizations.

The next important consideration related to BGMU is the expected rate increases. If BGSU takes a "do nothing" approach to energy consumption, BGSU will have to increase their budget by more than $1,000,000 over the next five years, just to keep up with the future planned rate increases. Along with the yearly expected rate increases, demand charges have continued to rise. Prior to 2014, only 25% of the electrical charges for BGSU were related to demand charges. After rate increases in 2014, this number jumped to 36%. This is a significant increase that basically pays for the "assurance" that the utility provider will be able to provide enough power on a peak condition day. The demand is not related to consumption costs or carbon footprint, but still represents a significant cost to the University.

Demand reduction is a key recommendation associated with this study. In addition to demand reduction, power factor correction is also a key recommendation related to this study since lower power factor increases generation and transmission costs. Demand reduction and power factor correction are both a win for the University and a win for the Utility company.

Priorities and Recommendations:

In the context of the relationship and challenges associated with the existing utility, a discussion related to Policy and Behavior, Energy Conservation Measures and Renewable Energy Systems can take place. The priorities and recommendations below are a summary of what is contained within the full body of the study. In some cases, a specific order, or priority, has been recommended. In other cases, it has not. Universities are large complex institutions with many moving parts. It would be very difficult to provide a complete recommendation of projects from 1 to 1000 due to these same complexities. However, there is a great deal of information provide in the recommendation section below that will help University planners and Staff prioritize future needs moving forward.

Policy and Behavior Priorities:

Setting priorities for the Policy and Behavior recommendations of this plan is less straightforward and linear than the priorities around energy renewable and conservation measures. This is largely because the upfront costs, energy savings and carbon reduction vary widely depending on the degree to which the strategy is pursued and adopted. Many of the strategies in this section have very minimal or even negligible upfront costs for implementation, but the cooperation and buy-in needed to achieve them is often significant. For this reason, this plan recommends that strategies that build on existing, successful campus programs or initiatives be targeted for implementation first.

In general, the most potentially impactful behavior and policy strategies that are presented in this plan are those that call for the centralization and/or reorganization of control structures such as the recommendation to create a central Energy Services Group and move control of the recycling program to the Office of Campus Sustainability. The reason for this is that for any plan to be successful, the responsibilities for achieving the plan must be as clear and straightforward as possible.

Renewable Energy System Priorities:

Renewable energy strategies relevant to the BGSU Campus were investigated as part of this study. They included Photovoltaics, Combined Heat and Power, Wind, and Biomass. These strategies will reduce both energy demand and consumption. Photovoltaics are the only renewable energy strategy recommended for immediate implementation at the BGSU campus. Combined Heat and Power (CHP) is not recommended to be incorporated into the campus at this time due to the standby charges that will be enacted from the utility provider. The recommended solution for CHP would be partnering with BGMU to provide another win – win scenario for the two organizations. Biomass and Wind could be used for education purposes on campus, but they will not have a significant impact on the carbon reduction for campus.

Energy Conservation Measure Priorities:

It is important to consider that a reduction in demand charges and consumption by at least 6% per year is required to maintain the current utility budget. Energy Conservation strategies are much easier to prioritize and recommend due to the ease of budgeting the upfront costs, energy savings and the associated carbon reduction. Seven energy conservation measures were analyzed included LED lighting, Building Automation Systems Upgrades, Power Factor Correction, Geothermal Heating and Cooling, Energy Storage, Thermal Storage and Decentralized Boilers.

There are two categories of recommendations associated with Energy Conservation Measures: those that effect consumption and those that effect demand. The recommended strategies associated with demand savings would include Power Factor Correction Banks and Energy Storage (battery) combined with PV. A 1% reduction of demand on a peak day will save up to 6% in demand charges for the year. The recommended strategies associated with consumption savings would include LED lighting upgrades, Geothermal Heating and Cooling upgrades and Building Automation Control System upgrades.

The final two systems that were investigated in this portion of the study were Thermal Storage and Decentralized Boilers. Both could be used on campus, however, due to the value of the existing heating and cooling infrastructure on campus, decentralized boilers are not recommended at this time. Thermal storage will also not be recommended due to the longer return on investment associated with this type of system being integrated into the infrastructure.

Conclusion:

In conclusion, we feel that BGSU can make a big leap towards achieving carbon neutrality by the year 2040. From a policy and behavior standpoint, there are easy changes that can be made that can make a big difference over time. These will just take time to achieve the campus community buy in required to move forward. On the energy reduction and renewable side, the University needs to reduce demand first and then consumption. There are three approaches that are recommended. First is the jump start the process. This jump start would consist of three signature projects that the students, faculty, staff and community could rally around. The second would be significant reductions in demand charges and the last would be energy consumption reductions.

<u>Policy and Behavior Recommendations</u>

New Construction and Renovation Standards Overview

Recommendation	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Maintain the requirement that new buildings meet LEED Silver or better in LEED v4	1-2% increase in construction costs	Variable	Variable
Expand LEED Silver or better requirement to major renovations	2-4% increase in construction costs	Variable	Variable
Create a specific requirement for energy use reduction for new buildings and renovations	Variable	Depends on Target set	Depends on Target set
Establish a process for comparing real energy performance to projected energy performance	Negligible	Variable- savings may be derived from identifying wasted energy	Variable- savings may be derived from identifying wasted energy
Create a standard for the type of Building Automation System and level of controllability required on all new systems	Negligible	Variable- savings may be derived from better monitoring and control	Variable- savings may be derived from better monitoring and control
Require that lifecycle assessment analysis be conducted on energy consuming components proposed for new construction and renovations	Negligible to perform analysis	Variable	Variable
Require LED lighting to be DLC qualified	Negligible	Minor	Minor

Building Scheduling and Operation

Recommendation	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Create a centralized approach to energy management across campus (Energy Services Group)	Negligible if existing staff is utilized.	Variable- savings may be derived from better monitoring and control	Variable- savings may be derived from better monitoring and control
Reinvest savings derived from energy use reduction into future energy use reduction strategies	None- self-funding.	Variable depending on future strategies chosen	Variable depending on future strategies chosen
Identify buildings that may be shut down over the Summer	Negligible.	Depends on the energy use and square footage of building that is closed	Depends on the energy use and square footage of building that is closed
Evaluate class scheduling to try to make space use as consistent and regular as possible and make sure BAS schedules are synced with building use schedules.	Negligible	Variable	Variable
Expand programs like Friday Night Lights where students proactively help in energy use reduction	None- depends on student volunteers	Variable	Variable
Provide training and expectations for university maintenance and custodial staff to turn off lighting when they leave a space	Negligible	Variable	Variable

Move from private offices for all or some faculty through faculty contract revisions and/or incentives, such as new technology or enhanced break room spaces, for faculty members who agree to shared work areas	May save money if less space has to be constructed in the future	322 kWh per year per office $31 per year per office	644 pounds of CO2 per year per office

Vehicles and Commuting

Recommendation	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Establish a minimum “Green Score” for all university purchased vehicles	Negligible	Variable- depends on target set	Variable- depends on target set
Require all new university purchased buses to be hybrid or alternative fuel	Hybrid buses are currently approximately 65% more expensive than standard diesel buses	Hybrid buses reduce fuel usage by an average of between 25% and 30% over diesel buses.	22.38 pounds of CO2 reduction for each gallon of diesel not used
Require new grounds and maintenance vehicles to be electric powered	Varies depending on equipment type	Varies depending on equipment type	19.64 pounds of CO2 reduction for each gallon of gas not used
Establish and Enforce a campus anti-idling policy	Negligible	Approximately 1 gallon of gas per two hours of idling eliminated	19.64 pounds of CO2 reduction for each gallon of gas not used
Conduct a commuting audit to identify who, when where and how people are commuting on and around campus	Low cost $1,000 to $3000	None for the audit itself	None for the audit itself
Explore incentives for encouraging carpooling and use of environmentally preferable vehicles such as reduced parking rates, priority parking selection and/or “preferred” prime parking spaces around campus	Variable depending on strategies chosen. Most are no to low cost.	Variable	19.64 pounds of CO2 reduction for each gallon of gas not used
Investigate carpooling and ridesharing technology such as Zimride	No to low cost depending on the technology chosen	Variable depending on adoption rates	19.64 pounds of CO2 reduction for each gallon of gas not used
Provide electric car recharging stations around campus to make driving an electric vehicle convenient	$10,000 to $15,000 per station	Varies depending on source energy. Solar charging stations are most beneficial	Varies depending on electric source

Technology Management

Recommendation	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Switch from desktop computer systems to laptops wherever possible	Negligible.	590 kWh per year per laptop $55 per year per laptop	1,180 pounds of CO2 per year per laptop
Evaluate existing computer labs to understand if they are still needed	None- self-funding.	Variable depending on future strategies chosen	Variable depending on future strategies chosen

Purchase projectors with LED bulbs, appropriate lumen levels and automatic shutoff	Minimal additional cost when purchasing new projectors. $1200 to $6000 per projector.	Up to 200 Watts per projector	.4 pounds of carbon per hour of projector use
Incorporate automatic controls such a timed "sleep" or auto-off modes	Negligible when purchasing new equipment.	Variable depending on use	Variable depending on use
Establish a policy that all computers, projectors and other technology equipment must be turned off when not in use	Negligible	Variable	Variable
Consider a student led program, like Friday Night Lights, to make sure computers and projectors are being turned off	None- depends on student volunteers	Variable	Variable

Purchasing

Recommendation	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Conduct a purchasing audit to identify most common purchases and which environmentally preferable purchasing criteria may be most appropriate	Low cost $1,000 to $3000	None for the audit itself	None for the audit itself
Establish purchasing criteria for ongoing consumables and durable goods based on the results of the purchasing audit	Variable depending on criteria	Variable depending on criteria	Variable depending on criteria
Continue the already established requirement for Energy Star labeled appliances and ensure that it applies to all appliance and equipment types that are Energy Star eligible	Negligible	Variable	Variable

Waste Management

Recommendation	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Move control of the recycling program under the Office of Campus Sustainability for better control and tracking.	Negligible	Variable	Variable
Continue to educate students, faculty and staff on what can and can't be recycled. Use waste audits to monitor performance and provide additional education.	Negligible	Variable	Variable
Keep an eye on recycling diversion rates delivered by your recycling provider. Consider more on campus oversight and involvement if waste diversion rates are low.	Low cost. $1,000 to $3,000 for an audit	Variable	Variable

Consider providing recycling options for electronics and sheet plastics.	Low cost. Depends on partnerships available	Variable	Variable
Investigate and consider implementing a reusable container option for food service providers on campus.	Low cost	Variable	Variable
Take the next step in the existing composting program and begin composting post-consumer produce either on-campus or through an off-campus partnership.	Moderate Cost- depends on types of organics chosen for composting	Variable	Variable

Carbon Sequestration and Offsets

Recommendation	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Calculate remaining annual carbon produced by campus energy use, waste production and transportation to understand how much carbon production needs to be offset to achieve carbon neutrality.	Negligible	None	Calculating existing impacts- no new impacts
Plant additional trees on campus	Approximately $400 per tree	None	48 pounds per tree per year
Purchase carbon offsets and/or RECs to offset annual carbon production. Ensure that offsets and RECs are purchased from reputable sources to ensure they are impactful.	$6.00 per 1,000 pounds of carbon offset	None	1,000 pounds of CO_2

<u>Energy Conservation Measures & Renewable Energy Recommendations</u>

Approach #1 – Jump Start (High Visibility for Students, Alumni and Visitors)

Recommendation	EUI	Projects	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Visitor Center-Place for new student's arrival to campus, visible, educational, low cost – 1,236 sqft	202 EUI	PV Array – Covered Parking and Walks 50% Geothermal/ Energy Recovery Ventilator LED Lighting Upgrade BAS Controls Pressure Testing Including Repairs Educational Storyboards	Construction Estimate: $75,000 PV for net zero: $37,500	Goal: 30 EUI Reduction: ~210,000 KBtu/yr ~62,000 KWH/yr ~$6,000/yr	<u>Site Energy:</u> If Renewable Energy is utilized: ~43 CO2 Equal Metric Tons ~46,500 pound of coal burned <u>Source Energy:</u> BGMU Purchased Energy: ~130 CO2 Equal Metric Tons ~136,500 pound of coal burned
Mileti Alumni Center-Demonstrate to alumni-(fund raising awareness) sustainable efforts – 15,964 sqft	110 EUI	Building Full Renovation (ceiling, flooring, FF&E) including: Geothermal/ Energy Recovery Ventilator LED Lighting Upgrade BAS Controls Pressure Testing Including Repairs Educational Storyboards PV Array - Overhangs and Entrances PV Array – Ground	Construction Estimate: $125/sqft $2,000,000 PV for net zero: $225,000	Goal: 30 EUI Reduction: ~1,275,000 KBtu/yr ~375,000 KWH/yr ~$36,000/yr	<u>Site Energy:</u> If Renewable Energy is utilized: ~275 CO2 Equal Metric Tons ~280,000 pound of coal burned <u>Source Energy:</u> BGMU Purchased Energy: ~800 CO2 Equal Metric Tons ~840,000 pound of coal burned

Jerome Library - Targets existing students -central and educational space – 193,865 sqft	98 EUI	Building Full Renovation (ceiling, flooring, FF&E) including: PV Overhand for Bike Storage and Covered Walkways and on Flat Roof Geothermal/ Energy Recovery Ventilator LED Lighting Upgrade BAS Controls Pressure Testing Including Repairs Educational Storyboards	Construction Estimate: $140/sqft $27,000,000 PV for net zero: $4,500,000	Goal: 35 EUI Reduction: ~12,233,000 kBtu/yr ~101,026 CCF/yr ~556,000 KWH/yr ~$53,500/yr Elec ~$38,000/ yr NG Total Savings: $91,500	Site Energy: If Renewable Energy is utilized: ~925 CO2 Equal Metric Tons ~417,000 pound of coal burned ~101,000 therms NG Source Energy: BGMU Purchased Energy: ~1,700 CO2 Equal Metric Tons ~1,250,000 pound of coal burned ~101,000 therms NG

Approach #2 - Demand Reduction and Renewable Energy

***** The best approach would be to install at the main substation. The 2nd and 3rd options may not do as much correcting since they would be on individual feeders on campus**

Recommendation	**Locations**		**Initial Financial Impact**	**Energy/Cost Reduction Impact**	**Carbon Reduction Impact**
Power Factor Correction Capacitor Banks (Auto/Multistage)	Load side of Utility substation.	Can only be utilized if BGSU managed.	$560k	$93k/yr based on new 0.98 PF	Limited
	Health and Human Services (New) and at Centrex 4160V Loop	Re-evaluate removed capacitor at Centrex. Replace with larger auto.	$640k	Max $62k/yr.***	Limited
	Ice Arena and CCP Transformers 480V		$320k	Max $31k/yr.***	Limited

Battery Storage	12470 Switch SW-5B feeding Ice Arena	Can be utilized with future PV project on building	$650k	No energy reduction. Peak reduction of 500kW. PJM modulation can boost savings. $100 to $215k annual savings.	Limited
	12470 Switch SW-00 feeding Stroh Center	Can be utilized with future PV project on building. Not recommended without PV.	$650k	No energy reduction. Peak reduction of 500kW. PJM modulation can boost savings. $100 to $215k annual savings.	Limited
15kW PV Canopy for Bus Stop Outside Centrex	Centrex	New switchboard located within the Centrex Building can easily handle new PV load	$60k	25,645 kW/ $2,474 per year	2 pounds of CO2 per kWh saved in consumption or production
5MW (or more) PV array via Power Purchase Agreement (PPA)	E Merry Avenue site		Just the loss of land for the array installation	$0.07 per kWh for consumed energy versus the $0.0965 currently paid	2 pounds of CO2 per kWh saved in consumption or production

Approach #3 – Building by Building (Target a 6% decrease per year to keep up with rising BGMU costs)

**** Top ECM of LED lighting and Top Renewable of Photovoltaics are shown in the tables below.**

Recommendation	EUI	Benchmark EUI	Projects	Initial Financial Impact	Energy/Cost Reduction Impact	Carbon Reduction Impact
Administration Building (Demo)	159	50				
Business Administration	124	60	LED Lighting Retrofit PV Array – Max Size of 168kW	$1 per sqft for LED tube replacement $106,485 $1.50 per watt $252,000	152,374 kWh/ $14,704 per year 214,239 kWh/ $20,674 per year	2 pounds of CO2 per kWh saved in consumption or production
Carillon Place	319	250	LED Lighting PV Array – Max Size of 67kW	$1 per sqft for LED tube replacement $19,073 $1.5 per watt $100,500	90,680 kWh/ $8,751 per year 85,467 kWh/ $8,247 per year	2 pounds of CO2 per kWh saved in consumption or production

CCP-1 (Chiller Plant)	1261	850				
Centennial Hall	97	55	LED Lighting PV Array – Max size of 213kW	$1 per sqft for LED tube replacement $142,758 $1.5 per watt $319,500	210,668 kWh/ $20,300 per year 270,218 kWh/ $26,076 per year	2 pounds of CO2 per kWh saved in consumption or production
Conklin	69	55	LED Lighting PV Array – Max size of 62kW	$1 per sqft for LED tube replacement $49,750 $1.5 per wall $93,000	76,265 kWh/ $7,360 per year 75,460 kWh/ $7,281 per year	2 pounds of CO2 per kWh saved in consumption or production
East Hall	152	60	LED Lighting PV Array – Max size of 42kW	$1 per sqft for LED tube replacement $45,552 $1.5 per watt $63,000	98,263 kWh/ $9,482 per year 53,504 kWh/ $5,163 per year	2 pounds of CO2 per kWh saved in consumption or production
Education Building	126	60	LED Lighting ** PV Array – Max size of 92kW	$1 per sqft for LED tube replacement $82,510 $1.5 per watt $138,000	263,766 kWh/ $25,453 per year 117,271 kWh/ $11,316 per year	2 pounds of CO2 per kWh saved in consumption or production
Eppler Center	82	60	LED Lighting PV Array – Max size of 381 kW	$1 per sqft for LED tube replacement $137,357 $1.5 per watt $571,500	247.495 kWh/ $23,883 per year 484,568 kWh/ $46,760 per year	2 pounds of CO2 per kWh saved in consumption or production
Falcon Heights	126	55	LED Lighting PV Array – Max size of 437 kW	$1 per sqft for LED tube replacement $195,632 $1.5 per watt $655,500	225,262 kWh/ $21,738 per year 555,188 kWh/ $53,575 per year	2 pounds of CO2 per kWh saved in consumption or production
Family & Consumer Science	197	60	LED Lighting PV Array – Max size of 25kW	$1 per sqft for LED tube replacement $17,750 $1.5 per watt $37,500	13,248 kWh/ $1,270 per year 32,375 kWh/ $3,124 per year	2 pounds of CO2 per kWh saved in consumption or production
Fine Arts	159	70	LED Lighting	$1 per sqft for LED tube replacement $108,901	201,018 kWh/ $19,398 per year	2 pounds of CO2 per kWh saved in consumption or production

Founders Quad	107	55	LED Lighting PV Array – Max size of 366kW	$1 per sqft for LED tube replacement $189,621 $1.5 per watt $549,000	323,439 kWh/ $31,212 per year 464,549 kWh/ $44,828	2 pounds of CO2 per kWh saved in consumption or production
Harshman Quad (Demo)	31	55				
Hayes Hall	172	60	LED Lighting PV Array – Max size of 50Kw	$1 per sqft for LED tube replacement $80,374 $1.5 per watt $75,000	410,109 kWh/ $39,576 per year 63,450 kWh/ $6.122 per year	2 pounds of CO2 per kWh saved in consumption or production
Ice Arena	319	200	LED Lighting PV Array – Max size of 939kW	$1 per sqft for LED tube replacement $93,372 $1.5 per watt $1,408,500	401,381 kWh/ $38,733 per year 1,596,768 kWh/ $154,088 per year	2 pounds of CO2 per kWh saved in consumption or production
Jerome Library	98	80	See “kick start” projects	n/a	n/a	
Kohl Hall	129	55	LED Lighting PV Array – Max size of 110kW	$1 per sqft for LED tube replacement $70,800 $1.5 per watt $165,000	101,518 kWh/ $9,796 per year 139.495 kWh/ $13,461	2 pounds of CO2 per kWh saved in consumption or production
Kreischer Quad	117	55	LED Lighting PV Array – Max size of 462kW	$1 per sqft for LED tube replacement $270,000 $1.5 per watt $693,000	424,671 kWh/ $40,981 per year 786,250 kWh/ $75,873 per year	2 pounds of CO2 per kWh saved in consumption or production
Life Science Building	140	60	LED Lighting PV Array – Max size of 98kW	$1 per sqft for LED tube replacement $126,300 $1.5 per watt $147,000	336.465 kWh/ $32,469 per year 124,378 kWh/ $12,002 per year	2 pounds of CO2 per kWh saved in consumption or production
Math Science Building	164	60	LED Lighting PV Array – Max size of 168kW	$1 per sqft for LED tube replacement $113,204 $1.5 per watt $252,000	252,125 kWh/ $24,330 per year 214,239 kWh/ $20,674 per year	2 pounds of CO2 per kWh saved in consumption or production

McDonald Quad	138	55	LED Lighting PV Array – Max size of 488kW	$1 per sqft for LED tube replacement $248,149 $1.5 per watt $732,000	255,226 kWh/ $24,629 per year 619,351 kWh/ $59,767 per year	2 pounds of CO_2 per kWh saved in consumption or production
McFall Center	136	50	LED Lighting PV Array – Max size of 32kW	$1 per sqft for LED tube replacement $42,679 $1.5 per watt $48,000	72,995 kWh/ $7,044 per year 40719 kWh/ $39,293 per year	2 pounds of CO_2 per kWh saved in consumption or production
Memorial Hall	116	60	LED Lighting PV Array – Max size of 175kW	$1 per sqft for LED tube replacement $74,872 $1.5 per watt $262,500	73,234 kWh/ $7,067 per year 222,075 kWh/ $21,430 per year	2 pounds of CO_2 per kWh saved in consumption or production
Mileti Alumni Center	109	50	See “kick start” projects	n/a	n/a	
Moore Musical Arts	156	70	LED Lighting PV Array – Max size of 437kW	$1 per sqft for LED tube replacement $122,175 $1.5 per watt $655,500	226,419 kWh/ $21,849 per year 555,188 kWh/ $53,575 per year	2 pounds of CO_2 per kWh saved in consumption or production
Oaks Dining Hall	403	250	LED lighting PV Array – Max size of 115kW	$1 per sqft for LED tube replacement $32,263 $1.5 per watt $172,500	110,784 kWh/ $10,691 per year 143,500 kWh/ $13,847 per year	2 pounds of CO_2 per kWh saved in consumption or production
Offenhauer	137	55	LED Lighting PV Array – Max size of 105kW	$1 per sqft for LED tube replacement $237,440 $1.5 per watt $157,500	407,255 kWh/ $39,310 per year 133,626 kWh/ $12,894 per year	2 pounds of CO_2 per kWh saved in consumption or production
Olscamp Hall	123	60	LED Lighting PV Array – Max size of 240kW	$1 per sqft for LED tube replacement $94,758 $1.5 per watt $360,000	198,774 kWh/ $19,182 per year 304,846 kWh/ $29,417 per year	2 pounds of CO_2 per kWh saved in consumption or production

Overman	175	70	LED Lighting PV Array – Max size of 142kW	$1 per sqft for LED tube replacement $93,780 $1.5 per watt $213,000	214,588 kWh/ $20,708 per year 180,864 kWh/ $17,453 per year	2 pounds of CO2 per kWh saved in consumption or production
Physical Science Lab	255	70	LED Lighting PV Array – Max size of 10kW	$1 per sqft for LED tube replacement $55,463 $1.5 per watt $15,000	235,006 kWh/ $22,678 per year 13,277 kWh/ $1,281 per year	2 pounds of CO2 per kWh saved in consumption or production
Psychology Building (Demo)	225	70				
Sebo Center	110	60	LED Lighting PV Array – Max size of 50kW	$1 per sqft for LED tube replacement $44,056 $1.5 per watt $75,000	142054 kWh/ $13,708 per year 63,450 kWh/ $6,122 per year	2 pounds of CO2 per kWh saved in consumption or production
Shatzel Hall	92	50	LED Lighting PV Array – Max size of 75kW	$1 per sqft for LED tube replacement $40,702 $1.5 per watt $112,500	51,278 kWh/ $4,948 per year 95,175 kWh/ $9,194 per year	2 pounds of CO2 per kWh saved in consumption or production
Stadium	139	60	LED Lighting	$1 per sqft for LED tube replacement $90,505	123,912 kWh/ $11,958 per year	2 pounds of CO2 per kWh saved in consumption or production
Visitor Information Center	201	50	See “kick start” projects	n/a	n/a	
Stroh Center	56	50	LED lighting PV Array – Max size of 625kW	$1 per sqft for LED tube replacement $142,848 $1.5 per watt $937,500	208,774 kWh/ $20,147 per year 793,125 kWh/ $75,536 per year	2 pounds of CO2 per kWh saved in consumption or production
Student Recreation Center	185	85	LED Lighting PV Array – Max size of 812kW	$1 per sqft for LED tube replacement $182,000 $1.5 per watt $1,218,000	416,524 kWh/ $40,195 per year 1,031,063 kWh/ $99,497 per year	2 pounds of CO2 per kWh saved in consumption or production
Student Union	60	50	LED Lighting PV Array – Max size of 275kW	$1 per sqft for LED tube replacement $222,569 $1.5 per watt $412,500	494,499 kWh/ $47,816 per year 348,642 kWh/ $33,643 per year	2 pounds of CO2 per kWh saved in consumption or production

Technology Building	51	50	LED Lighting PV Array - Max size of 120kW	$1 per sqft for LED tube replacement $76,131 $1.5 per watt $180,000	111,529 kWh/ $10,763 per year 153,026 kWh/ $14,767 per year	2 pounds of CO2 per kWh saved in consumption or production
Williams Hall	67	50	LED Lighting PV Array – Max size of 81kW	$1 per sqft for LED tube replacement $35,950 $1.5 per watt $121,500	39,990 kWh/ $3,859 per year 103,106 kWh/ $9,949 per year	2 pounds of CO2 per kWh saved in consumption or production
Wolfe Center	63	50	LED Lighting PV array – Max size of 206kW	$1 per sqft for LED tube replacement $119,325 $1.5 per watt $309,000	105,642 kWh/ $10,195 per year 262.540 kWh/ $25,335 per year	2 pounds of CO2 per kWh saved in consumption or production

Existing Energy Considerations

III. Bowling Green State University Existing Energy Considerations

To properly coordinate a sustainability plan, the utility landscape for the end user needs to be fully understood. How utilities are purchased and produced dictates paybacks and highlights areas for the largest improvement with respect to carbon reduction. This understanding helps to inform the rest of the master plan since it is the energy consuming systems on Campus and the costs of consumption that will have the greatest impact on potential recommendations. Bowling Green State University (BGSU) purchases power through Bowling Green Municipal Utilities (BGMU) and natural gas on the open market through EDF Energy Services. This section will go through the existing relationships between the University and Its energy providers and look for opportunities that could potentially provide a win-win scenario for the University and the Utility providers.

Electric Utility Discussion:

The electric service is unique for this project in that BGSU cannot go out onto the open market to purchase power from a supplier at its discretion. The City of Bowling Green and all of their residents are required to purchase energy from BGMU. This will be an important issue to keep in mind throughout this study as future projects reduce energy on campus. Since the City and its residences share the responsibility as a stakeholder in BGMU, any major reduction in consumption at BGSU will proportionately affect the rest of the customer base. In addition to this situation, BGSU has been historically the largest user for the utility provider (BGMU) consuming around 526,285MWh making the campus 13.03% of BGMU's total sales.

Another thing issue that will carry through this study is that BGMU has recently increased its rates due to increased supply costs. A 25% rate increase went into effect in 2014 that is going to be spread out over five years. That rate history and expected effect on the electric spend are shown below in Table 1.

Year	Demand Rate ($/kVA)	Consumption Rate ($/kWh)	Blended Rate ($/kWh)	Rate Increase	Electric Spend
2013	$9.70	$0.05335	$0.08456		$ 6,088,018
2014	$16.00	$0.06743	$0.09029	7%	$ 6,176,555
2015	$16.00	$0.06743	$0.09452	5%	$ 6,481,114
2016*	$16.00	$0.06743	$0.09925	5%	$ 6,805,170
2017*	$16.00	$0.06743	$0.10421	5%	$ 7,145,428
2018*	$16.00	$0.06743	$0.10942	5%	$ 7,502,700
2019*	$16.00	$0.06743	$0.11489	5%	$ 7,877,835

Table 1. BGMU Large Power Service Rate Schedule

These rates will significantly affect the utility budget for BGSU. By taking a “do nothing” approach to energy consumption, BGSU will have to increase their utility budget by more than **$1,000,000** over the next five years, just to keep up with the future “planned” rate increases. These supply costs are being felt throughout the region, however they are hitting BGSU harder than most. Since January 2013, the average commercial electric rate in Ohio has increased by 7% and the average industrial electrical rate has increased by 12%. In the same time frame, BGSU’s electric rate has increased by 20%. These rate comparisons are shown in Figure 1.

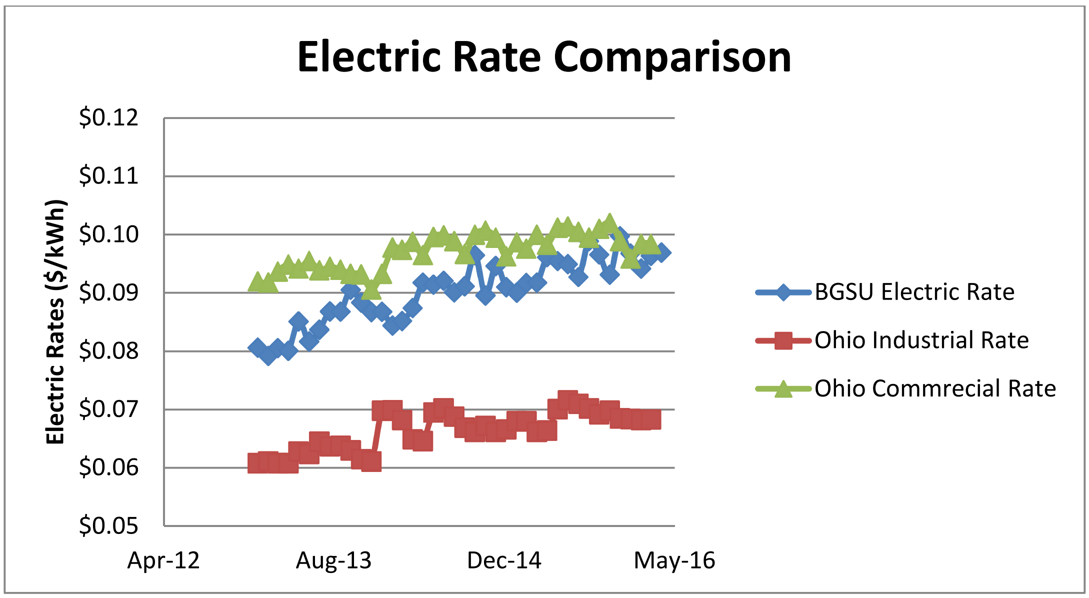


Figure 1. Ohio electric rate comparisons from January 2013 - March 2016

A majority of the electric supply cost increases are based on infrastructure costs during high demand periods in the electric grid. These demand periods could be related to extreme heat conditions in the summer or extreme cold conditions in the winter. As a utility provider, the infrastructure has to be sized to handle these peaks, even though these events are not the norm. The economic burden of this infrastructure increase has to be passed onto its customer base. This infrastructure includes power generation stations, transmission systems and distribution substations. This infrastructure is put under the most strain under high load conditions and therefore electric utility companies have started to charge for this electric demand to more accurately reflect their true costs. An example of this increase in supply cost is shown in Figure 2. One of the many sources that BGMU purchases power from is the PJM regional transmission organization. PJM is a competitively bid whole sale electricity market that serves much of the Eastern United States. During periods of high demand, the cost of power can increase by 500%. Figure 2 shows one such event that occurred during a cold streak in February of 2015.

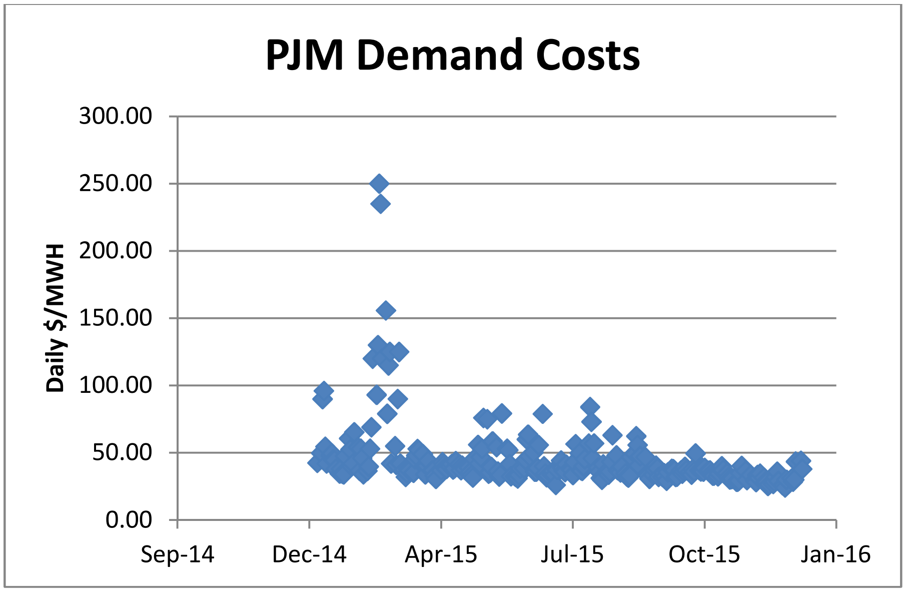


Figure 2. PJM Daily Electric Supply Costs for 2015

These costs are passed along to end users in the form of demand charges. This change in rate is being seen across the electric utility market as these supply costs are becoming greater than fuel costs. Many demand rates are increasing to as much of 50% percent of the overall electric bill. The 2014 BGMU rate change followed this trend and increased the existing demand cost by 65%. This changed the electric cost breakdown as shown in Figure 3.

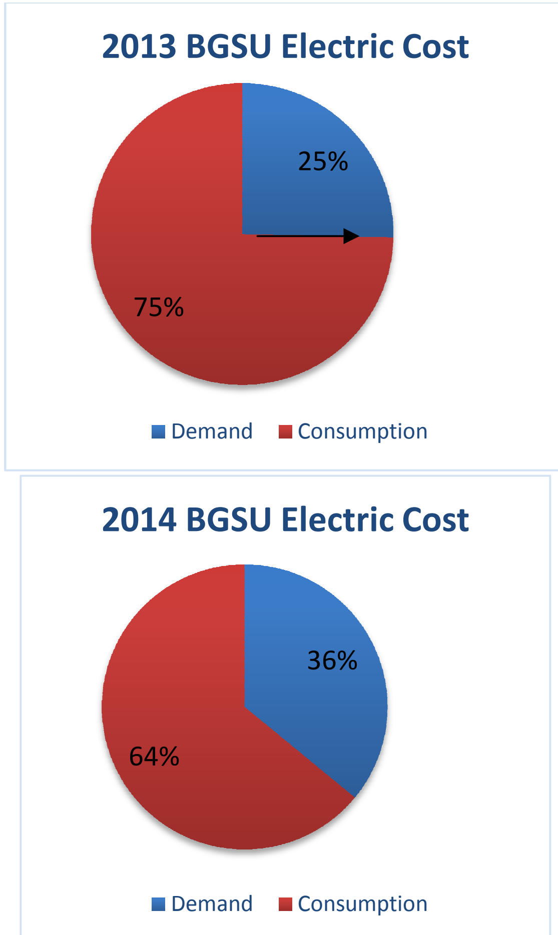


Figure 3. BGSU's change in electric cost breakdown between 2013 and 2014

As seen in Figure 3 above, prior to 2014, only 25% of the electrical charges for BGSU were related to demand charges. After the rate increase in 2014, this number jumped to 36%. This is above the normal consumption charges that the University would typically pay for. This charge is paying for the assurance that the utility will be able to provide power on a peak condition day.

Electric Utility Recommendations:

As the University Stakeholders know, the existing situation with the electric utility provider has made decisions more difficult. As a result of this study, we have spent most of our time looking for Win – Win energy savings that can meet the needs of BGSU but also BGMU.

To effectively reduce utility spend, as one of the largest users in the BGMU system, BGSU will need to reduce its electric consumption in way that also reduces BGMU's costs. This can be done in three ways, by reducing demand, increasing load factor and increasing power factor. Some of these solutions are already being considered and implemented at the University and others are not.

1) Demand Reduction

Since the 2013, BGSU has been making strides by reduced their billed electric demand by 10%. Figure 4 shows this reduction in monthly demand over the course of a calendar year.

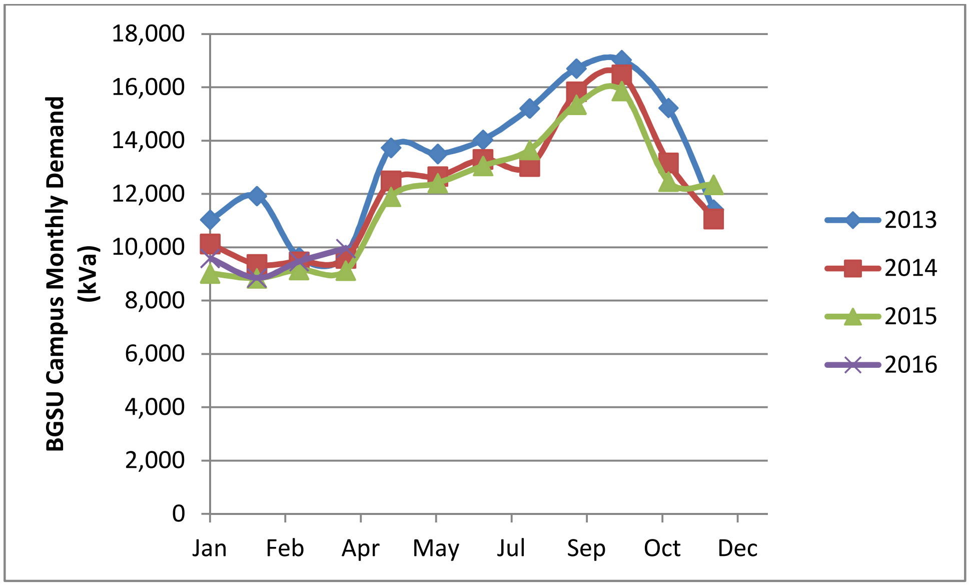


Figure 4. BGSU Monthly Campus Demand 2013-April 2016

Figure 4 focuses on the monthly peak demands, however to truly understand how to address demand costs, a look at the annual demand is necessary. A load duration curve is used in electric power generation to illustrate the relationship between generating capacity requirements and capacity utilization. Utility providers like to see as flat a profile as possible. This allows them to properly predict and supply power at a steady rate. A load duration curve for BGSU is shown in Figure 5.

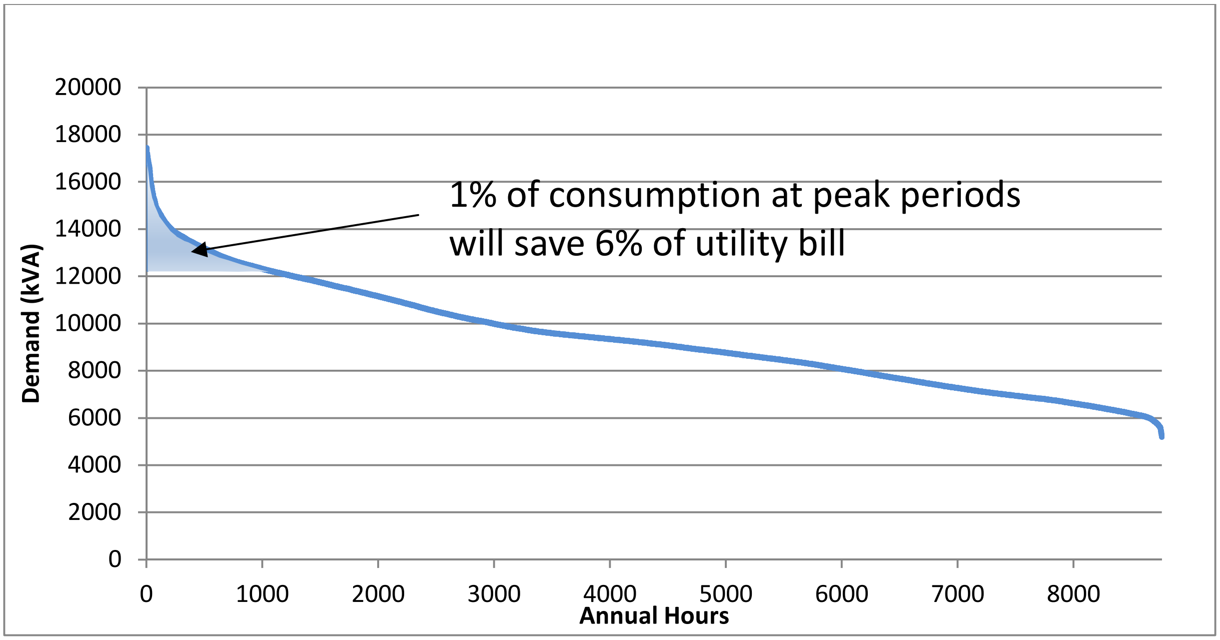


Figure 5. BGSU Load Duration Curve

The highlighted area in Figure 5, shows a steep climb in demand for a small percentage of annual hours. By eliminating the top 1% of consumption at peak periods, a 6% savings would be realized on the electric bill. This is a savings that would also help BGMU reduce their supply costs. Plotting the campus demand values against outside air temperature, as seen in Figure 6, gives an idea on what is driving the demand in this top 1% of the load duration curve.

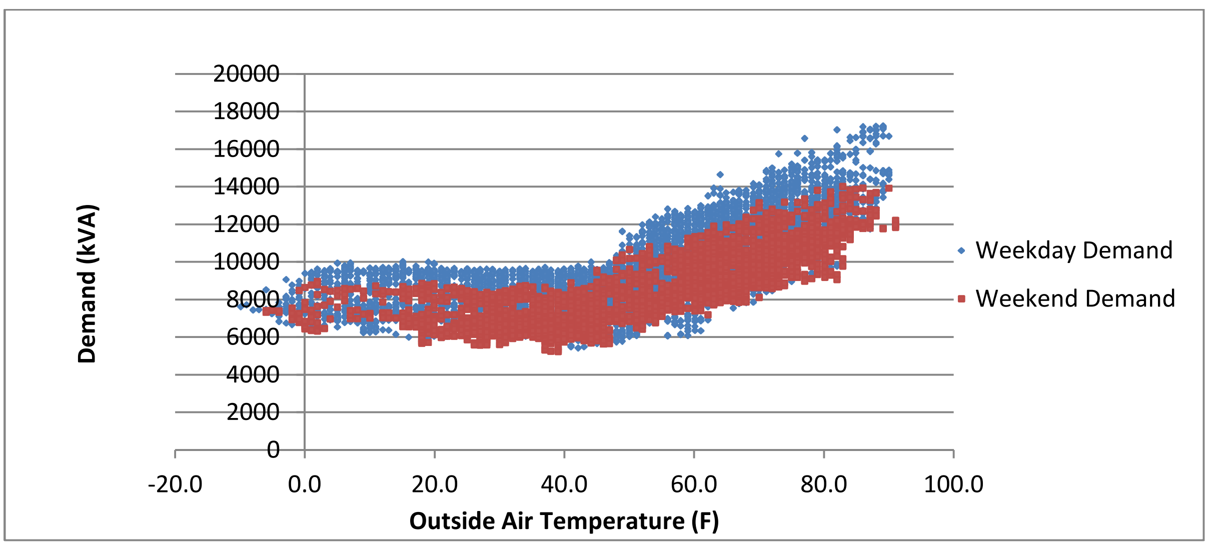


Figure 6. BGSU Campus Demand versus Outside Air Temperature for 2015

This plot shows that BGSU is peak demand is completely cooling dependent. Any conservation measures that can reduce the load in high outside air conditions would help reduce the demand conditions.

The most popular strategies to accomplish this are:

- *Ice storage*
- *LED lights*
- *Demand Control Ventilation*
- *Building Automation Demand Sequences*
- *Chilled water improvements*
- *Combined Heat and Power*
- *Gas Powered Chiller*

These strategies will be discussed in depth in the remainder of this report.

2) Increasing Load Factor

As discussed previously, a flat load factor is advantageous to the utility supplier for multiple reasons. This accomplished in two ways:

1) Reducing the peaks through demand reduction strategies. These strategies are listed above.
2) Increasing electric consumption in low load conditions.

Increasing electric consumption in low load conditions seems counterintuitive to saving energy and increasing sustainability. When you look at Figure 6, this increase needs to be done by increasing electric consumption in colder temperatures. By adding geothermal heat pumps, the most efficient HVAC system, it helps reduce overall energy usage while simultaneously increasing electric used during the heating season. The net effect of this conservation measure is a win-win for BGSU and BGMU. In preliminary discussions with BGMU, there is the possibility of a Geothermal rate structure being created that would help the University and all Bowling Green residents that decide to pursue geothermal as a heating and cooling strategy.

3) Increasing Power Factor

The last win-win savings approach is increasing the power factor for the campus. Power factors below 1.0 force a utility to generate more than the minimum volt-amperes necessary to supply the real power used by the customer (watts). This increases generation and transmission costs. BGSU has been making strides in this area for the past few years by adding capacitor banks on the secondary side of the 480 V systems throughout the campus. This savings approach is discussed more in depth in the remainder of the report.

<u>Natural Gas Utility Discussion:</u>

In contrast to electric supply, BGSU has the capability to buy natural gas on the open market. Due to the quantity purchased annually, BGSU has secured a very favorable rate. This rate is on average almost half the average rate for Ohio industrial and commercial clients. This rate comparison is shown in Figure 8.

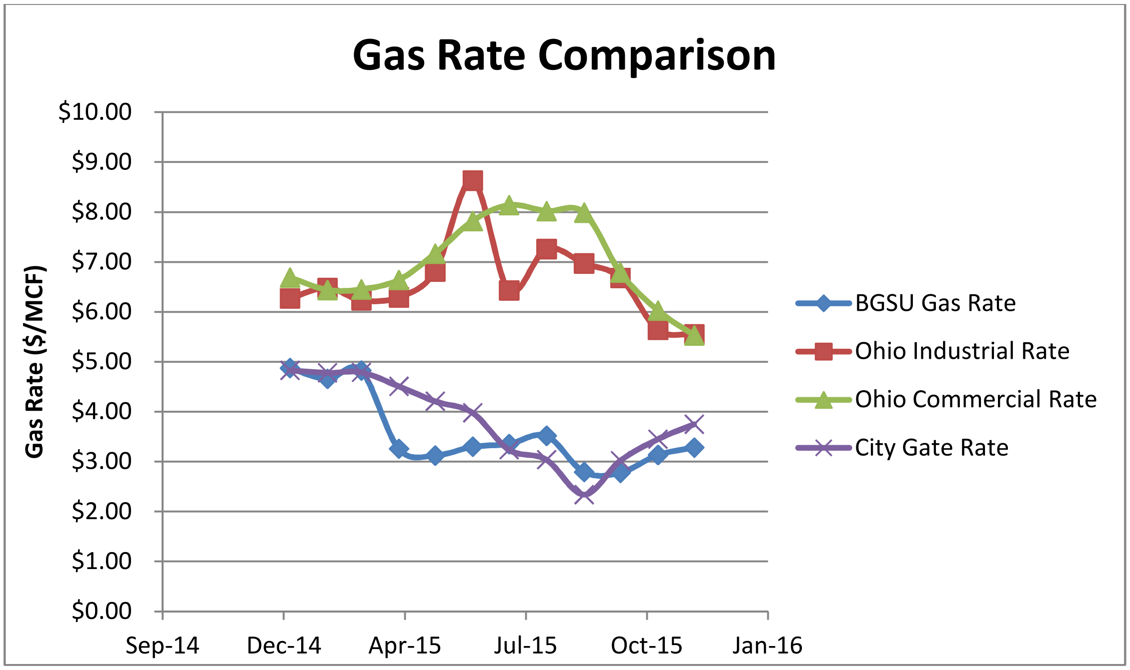


Figure 7. Gas Rate Comparison for 2015

This low gas rate is seen even lower when compared to the effective electric rate. When compared using the same energy units, Table 2 shows how much cheaper per unit of energy gas is than electric.

Year	Gas Rate ($/MMBtu)	Electric Rate ($/MMBtu)
2015	$3.74	$27.70

Table 2. Gas and Electric Energy Cost Comparison

Natural Gas Utility Recommendations:

In contrast to electric supply, BGSU has the capability to buy natural gas on the open market. Due to the quantity purchased annually, BGSU has secured a very favorable rate. There are multiple ways to take advantage of this rate discrepancy. Any opportunity to transfer electric loads to natural gas loads will reap the benefit of these savings. These opportunities include:

- Combined Heat and Power
- Gas powered chillers

Any of these opportunities would need to be developed in conjunction with both the gas and electric provider. These strategies will be discussed in depth in the remainder of this report.

Policy & Behavior

IV. Policy and Behavior

BGSU has a longer and more extensive track record of implementing policies around sustainability than most other universities in this region. The University formalized its efforts around sustainability in 2008 through the creation of the Office of Campus Sustainability. The stated goals of this department are emissions reduction, waste reduction and resource conservation, and education, awareness and outreach. Through the course of its eight-year history, the Office of Campus Sustainability has instituted many successful initiatives including the creation of a Climate Action Plan, a Green Office Certification Program, Green Game Day, Friday Night Lights and more. This section will look at ways in which the initiatives that have already been instituted can be enhanced as well as suggesting additional policy and behavioral opportunities for carbon reduction.

New Construction and Renovation Standards Overview

BGSU currently requires all new construction on campus to achieve LEED Silver Certification under the current, LEED 2009 Rating System. The university has also applied this standard to at least some major renovation projects such as the newly renovation Architecture and Environmental Design building which is currently pursuing LEED Certification. A logical step in strengthening building design and construction requirements seems to be requiring the next highest LEED certification, “Gold”, instead of the current requirement for “Silver” level certification. However, the newest version of the LEED Rating Systems, LEED v4, is set to become the only available rating system for use as of November 1, 2016. LEED v4 is already more stringent in all categories than LEED 2009. Consequently, keeping the requirement for LEED Silver in the new LEED v4 Rating System will be just as impactful as a change from LEED Silver to LEED Gold in the current (soon to retire) LEED 2009 Rating System. Increasing the requirement to LEED Gold in LEED v4 may be an eventual step, but starting with maintaining the LEED Silver requirement using the new LEED v4 Rating System is the appropriate next step in increasing building sustainability without making the requirement unattainable or economically infeasible.

While LEED is a terrific measure of overall building sustainability, it is possible to achieve most of your points in the LEED rating system for strategies that have little to nothing to do with energy efficiency or carbon reduction. In addition to an overall requirement for LEED Certification, it would be extremely helpful to enhance current requirements for energy performance for new construction and major renovation projects. These current energy reduction targets are 20% better than ASHRAE 90.1 on new construction and 15% better on renovations. BGSU may choose to format specific energy reduction requirements in one of two ways:

1. Require an overall reduction in energy use as demonstrated through the results of a building energy modeling process. The percentage reduction of energy use should be benchmarked against the current version of ASHRAE 90.1 standard which is the baseline for building code energy requirements as it is a familiar standard that all building design teams are familiar with. It will be up to BGSU to determine what the correct percentage reduction to require should be based on typical project budgets and energy consuming system preferences. A 30% reduction for new construction projects and a 25% reduction for renovation projects

would be a good requirement to evaluate as a starting point as it is aggressive enough to result in significant reductions in energy use but not so aggressive that economic feasibility will become an insurmountable hurdle.

2. Require specific energy use efficiencies for individual building systems such as HVAC, lighting and building envelope insulation. Again, the current version of ASHRAE 90.1 should be the standard that reduction is benchmarked against. Evaluating individual systems instead of the building will give a less holistic view of energy use than a full energy model, however, this more prescriptive approach may be easier for design teams to follow and implement. Similar to setting an overall requirement for energy efficiency, BGSU will need to evaluate what efficiency requirements are financially feasible while still providing desired impact. A requirement for HVAC systems that are 30% more efficient than required by ASHRAE 90.1, Lighting Power Densities that are 30% lower than required by ASHRAE 90.1 and building insulation R values that are 30% higher than required by ASHRAE 90.1 would be a good starting point for evaluation.

The above two methods for requiring energy efficiency performance are a great step in trying to control energy use during the design stage of a project. Energy use projections, however, are never perfect. A process should be created to document actual building energy performance one year after a construction or renovation process is complete, and compares it to the projected energy use reduction. This process will help hold the design team accountable as well as helping understand if buildings are performing dramatically different than projected which may lead to the discovery of a disconnect in how the project was designed and how it is actually being used.

LEED Certification and energy efficiency requirements for new buildings and major renovations are the heart of the impactful requirements for building design and construction. However, the impact of adding requirements for building controllability should also not be overlooked. Occupancy sensors are already required in many space types by current building code. Additional energy use reductions may be achievable, though, by setting a requirement for use of a standard Building Automation System across campus and/or requiring additional methods of automatic control such as integrated daylight harvesting.

In addition to energy efficiency targets, it is important for BGSU to institute requirements for performing lifecycle cost analyses on energy consuming systems that are proposed for new construction and renovation projects. Performing lifecycle analyses allows the project team to look not just at the first cost of a system, but also the ongoing operations and maintenance cost and make an informed decision on the lifetime financial and energy cost. As a start, BGSU may want to require that lifecycle analysis be performed on at least three HVAC system options for each project. The lifecycle analysis requirement can also be extended to lighting and hot water heating systems as well as building envelope designs for insulation values.

As a final, more isolated requirement, BGSU should put a policy in place to require that all LED lighting installed on new projects and renovations/replacements be DesignLights Consortium (DLC) qualified. Use of DLC qualified LED products help ensure the quality, dependability and energy performance.

New Construction and Renovation Standards Recommendations

- Maintain a requirement for new construction to achieve a LEED Silver or better certification level in the new LEED v4 rating system.
- Expand LEED Silver or better certification requirement for major renovations that include HVAC system replacement.
- In addition to the overall requirement for certification level, specific requirements for energy use improvement should also be added. The requirements could be in the form of a required reduction in overall energy use demonstrated through an energy model or through required improvement in energy performance for individual components such as a requirement for a 30% improvement in HVAC system equipment efficiency and lighting power density over what is required by the current version of ASHRAE 90.1.
- Establish a process for comparing actual energy performance of construction and renovation projects to projected energy performance.
- Create a standard for the type of Building Automation System and level of controllability required for all new and replaced HVAC systems. This standardization will help with data reporting and monitoring.
- Require that lifecycle assessment analysis be conducted on energy consuming components proposed for new construction and renovations, especially HVAC system options
- Require LED lighting to be DLC qualified

Building Scheduling and Operation Overview

Policies that govern the way in which campus buildings are operated and when they are used can have a dramatic impact on energy use. BGSU has already instituted some policies in this area, such as only operating one dining hall during Summer Semester. Additional impacts can be realized, though, a combination of large moves like fully shutting down additional buildings that are lightly or infrequently used during summer session and smaller scale policy initiatives such as setting a standard for acceptable temperature settings in all buildings across campus.

While the decision to close a specific building for the summer is likely to be a politically sensitive issue, a good, objective, starting point to identify which buildings may be prime targets for summer closure is to look at the Energy Use Intensities (EUIs) for all of the buildings across campus. Those will the highest EUIs demonstrate the opportunities for realizing the greatest energy savings from a summer shutdown. These EUIs can be viewed in conjunction with a schedule of department and programs that need space over the summer to look for logical overlaps of high energy use and lower demand spaces. Residence Halls may be particularly good targets for summer shut down with only the most energy efficient residence halls being used to meet summer program needs. A chart of the EUIs for most of the campus residence halls is included below to quickly illustrate how much energy each residence hall uses each month and, therefore, how much potential for savings there is by closing a hall during the summer.

Figure 4.1: Campus Residence Hall Energy Use

Building	EUI	Square Footage	Full Building Energy Use (Per Month)
Centennial Hall	97	142,758	1,153,960 kBtu
Conklin North	69	49,750	286,062 kBtu
Founders Hall	107	189,621	1,690,787 kBtu
Kohl Hall	129	70,800	761,100 kBtu
Kreischer Quadrangle	117	275,000	2,681,250 kBtu
McDonald Hall	138	248,149	2,853,713 kBtu
Offenhauer Towers	137	237,440	2,710,773 kBtu

Additionally, buildings with HVAC systems that are able to be "zoned" for partial occupancy may be more desirable for summer use if only a portion of a building is needed to meet demand. In order to incentivize departments to close or partially close buildings during the summer, a policy for sharing the utility savings derived from the closure with the department that agreed to it may be wise to investigate.

On a less dramatic scale, building scheduling policies for typical weeks during school semesters may also be able to be implemented to reduce energy use. It is very typical for university faculty to have preferred class times that often leave buildings under occupied at certain times such as Monday mornings and Friday afternoons. In many cases, these under-occupied spaces may still be fully conditioned during these times when the spaces are sitting empty due to building automation system schedules. Finding ways to make building occupancy more consistent and aligned with building control schedules would be beneficial in overall building energy use.

Setting standards for Building Automation Systems and building controls for new construction and renovations was discussed in the section above, but these principles can also be implemented in existing buildings whether they are being renovated or not. While automatic control systems are relatively easy to implement in new projects, they may be very difficult or expensive to integrate into existing buildings. In these cases, it may be necessary to rely on and expand existing programs like Friday Night Lights which focuses on turning off lights in academic buildings on Friday nights. It may be possible to expand this program to more nights of the week by designating groups of students to act as "light monitors" for specific buildings that are most likely to have lights left on after occupied hours. A practice should also be established to ensure that all buildings that will be lightly occupied or even vacant over the summer and school breaks be swept at the beginning of those periods to turn off lights. Finally, training and performance accountability for turning off lights after a space is vacated should be implemented amongst all university maintenance and custodial staff.

As can be imagined, implementing the strategies presented above will require coordination and agreement among many different departments on campus. In order to facilitate this process and create more cohesive plans, it may be advisable to create a more centralized approach to energy management across campus. This would allow the creation and implementation of more centralized and consistent policies around energy use. Additionally, a central control mechanism would allow for the creation of a system under which financial savings derived from energy conservation can be directly feed back into additional energy efficiency projects and strategies. This would ensure that a culture of prioritizing energy efficiency is created and that it becomes self-sustaining through its own realized savings.

A final strategy worth mentioning is a move away from traditional, individual faculty offices toward smaller, more flexible shared workstations. Faculty office spaces represents a large amount of square footage across campus and with recent moves towards a more mobile society, these traditional offices are often being used less and less, especially by younger faculty members. One 120 SF office can easily be replaced by an open office environment that serves 2-3 people in the same amount of square footage. Reducing square footage inherently reduces energy use. If a mid-range energy use of 55 kBtu/sf/yr is assumed, this translates into 16.1 kWh/sf/year. If a typical office is 120 SF, that is 322 kWh per year. At your current blended electric rate of $0.09925, that translates into an energy cost of approximately $31 per year per office. That may not seem like a significant number, but if the total number of offices on campus can be cut in half or by two thirds, it’s a number that will add up very quickly. Moving from private offices to shared workstations across campus is certainly a daunting task. Small moves like revising new faculty contracts to provide a “work space” instead of an “office” and creating incentives for existing faculty who are willing to move to shared work spaces would be effective first steps in a long-term change.

Building Scheduling and Operation Recommendations

- Consider creating a centralized approach to energy management across campus. This may necessitate the creation of an energy services group.
- Look to reinvest savings derived from energy use reduction directly into additional energy reduction strategies to continue feeding future reductions.
- Identify buildings that are good candidates for being shut down over the summer through an analysis of high EUI buildings and what types and number of spaces are needed to meet program and department needs. Create incentives for departments to accommodate summer shutdowns through shared savings.
- Establish a standard for acceptable thermostat temperature settings across campus. For instance, thermostats should be set between 68 and 71 in the winter and between 73 and 75 in the summer.
- Evaluate class scheduling to try to make space use as consistent and regular as possible and make sure BAS schedules are synced with building use schedules.
- Expand programs like Friday Night Lights where students proactively help in energy use reduction
- Provide training and expectations for university maintenance and custodial staff to turn off lighting when they leave a space
- Move from private offices for all or some faculty through faculty contract revisions and/or incentives, such as new technology or enhanced break room spaces, for faculty members who agree to shared work areas

Vehicles and Commuting Overview

As indicated by the BGSU Greenhouse Gas Inventory completed in 2013, campus commuting accounts for 14% of the overall campus greenhouse gas emissions, which is a significant area where reductions can be made. There are also additional emissions from vehicles used for campus services such as maintenance. BGSU has made several strides in this area including the creation of the shared Orange Bike Program, BGSU shuttle service including some hybrid buses, and some strides in purchasing more fuel-efficient vehicles for university employee use.

The easiest to control actions to reduce vehicle emissions are clearly in the area of vehicles that the university itself purchases. For example, policies can and should be created to require all future busses purchased by the university to be hybrid or alternative fuel. Similarly, specific policies that set fuel efficiency requirements for all other university purchased vehicles should be created. The American Council for an Energy-Efficient Economy's (ACEEE) "Green Score" rating system would be a good basis for setting a standard that can be used for selecting vehicles to be purchased campus wide. The Green Score system takes into account four criteria: tailpipe emissions, fuel-economy, vehicle mass and battery mass. Each model year, all common vehicle makes are assigned a "Green Score" based on these four aspects. A score of 40 or higher is generally considered to be an environmentally friendly choice and would be a good requirement to set. While hybrids and alternative fuel vehicles are most likely to achieve a score of 40 or higher, small vehicles and those with advanced combustion engine systems often comply as well. A standard could also be set to require all grounds and maintenance vehicles such as golf carts, gators and some lawn maintenance trimmers and equipment to be electric instead of gas powered.

Another straightforward method for reducing vehicle emissions is to establish and enforce a no-idle policy for all vehicles on campus and all university owned vehicles whether they are on or off campus. Simply turning off a vehicle that is stationary is an easy way to reduce emissions and improve air quality on campus. There are many outdated ideas that restarting a vehicle's engine uses more fuel than letting the vehicle idle. With modern vehicles, though, that is simply not the case. For most vehicles, idling the engine for more than 10 seconds results in the use of more fuel than restarting the engine. Most institutions that establish ant-idling policies require that all gas or diesel powered passenger vehicles and light trucks are not allowed to idle for more than 30 seconds. Larger diesel powered vehicles are typically given a longer acceptable idling period of up to 3 minutes.

In order to fully identify the strategies that would be most effective in reducing emissions from student, faculty and staff commutes, a commuting audit needs to be conducted in order to understand who, when, where and how people are commuting to and around campus. This audit can be as simple as an electronic survey, but it should be distributed as widely as is practical to ensure that results are as comprehensive as possible. Once the survey as complete, the results can help BGSU prioritize policies and incentives. It is likely that there is the most potential for impact in reducing single occupant passenger vehicle commuting, so the survey should be formatted specifically help identify what would be the most effective ways to encourage these single occupant commuters to ride public transit, consider walking or biking, or participate in carpooling or ridesharing. Consider including questions on the survey about what sort of incentives, such as reduced parking prices or dedicated "preferred" parking spaces in desirable locations would be necessary to create real change. Questions could also be included around how or if technology such as carpooling software and apps like Zimride could be utilized to improve options for ridesharing on and around campus.

In addition to encouraging carpooling through financial incentives and preferred parking spaces, policies could also be established to encourage commuters to drive more environmentally friendly vehicles. Just like setting a minimum Green Score for university vehicle purchases, a Green Score could be identified that would make owners of environmentally friendly vehicles eligible for reduced parking rates, priority in parking area selection and/or desirable "preferred" parking spaces around campus. Providing electric vehicle charging stations at regular intervals around campus is also a common and potentially effective method for encouraging electric vehicle use through increased convenience.

Vehicles and Commuting Recommendations

- Establish a minimum "Green School" for all university purchased vehicles
- Require all new university purchased buses to be hybrid or alternative fuel
- Require new grounds and maintenance vehicles to be electric powered
- Establish and Enforce a campus anti-idling policy
- Conduct a commuting audit to identify who, when where and how people are commuting on and around campus
- Explore incentives for encouraging carpooling and use of environmentally preferable vehicles such as reduced parking rates, priority parking selection and/or "preferred" prime parking spaces around campus
- Investigate carpooling and ridesharing technology such as Zimride
- Provide electric car recharging stations around campus to make driving an electric vehicle convenient

Technology Management Overview

Technology is a prime component of today's connected classroom environments. Computers, projectors, and other technology components, however, can be very energy use intensive and also have a tendency to be left powered on even when not in use. The two primary strategies that can be used to reduce energy use for technology are to source more efficient equipment and to ensure equipment is turned off through automatic controls and/or behavioral policies.

Laptop computers are, in general, much more energy efficient than desktop computer systems. A typical laptop uses about 80% less energy than a desktop computer system. In addition to operating on much less power, laptops typically also do not continue to draw power if they are turned off but still plugged in. Desktop computers, conversely, continue to draw about six watts of power per hour even if they are turned off. This phantom, or vampire, power use even when the computer is off can add up significantly. Establishing purchasing policies that give preference to purchasing laptops instead of desktop computers can result in real energy savings. Each desktop that is replaced with a laptop will save approximately $55 per year in energy use.

A related issue to the high power draw of desktop computers is the existence of computer labs on campus. Computer labs are quickly become a relic of past times when technology was less ubiquitous. There may still be a few logical applications for computer labs such as for programs that require the use of very specialized or expensive software, but generic, general use computer labs are becoming much less relevant as nearly all students have access to personal computers. Computer labs tend to utilize desktop computer systems that are energy inefficient and also have high air conditioning loads due to the heat the computers produce. All computer labs on campus should be evaluated to understand whether or not they are still necessary and eliminated if found to be irrelevant.

Projectors are the other primary contributor to technology energy use. Thankfully, newer projectors use LED bulbs that are much more efficient than older incandescent projector lamps. There are three things to keep in mind in purchasing projectors for energy efficiency:

1. Select projectors with LED bulbs
2. Select a projector that has the lowest lumen output that will meet the needs and lighting environment of the space it serves. Higher lumen projectors are only needed to overcome very bright spaces. A projector with higher lumen output than the space requires will not improve image quality, it will only waste energy
3. Ensure that the projector has an automatic shutoff that turns the power off when not in use

Even if you are using energy efficient computers and projectors, it is important to ensure that the equipment is being turned off when it is not in use. Powering off seems incredibly simple, but due to human nature may actually be fairly difficult to accomplish. The best way to ensure success is through the use of a multi-pronged approach. All equipment should be purchased or configured to power off or at least “sleep” after an extended period of no activity. Computers can also be scheduled to automatically power off or sleep during specific hours with low typical use such as overnight. An IT policy to configure all new computers this way should be established if it does not already exist. These automatic controls are often the most effective since they do not rely on human action. Setting a policy that all computers, projectors and other technology equipment should be powered off when not in use is still an important step, though, because it sets an expectation for acceptable behavior. Finally, if automatic controls and establishment of a policy are not enough, it may be advisable to involve teams of students to turn off equipment in specific buildings along the lines of the existing Friday Night Lights program.

Technology Management Recommendations

- Switch from desktop computer systems to laptops wherever possible
- Evaluate existing computer labs to understand if they are still needed
- Purchase projectors with LED bulbs, appropriate lumen levels and automatic shutoff
- Incorporate automatic controls such a timed “sleep” or auto-off modes

- Establish a policy that all computers, projectors and other technology equipment must be turned off when not in use
- Consider a student led program, like Friday Night Lights, to make sure computers and projectors are being turned off

Purchasing Overview

Sustainable purchasing practices help give preference to environmentally preferable products and can also help reduce waste when lifecycle and durability factors are considered. In general, there are two categories of sustainable purchasing policies that are commonly pursued: ongoing consumables and durable goods.

Ongoing consumables are a wide category that covers low-cost supplies and materials that are purchased and replaced regularly. Common examples of ongoing consumables include copier paper, toner cartridges, writing utensils and batteries. Since this is such a broad category of products, it is hard to set environmentally preferable purchasing criteria that will cover them all. Instead, instituting a broad sustainable purchasing policy for ongoing consumables that contains individual requirements for typical product purchases is typically best. Some of the criteria to consider including in such a policy include:

- Give preference to products that contain at least 20% recycled content
- Give preference to materials to use rapidly renewable source materials
- Purchase reused or remanufactured products, such as refilled toner cartridges, where practical
- Give preference to reusable products, such as rechargeable batteries, over disposable ones
- Buy from companies that have reclamation processes in place for their used products
- Give preference to locally produced goods where possible to minimize transportation costs

The other typical category for sustainable purchasing policies is for durable goods. In contrast to ongoing consumables, durable goods are higher cost items that are replaced infrequently. The most typical types of durable goods purchases are electronics and furniture. BGSU already has a policy in place for requiring appliances to be Energy Star labeled. This is by far the most common criteria for sustainable purchasing as it relates to electronics. When it comes to furniture, the most common criteria to include in a sustainable purchasing policy are similar to some of the criteria for ongoing consumables and include:

- Give preference to furniture that contains at least 20% recycled content
- Give preference to furniture that utilizes rapidly renewable materials
- Purchase used or refurbished furniture products and/or buy from companies that will reclaim your furniture after use for resale
- Purchase Greenguard Certified furniture to protect indoor environmental quality
- Purchase furniture with long warranties and expected life spans to reduce end of use waste and the need for replacement

Much as it would be helpful to conduct a commuting audit, it would also be helpful to conduct a purchasing audit to help identify exactly what types of purchases are most prevalent and which criteria would be most logical and impactful to include in sustainable purchasing policies.

Purchasing Recommendations

- Conduct a purchasing audit to identify most common purchases and which environmentally preferable purchasing criteria may be most appropriate
- Establish purchasing criteria for ongoing consumables and durable goods based on the results of the purchasing audit
- Continue the already established requirement for Energy Star labeled appliances and ensure that it applies to all appliance and equipment types that are Energy Star eligible

Waste Management Overview

Sustainable waste management can cover a broad range of strategies including waste reduction, recycling, reuse of used goods and composting. BGSU has already established a wide variety of strategies aimed at waste management. These include ongoing programs such as recycling collection across campus, bottle re-fill stations and resale programs that make donated items from residence hall move outs and surplus office equipment and supplies available for purchase. Event-based efforts such as the Green Game Day program to reduce waste and increase recycling on football game days and participation in the annual Recyclemania competition are also parts of BGSU's current efforts. With such a diverse range of initiatives already in place, focus in this area can mainly be targeted on incremental improvements. The one major change to the recycling program, however, is for management of the program to move from Grounds Services to the Office of Campus Sustainability. This move will allow much better control and tracking of the program and its ability to contribute to the university's carbon reduction.

Recycling programs are only as effective as the infrastructure that processes the recyclables and the education level of the students, staff and faculty participating in the program. Accordingly, ensuring that your recycling program is effective relies primarily on making sure users know exactly what is recyclable and where to put these recyclable items, and making sure that your recycling management company has high diversion rates and also accepts the most common types of recyclables the program users are producing. BGSU has great information on what recyclables are accepted by their recycling program on the Office of Campus Sustainability website and flyers are distributed to every student living on campus at move in. These education efforts should continue. Periodic waste stream audits of both recycling and landfill containers with publicly posted results showing commonly misplaced items may be a helpful added strategy to improve user education and performance.

BGSU currently uses single stream recycling for most recyclable items with collection services provided by Waste Management. Single stream recycling is extremely convenient for users, but it may be especially prone to contamination by non-recyclable items when users are not sure what is and is not recyclable. Large recycling facilities, such as Waste Management's, are likely to have fairly high volumes of recyclables “contaminated” by non-recyclable items sent to the landfill, reducing their overall diversion rates. The convenience benefits, however, of single stream recycling typically outweigh this potential risk, though, through the increase in use of comingled recycling program versus one that requires separation by users. The only way to improve the diversion rates and still use a comingled recycling for the waste producing users would be to create campus infrastructure to handle your own recycling so that materials can be effectively sorted on campus by the recycling program before being sent off site.

In addition to common recyclables such as paper, cardboard, plastics (#1-7), aluminum and steel cans and glass, BGSU also has separate recycling programs in place for batteries, ink jet cartridges and scrap metal. The other two common recyclable materials that BGSU is not currently addressing are electronics and sheet plastics such as plastic grocery bags and zippered storage bags. Consideration should be given to establishing programs that cover these materials as well.

Reducing the production of waste through the use of reusable, instead of disposable, products is another good way to approach sustainable waste management. As noted previously, BGSU already has water bottle re-fill stations located around campus. A similar strategy, which would be a good next step, would be to target the use of reusable food and beverage containers at as many food service operations on campus as possible. The dining halls themselves use washable dishware and do not allow “to-go” food, so this strategy would primarily apply to food and drink vendors in the Student Union in particular. The strategy would need to be two-fold. First, the vendors would have to agree to allow the use of reusable containers and set the standards for what types of containers are allowed. Second, incentives, likely in the form of small discounts, would likely need to be put into place to encourage consumers to bring their own container. This is very similar to the reusable bag shopping bag programs that many retailers have in place. As some of these retailers do, the incentive could also potentially be in the form of a small donation to a non-profit that consumers are in support of or even a contribution to the already established Student Green Initiatives Fund to pay for more sustainable initiatives on campus.

Composting is the final area where more sustainable waste management can occur. BGSU Dining currently collects pre-consumer produce waste and transports it to a nearby facility at Hirzel Farms for composting and use. This is a fantastic start and already more than most universities are doing in the area of composting. The next step would be to begin composting of post-consumer fruit and vegetable waste. Fruit and vegetable wastes are the easiest to compost and are often the easiest for students and staff to sort and separate into collection bins as well. If this composting is done on campus, it could provide a ready, easy to use supply of compost to use for campus landscaping. If the desire for on-site composting is not there, the relationship with Hirzel Farms could be expanded.

Waste Management Recommendations

- Continue already established programs such as bottle re-filling stations, campus wide recycling, bottle refilling stations, and resale opportunities.
- Move control of the recycling program under the Office of Campus Sustainability for better control and tracking.

- Continue to educate students, faculty and staff on what can and can't be recycled. Use waste audits to monitor performance and provide additional education.
- Keep an eye on recycling diversion rates delivered by your recycling provider. Consider more on campus oversight and involvement if waste diversion rates are low.
- Consider providing recycling options for electronics and sheet plastics.
- Investigate and consider implementing a reusable container option for food service providers on campus.
- Take the next step in the existing composting program and begin composting post-consumer produce either on-campus or through an off-campus partnership.

Carbon Sequestration and Offsets Overview

Once energy use has been minimized and renewable energy sources have been incorporated, the last step in getting a building or a campus to "carbon neutral" is typically through carbon sequestration strategies and/or the purchase of carbon offsets or renewable energy certificates. The first step in completing this final step is to calculate how much energy from non-renewable sources you are using per year. In order to be as accurate as possible, these calculations should identify how much energy you use per source type: natural gas or electric. In the case of electricity use, the analysis should go even deeper to analyze the method by which the power grid supplying this electric power produces their electricity. Once you know the energy quantities, sources and production methods you can use one of several available online calculators to convert the power use the amount of CO2 created. Similar calculators also exist to help calculate the amount of CO2 produced by through waste production and transportation.

Once you have calculated the amount of CO2 produced through power use, waste generation, transportation and any other categories of impact you would like to include, you can begin selecting the appropriate offsets. All calculations should be done in the context of amount of CO2 produced or offset in a one year period. In general, a typical, average size tree is expected to offset approximately 48 pounds of CO2 per year through carbon sequestration. 48 pounds of CO2 is roughly the equivalent of 35 kWh of electricity use or the energy to power one 100-watt equivalent compact fluorescent bulb for nearly 2,000 hours or a ceiling fan for 200 hours. Consequently, the impact of planting trees on campus such as the 103 trees recently planted as part of the Bowling Green City tree grant program should not be discounted, but more significant offset sources will be necessary to reach carbon neutrality.

The purchase of carbon offsets is a growing market, but faces some skepticism. Carbon offset programs are not fully regulated and sometimes the value of the energy efficiency or sequestration projects used to produce the available offsets are of questionable value. Projects undertaken to produce carbon offsets for purchase vary widely from power production from agricultural waste, landfill gas recapture, renewable energy production, planting trees or even providing energy efficiency options such as CFL light bulbs to developing countries. In order to make sure the carbon offsets you purchase are impactful, they should be purchased from a reputable source. Green-e certification is widely considered to be the mark of a reputable carbon offset provider. The cost of carbon offsets fluctuates with supply and demand. Currently, the going cost for Green-e certified carbon offsets is approximately $6.00 per 1,000 pounds of carbon offset.

A final option, which is similar to purchasing carbon offsets, is purchasing Renewable Energy Certificates/Credits (RECs). RECs are more heavily regulated than carbon offsets and are all sourced from renewable energy production. Essentially, when a company produces renewable energy, they are credited with one green energy credit for every 1,000 kWH of renewable energy produced and they can then sell those credits on the open market. Again, certification is key in sourcing reputable RECs and Green-e certification the primary certification player in this market as well. RECs also vary in price but are typically very similar to carbon offsets. The going price for RECs right now is around $5.00 per 1,000 kWh that you would like to offset. Depending on energy source, one kWh is equivalent to roughly 1,400 pounds of carbon which makes RECs very cost competitive right now.

Carbon Sequestration and Offsets Recommendations

- Consider sequestration and offset strategies for carbon neutrality only after energy use has been reduced and renewable energy strategies have been implemented
- Calculate remaining annual carbon produced by campus energy use, waste production and transportation to understand how much carbon production needs to be offset to achieve carbon neutrality.
- Each tree planted on campus can be expected to offset approximately 48 pounds of carbon per year. Count the number of trees on your campus to calculate the carbon sequestration impact that is already occurring each year.
- Purchase carbon offsets and/or RECs to offset annual carbon production. Ensure that offsets and RECs are purchased from reputable sources to ensure they are impactful.

Renewable Energy Overview

V. Renewable Energy Overview

a. Photovoltaics (PV)

The Midwest, and specifically Ohio, is not known for being a very sunny state. In fact, Ohio is ranked one of the least sunny states in terms hours of sunshine. Fortunately, in terms of solar energy, the variance is not severely drastic. The states with the most solar energy (Arizona is ranked #1) are able to produce up to 7.5kWH/m²/Day (average annual solar resource) whereas the low end of the continental United States is able to produce 4.0kWH/m²/day. Meaning the sunniest areas are only able to produce 85% more solar energy than the least sunny areas. The closest local resource from BGSU for solar weather data is Toledo, Ohio. The solar resource in that area is approximately 4.44kWH/m²/day. Although there are areas in the country that produce more solar resource, PV is also more cost effective that it has ever been.

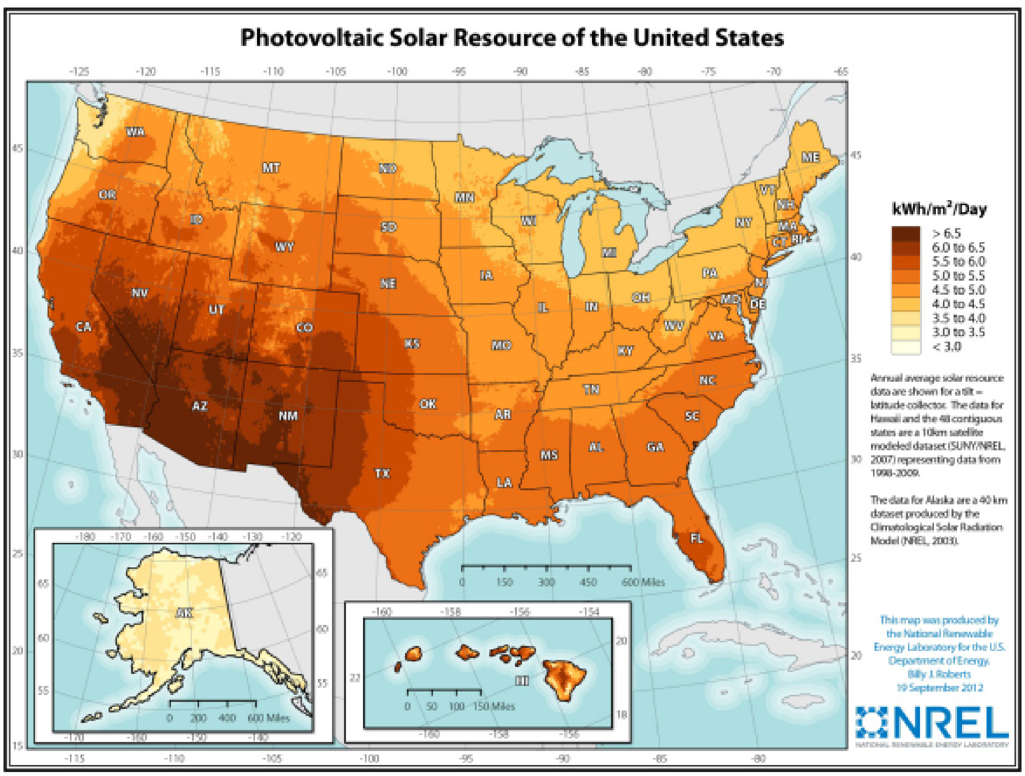


Figure 1. NREL Photovoltaic Solar Resource Map

PV has had significant leaps in terms of production capacity and technology, that and the overall popularity driving market demand and competition has resulted in a consistently decreasing cost for PV systems. As the market growth increases, the amount of qualified installers as well as sales distribution networks increases, driving installation costs and soft costs down. You can see in the image below that module price alone is not the only driving factor in installed cost decline. The data collected stops at 2014, but since then the installed cost has continued the trend of reduced cost per watt. The graph shows a large scale (>500kW) at around $2.50/watt, however such systems can currently be installed at under $1.00/watt. That being said, an array installed just a few years ago in the sunniest area of Arizona would have cost more than a similarly producing array in Bowling Green today.

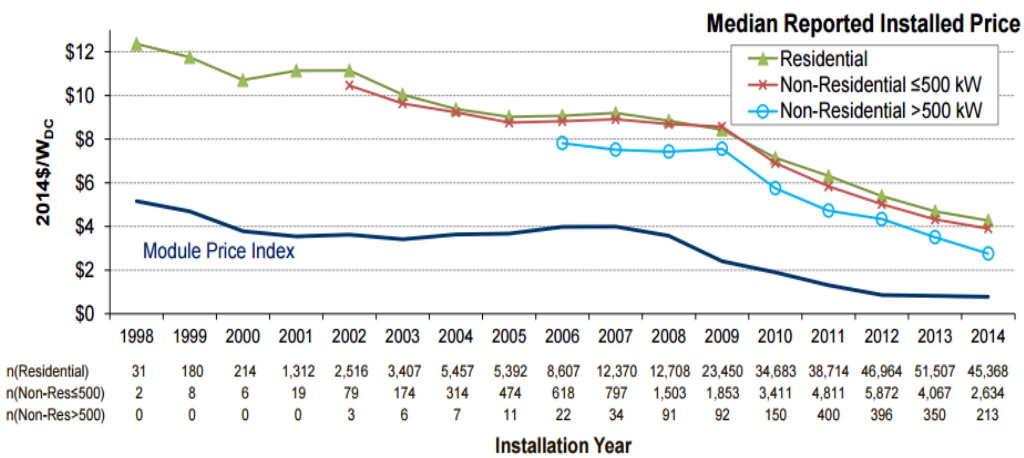


Figure 2. PV Array Historical Installed Price Graph

<u>Array Considerations:</u>

There are three types of arrays that can be considered for the BGSU campus. Rooftop arrays can be installed on buildings with available space with little impact on existing infrastructure or real estate. Canopy arrays can be installed overtop of existing or new parking lots, providing renewable energy on the site as well as shade for walking traffic. Ground mount arrays can be installed in currently unused land. Although they take up potential future real estate, they are the most cost effective systems.

Rooftop PV

There is over 1.4 million square feet of rooftop area on the BGSU campus. Out of that, there is approximately 740 thousand square feet of area that is suitable for PV arrays. Structural analysis may be required for buildings to determine if the added dead load affects the existing structure, however alternate PV panels with lower weights are becoming more popular. The majority of the buildings on campus have relatively flat roofs, which will help lower installation costs as well as provide the opportunity for increased PV array density.

The previous concept for ideal PV arrays on a flat surface was to face panels south at an angle slightly under latitude. This provided the best kWh output per kW of panels installed. However, in doing so gaps between rows are introduced into the system to prevent shading from adjacent rows. Most flat surface PV arrays have a panel density of 40-60%. The array on the Ice Arena has an approximate density of 80%, which allows for higher generation density, but more shading in the morning/afternoon. Since the decreased cost in PV modules over the past decade, it has become economically feasible to use an East/West facing system to permit additional panels per square foot. Such an installation can increase the density of the array. Although individual panel performance isn't as much as a south-facing system due to the panel orientation, the power generation density is increased due to the increased quantity of panels per square foot. The image adjacent shows an example of an East/West array.

Figure 3. Self-Ballasted East/West PV Array

In the climate of the BGSU campus, the power generation density can be increased by 16% using an East/West array while using 25% more panels, using the Ice Arena spacing configuration as an example. In addition to the increased power generation density, East/West arrays also can help contribute to reduced demands in hot afternoons (where cooling systems are running more intensely) as the West facing portion of the array generates more power in the afternoon compared to a South facing system. The figure below shows the monthly generation density for an East/West roof array compared to a South facing roof array at the BGSU campus.

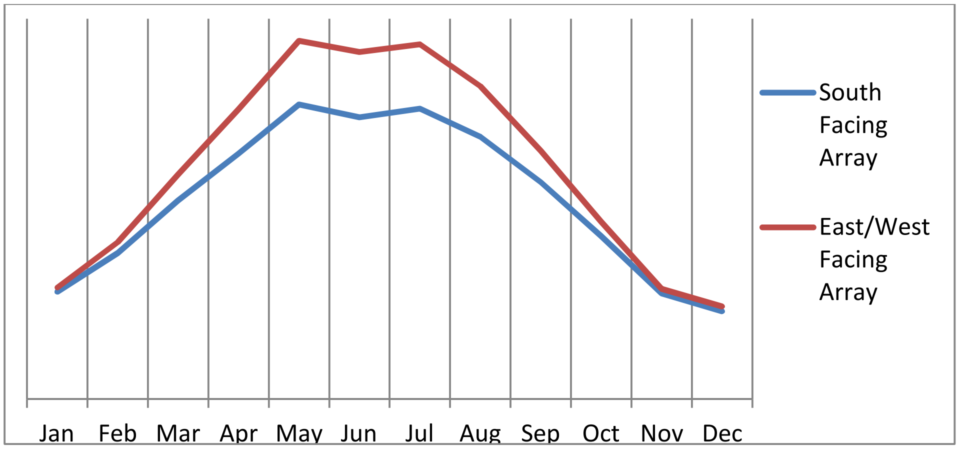


Figure 4. Array Orientation Power Generation Density by Month

For the consideration of this report, South facing arrays with a coverage ratio of 80% were used for the rooftop generation capabilities of the buildings. It should be noted that East/West arrays will increase the annual kWh generated by 16%, but will increase the system cost by 25%. The chart below indicates the generation potential of all the buildings on campus with available rooftop space.

Rooftop PV Generation					
Building	Roof Area (sf)	Useable Roof Area (sf)	Array Size	Annual kWh	Cost @ $1.70/w
Ice Arena	94,450	75,142	939,275	1,191,940	$1,596,768
Kreischer & Harshman	98,826	74,000	925,000	1,173,825	$1,572,500
Student Recreation Center	91,207	65,000	812,500	1,031,063	$1,381,250
Stroh Center	86,358	50,000	625,000	793,125	$1,062,500
McDonald Hall	93,709	39,045	488,063	619,351	$829,706
Falcon Heights	49,881	35,000	437,500	555,188	$743,750
Moore Musical Arts Center	57,375	35,000	437,500	555,188	$743,750
Eppler Center	58,956	30,548	381,850	484,568	$649,145
Founders Hall	48,089	29,286	366,075	464,549	$622,328
College Park Office Building	27,972	22,200	277,500	352,148	$471,750
Bowen-Thompson Student Union	79,210	21,979	274,738	348,642	$467,054
Central Services Building	32,023	19,616	245,200	311,159	$416,840
Architecture and Environmental Design	24,393	19,500	243,750	309,319	$414,375
Olscamp Hall	50,232	19,218	240,225	304,846	$408,383
Centennial Hall	29,423	17,035	212,938	270,218	$361,994
Wolfe Center	48,462	16,551	206,888	262,540	$351,709
Memorial Hall	29,404	14,000	175,000	222,075	$297,500
Business Administration Building	41,165	13,506	168,825	214,239	$287,003
Overman Hall	40,756	11,402	142,525	180,864	$242,293
Health & Human Services	26,217	11,388	142,350	180,642	$241,995
Technology Building	33,283	9,647	120,588	153,026	$204,999
Kohl Hall	15,966	8,794	109,925	139,495	$186,873
Offenhauer Building	29,828	8,424	105,300	133,626	$179,010
Psychology Building	17,411	8,000	100,000	126,900	$170,000
Life Sciences Building	24,152	7,841	98,013	124,378	$166,621
Hanna Hall	9,398	7,760	97,000	123,093	$164,900
Moseley Hall	9,702	7,587	94,838	120,349	$161,224
Education Building	22,198	7,393	92,413	117,271	$157,101
University Hall	18,271	6,541	81,763	103,757	$138,996
Williams Hall	9,656	6,500	81,250	103,106	$138,125
Shatzel Hall	12,502	6,000	75,000	95,175	$127,500
Carillon Place	17,621	5,388	67,350	85,467	$114,495
Jerome Library	24,256	4,248	53,100	67,384	$90,270
Hayes Hall	17,596	4,000	50,000	63,450	$85,000
Falcon Health Center	11,352	4,000	50,000	63,450	$85,000
Mileti Alumni Center	8,177	4,000	50,000	63,450	$85,000
Administration Building	11,908	3,500	43,750	55,519	$74,375
East Hall	11,173	3,373	42,163	53,504	$71,676
McFall Center	14,750	2,567	32,088	40,719	$54,549
South Hall	10,503	2,041	25,513	32,375	$43,371
Centrex	7,586	1,500	18,750	23,794	$31,875
Physical Science Building	10,318	837	10,463	13,277	$17,786
Total	**1,455,715**	**739,357**	**9,241,963**	**11,728,050**	**$15,711,336**

Figure 5. Rooftop PV Generation Potential

The buildings at the top of the graph indicate the largest arrays possible. The total generation potential for all the buildings is 11,728MWh. This is roughly 5.8% of the total campus energy usage with the current EUI of 132. The referenced cost of $1.70/W was used based on known data for medium scale rooftop installations without the need for structural modifications. For the larger arrays (500kW and above) the systems may be installed for less than the referenced $1.70/W.

Canopy PV

There is a great deal of parking at BGSU campus. The combined area of all the major lots is over 2.7 million square feet. Considering that the canopies will only be over the rows of parked cars and not down the aisles, there is still over 1.3 million square feet of usable area for PV panels. Although there is such a large area available for canopy PV, unlike rooftop PV, there is no structure to mount the panels too. The current cost for PV canopy structures exceeds the panel module cost, brining the average PV canopy cost to $4.00/W installed price.

One of the major benefits of canopy PV is the instant visibility of renewable energy on site. The panels would be in a high traffic area and would be noticed by everyone that used the lot. PV canopies can also provide shade and cover to pedestrian traffic. By creating a dry route to campus would be an added benefit to commuting students. Shading the ground by means of a canopy also reduces the heat-island effect, reducing the overall parking lot and campus temperature. PV canopies can also be an architecturally pleasing element. Semi-transparent PV canopy systems can allow some light penetration while making the canopy even more appealing. Transparent systems typically add around $0.50/W. Although PV Canopies are more of an upfront investment, they provide elements to the space that other forms of PV arrays cannot. Instead of being hidden behind the scenes, they can become a visual reminder of the active pursuit of sustainability on campus.

Figure 6. Semi-Transparent PV Canopy

Much like rooftop systems, the larger the scale of the project, the higher potential for cost reduction. A total of five lots make up the majority of the availability for potential PV canopies. They would be ideal choices for large-scale arrays ranging from just over 1MW to over 3MW potential arrays.

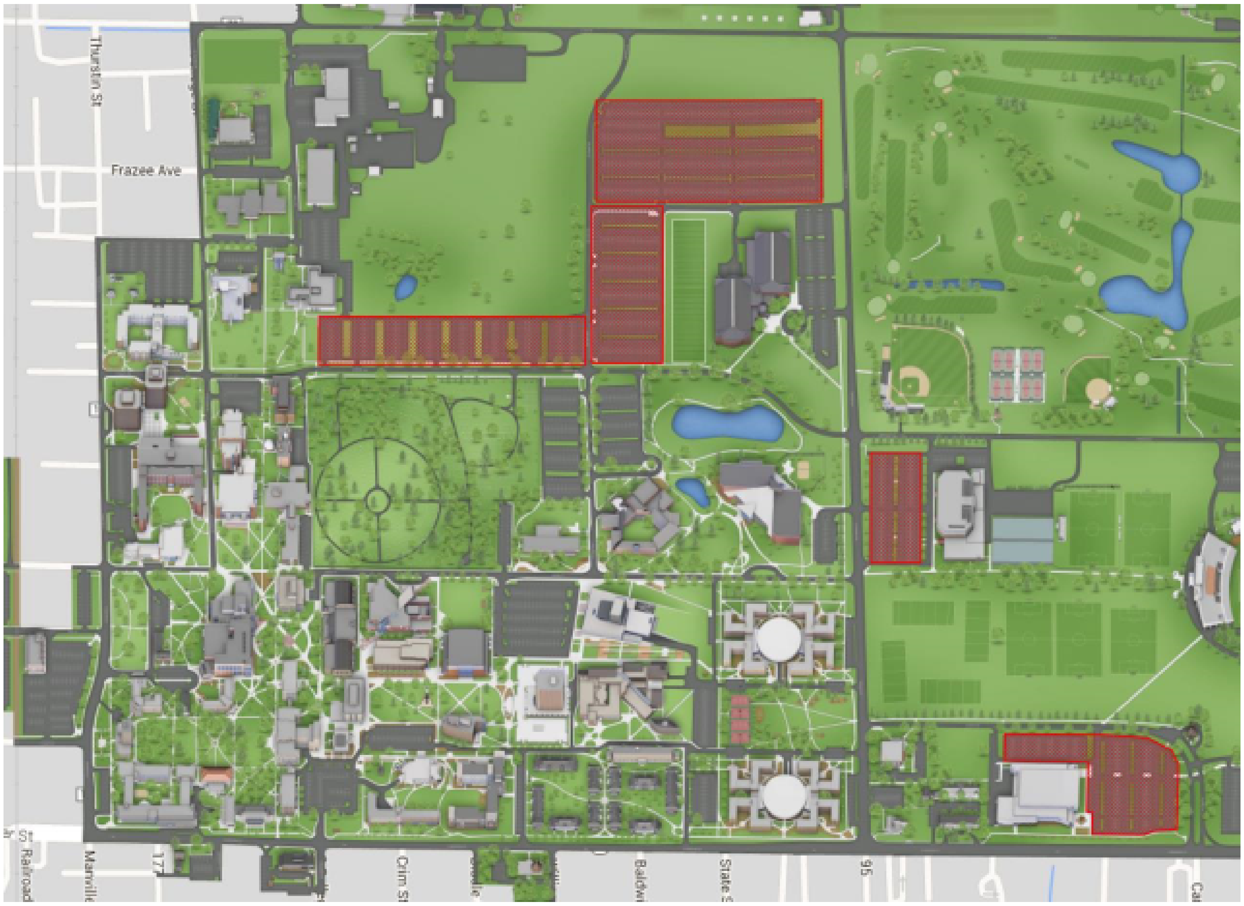


Figure 7. Map of 5 Largest Potential PV Canopy Arrays

PV Parking Canopy Generation						
	Area	PV Usable Area	PV Size	kWh	Cost @ $3.50/w	Transparent Panels Cost @ $4.00/w
Lot 12	544,500	272,250	3,335,063	4,108,797	$11,672,719	$13,340,250
Lot 12 S	250,000	125,000	1,531,250	1,886,500	$5,359,375	$6,125,000
Lot 5	280,000	140,000	1,715,000	2,112,880	$6,002,500	$6,860,000
Lot 24	205,000	102,500	1,255,625	1,546,930	$4,394,688	$5,022,500
Lot 10	171,000	85,500	1,047,375	1,290,366	$3,665,813	$4,189,500
Lot 13	140,000	70,000	857,500	1,056,440	$3,001,250	$3,430,000
Lot N	125,000	62,500	765,625	943,250	$2,679,688	$3,062,500
Lot 18	118,000	59,000	722,750	890,428	$2,529,625	$2,891,000
Lot 1	105,000	52,500	643,125	792,330	$2,250,938	$2,572,500
Lot E	101,000	50,500	618,625	762,146	$2,165,188	$2,474,500
Lot 8	91,000	45,500	557,375	686,686	$1,950,813	$2,229,500
Lot M	79,000	39,500	483,875	596,134	$1,693,563	$1,935,500
Lot L	70,500	35,250	431,813	531,993	$1,511,344	$1,727,250
Lot C	69,376	34,688	424,928	523,511	$1,487,248	$1,699,712
Lot W	55,000	27,500	336,875	415,030	$1,179,063	$1,347,500
Lot 4	54,000	27,000	330,750	407,484	$1,157,625	$1,323,000
Lot 16	48,000	24,000	294,000	362,208	$1,029,000	$1,176,000
Lot 3	40,000	20,000	245,000	301,840	$857,500	$980,000
Lot 20	39,000	19,500	238,875	294,294	$836,063	$955,500
Lot J	32,000	16,000	196,000	241,472	$686,000	$784,000
Lot K	31,000	15,500	189,875	233,926	$664,563	$759,500
Lot H	28,000	14,000	171,500	211,288	$600,250	$686,000
Lot X	25,700	12,850	157,413	193,932	$550,944	$629,650
Lot C	23,600	11,800	144,550	178,086	$505,925	$578,200
Total	**2,725,676**	**1,362,838**	**16,694,766**	**20,567,951**	**$58,431,681**	**$71,987,829**

Figure 8. Canopy PV Generation Potential

As indicated by the generation chart above, the total generation potential on the entire campus is 20,567MWh annually. This is approximately 10.3% of the total campus energy usage with the current EUI of 132. The first five lots on the graph represent over half of the canopy PV generation capacity on campus. All the arrays were indicated with an estimated rate of $4.00/W; however this is conservative figure for the larger scale canopies.

Ground Mount PV

Ground-mount PV is currently the cheapest option for PV systems. Utility scale systems are currently being installed at less than $1.00/W. The BGSU campus does not have many potential available locations where ground-mount PV is feasible. The only area indicated usable was the lot on the corner of E Merry Ave and Willard Dr.

The typical installation of ground-mount PV is long rows of south-facing panels, angled at around 20°. To minimize structure size and potential wind uplift issues, a good configuration is to be stacked two high in portrait orientation. This arrangement results in panel rows spaced apart at a distance slightly wider than row width. In the geographical region of BGSU's campus, the ideal array ground cover ratio is 0.46, meaning the panels take up 46% of the ground coverage on the field.

Figure 8. Typical Ground-Mount PV Array Configuration

An alternate installation is to mount the panels East/West at a slightly reduced angle (most are designed at 10°). This is a similar installation to the rooftop configuration mentioned earlier in the report. In the case of ground-mount PV, due to the increased spacing between the panels in the normal configuration, the generation density can be greatly increased. Assuming a 5% spacing to allow for maintenance a 1MW East/West system can be installed in half of the space as 1MW South facing system. Due to the reduced efficiency of the East/West configuration the total output per installed kW decreases by 11.2%, but the generation density is increased by 77% making this configuration ideal for instances when space is limited.

Figure 9. East/West Ground-Mount PV Array Configuration

PV Ground Generation - South Facing Configuration					
	Area	PV Usab	PV Size	kWh	Cost @ $1.00/w
E Merry Ave	860,000	688,000	4,588,960	5,984,004	$4,588,960
Total	**860,000**	**688,000**	**4,588,960**	**5,984,004**	**$4,588,960**

PV Ground Generation - East/West Facing Configuration					
	Area	PV Usab	PV Size	kWh	Cost @ $1.00/w
E Merry Ave	860,000	688,000	9,477,200	11,110,084	$9,477,200
Total	**860,000**	**688,000**	**9,477,200**	**11,110,084**	**$9,477,200**

Figure 10. Ground-Mount PV Generation Potential

The usable area by E Merry Ave has approximately 688,000 square ft of usable space for ground-mount PV. Using a South facing system, this could produce a 4.6MW array, producing 5,984MWh annually, or 3% of current campus usage based on the current 132 EUI. Using the East/West facing system this area can fit a 9.5MW array producing 11,110MWh annually or 5.5% of the current campus usage.

Cost

The cost for PV systems varies by system type from ground mount being the cheapest at $1.00/W, to rooftop at around $1.40/W to canopy systems, which can cost $4.50/W on the high end. The ROI varies based on the installed cost of the system. The quickest ROI would be a south-facing ground-mount system at E Merry Ave. Such a system would offset 5,984MWh annually. Based on the current electrical utility rates and the documented inflation of 5% annual rate increase by BGMU the payback for such system would be 6.7 years.

A canopy system brings more value as a visual indication of renewable energy on campus. A typical canopy installation would take approximately 18 years to break even whereas a transparent canopy may have an ROI of 21 years or more.

The ROIs indicated above only consider usage savings. There are also peak demand savings that could play a significant role in the ROI. When coupled with a means of energy storage, a 1MW array has the potential to reduce the campus peak demand by upwards of 500kW or $8,000 a month during summer months. Note that without energy storage means, the peak demand reduction could be much less if there was cloud cover during the utilities peak demand reading.

Since BGSU cannot take advantage of solar related tax incentives, a third party PPA agreement could be a very attractive option. This type of agreement could be implemented with the array being located on campus or even offsite. A large ground mounted array (>5MW) at the E Merry Ave site could provide rates of 7¢/kWh with 1% annual escalation for a contract period of 20-25 years. PPA agreements often include an option for the customer to purchase the system once the contract period expires. The PPA provider would sell the more valuable SREC's generated but sell REC's back to BGSU in order to offset GHG's.

If the offsite approach is preferred, a solar farm would be developed and the output blended with the customer's onsite generation or grid power through the existing utility grid. Developers will often develop very large utility scale systems in order to service multiple contracts which helps to reduce costs. This type of agreement could yield rates as attractive as an onsite PPA but would allow BGSU to eventually completely offset GHG footprint. This would be impossible to do wholly onsite due to space constraints.

Recommendation:

Given that the current cost for PV systems is at an all-time low in terms of cost/W, it is highly recommended that BGSU considers PV as a renewable resource in the near future. Energy savings captured from the PV arrays can be used to fund other ECMs on campus. Due to the quick ROI of the (majority of) PV systems, it is recommended that PV projects are coupled with less cost-effective ECMs in order to obtain proper project funding through ESCos.

Due to the low cost per kW on current PV modules as well as the limited area available for BGSU, it is recommended to utilize an East/West fixed configuration on the roofs and ground-mount arrays in lieu of a tracking system as recommended by the city of Bowling Green in their Carbon Action Plan. It is more beneficial to increase the generation density and take advantage of inexpensive PV modules than to invest in a marginally more efficient tracking system that sacrifices usable area and adds required maintenance to the system. In addition, the west facing portion of the system will help decrease the peak demand during afternoon hours.

Due to the high cost of canopy PV systems, we recommend installing a small semi-transparent canopy PV system near a high-traffic area for aesthetical purposes. Such a canopy would be more of an investment as an icon of campus-wide renewables and the public attention it will bring to the campus. It is recommended that it is installed in an area that visitors are likely to park, particularly near the Stroh Center or other athletic facilities. If the demand for a covered parking structure or walkway is ever considered, it is highly recommended to install a PV canopy as the majority of the cost is in the structure itself. It is also very likely that PV canopies will be more common and more cost effective in the near future.

The first large-scale system on campus should be an East-West ground-mount system in the area near E Merry Ave. Such a system would cost $9.5M, but has an ROI of only 7.5 years solely considering power usage reduction. The system also has the potential to single-handedly reduce the electrical peak demand by over 30% in summer hours if an appropriate energy storage solution is considered. Such a system could play a very large role in the overall goal to Net Zero.

It is also recommended to use the Ice Arena as the first large-scale building mounted array. From the information that could be gathered, the building was designed to accommodate the added PV dead loads. There is also a significant amount of area for the PV array on the roof. The Ice Arena has a larger electrical service than most other buildings, so the supplemental PV array would likely be able to be installed without any electrical infrastructure modifications, resulting in a lower installed cost for the system.

It is also highly recommended to renegotiate the electrical utility rate and demand structure with BGMU prior to the installation of any large-scale system. The utility does not currently have a defined plan for Net Metering on large scale systems and they currently are not required to per PUCO. Fortunately, the demand offset that could be realized by a large-scale PV array would be detrimental to the peak demand charge paid by the utility due to peak usage rates. The municipal utility should be very interested in taking advantage of such savings.

Finally, BGSU should explore the option of a third party PPA agreement. This could allow the university to defer first costs while also locking in an attractive energy rate. Any agreement would need to include BGMU in order to ensure that savings would be realized.

V. Renewable Energy Overview

b. Combined Heat and Power

Ohio's 21st Century Energy Policy, of June 1, 2014, defines Combined Heat and Power (CHP) as a renewable resource. As such, implementation of CHP systems can help state institutions and utilities meet state-mandated goals as a renewable energy resource and an advanced energy resource under the Alternative Energy Portfolio Standard. CHP systems can be used as part of a strategy to provide a reduction in the electrical energy peak demand and overall electrical energy consumption levels. In addition, CHP systems can provide utility bill savings by helping to shift energy spending from electrical to other sources, such as natural gas, add additional reliability to the end user, and can help reduce carbon emissions by offsetting less-efficient and dirtier coal-fired electrical production.

CHP Concept for BGSU:

A Combined Heat and Power analysis was performed on the utility demand and consumption data that was provided. Based on this historical data, it appears that a base-loaded 2MW CHP system would be viable at BGSU. The analysis compared the electrical and thermal energy demands over time with the potential electrical and thermal outputs of different theoretical CHP plants and configurations. Figure 1 shows the hourly electrical demand (East Loop – Feeders NE and SE) and thermal demand (Central Plant) and the highlighted area represents the output of a theoretical 2MW reciprocating, internal-combustion engine-based CHP plant.

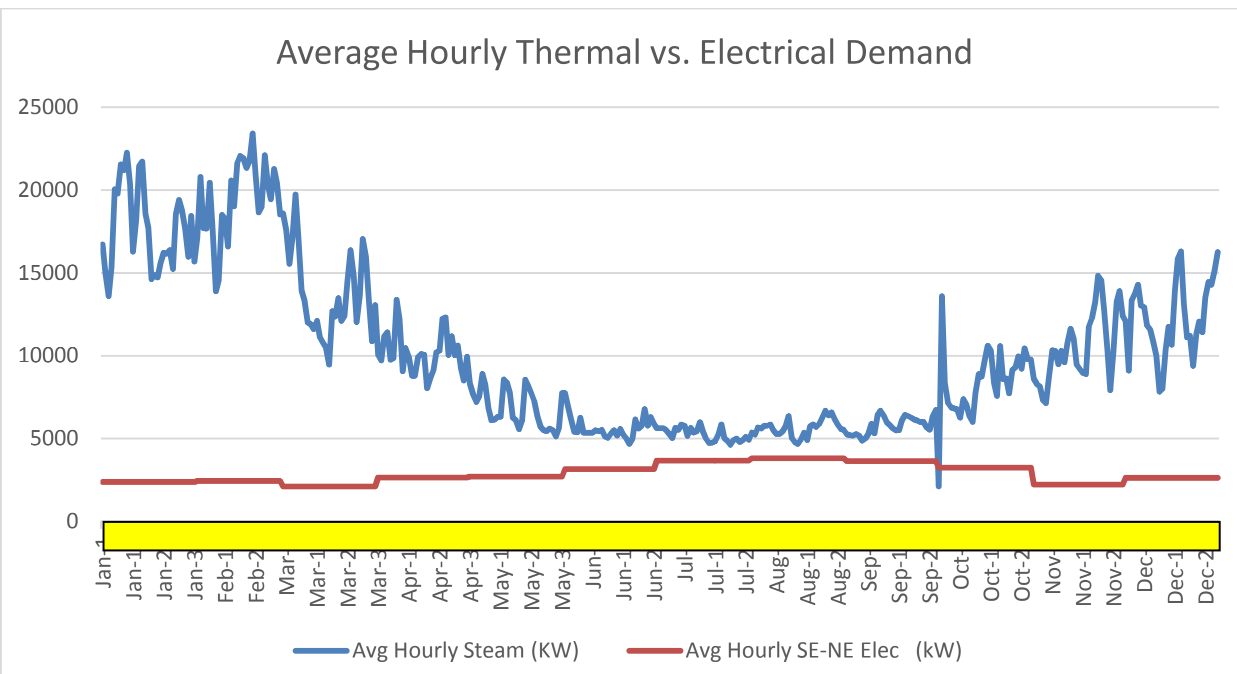


Figure 1. BGSU Historical Hourly Thermal and Electrical Demand

Figure 2 illustrates the configuration of the theoretical CHP plant that was used in the analysis. The system modeled would utilize a 2MW internal combustion engine - Caterpillar Model G3516H was used as the prototypical prime mover. This engine would drive an integral generator to provide high-voltage electricity to the existing HV distribution and would recover heat from the engine jacket and exhaust stream to produce both steam (assumed at 100psi for analysis) and hot water (assumed at 180^{0}F for analysis) for use on the campus.

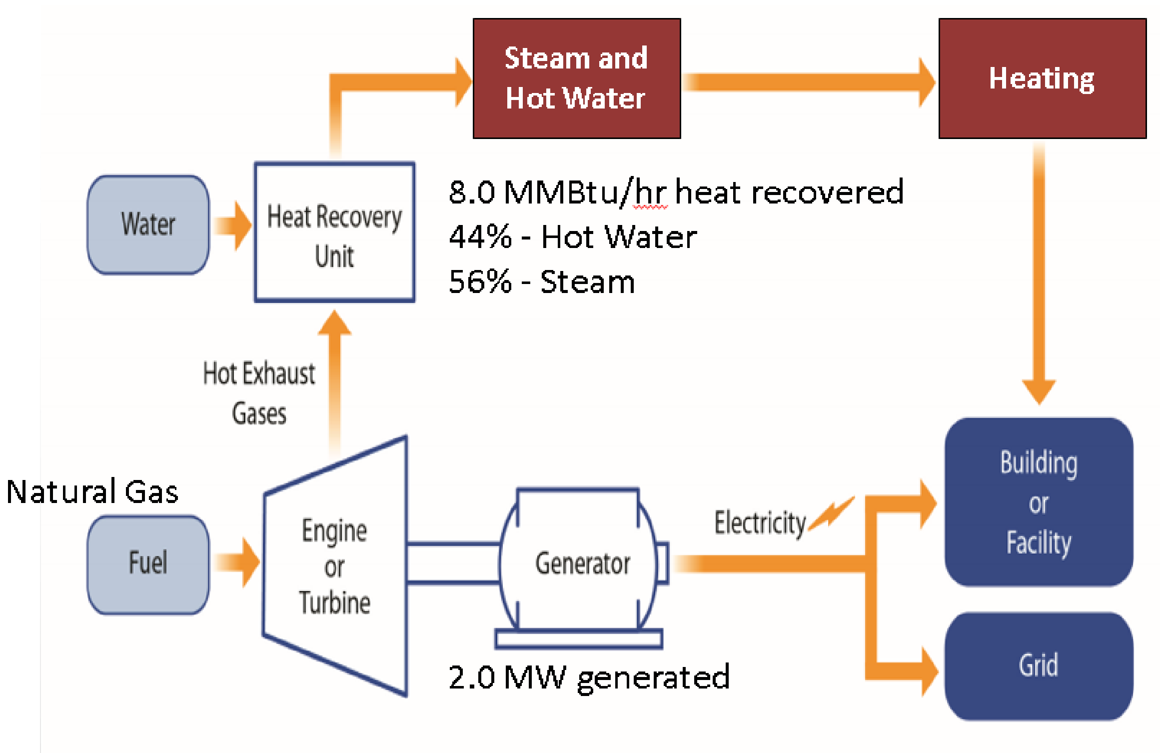


Figure 2. Configuration of the CHP Plant used in the analysis

Because the system would provide both electrical and thermal energy to the campus and use natural gas, it is important that it be located in close proximity to the existing distribution systems to avoid excessive installation cost. A brief review of the campus map and electrical single-line diagrams suggests that there may be available space adjacent to "Central Chiller Plant #1". See Figure 3. The availability of sufficient natural gas capacity (supply and pressure) at this location has not been verified with the local utility. It is important that this be verified early in any potential CHP plant design process. Equipment such as that modeled in the analysis typically requires a dedicated natural gas service at around 5psi.

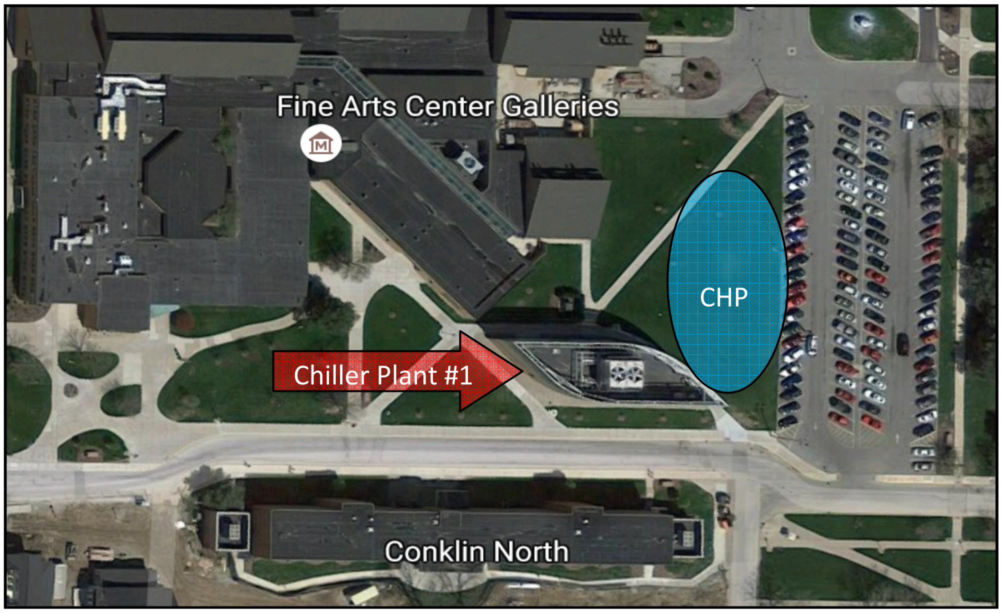


Figure 3. Potential Site for CHP Plant

Energy Savings and First Costs:

Further analysis and design is required to determine the final sizing, design, and location of the CHP Plant. The modeled system was chosen to allow the plant to run in a base-load configuration. As such, it was assumed to run at full capacity 24/7/365. Typical estimates of downtime for service and failure would be approximately 10-15%. Further, the system was assumed to run in parallel connection to the utility grid to offset a portion of the campus electrical consumption. A CHP plant similar to the one modeled could burn up to 155,000 MMBTU of natural gas annually and could produce over 16 million kwh of electricity, over 33,000 MMBTU of steam, and over 26,000 MMBTU of hot water. Based on the electrical and natural gas utility rates provided, it is predicted that such a plant could provide approximately $ 508,000 in energy savings annually. It is important to note that these savings are exclusive of any standby charges that the local utility might impose.

Assuming that the equipment could be housed in a metal prefabricated building, it is estimated that the system first cost would be in the range of $ 5.5 million. A summary of these costs and savings is resented in Figure 4. Based on this analysis, the installation of a CHP system at BGSU could provide a simple payback in 10-11 years.

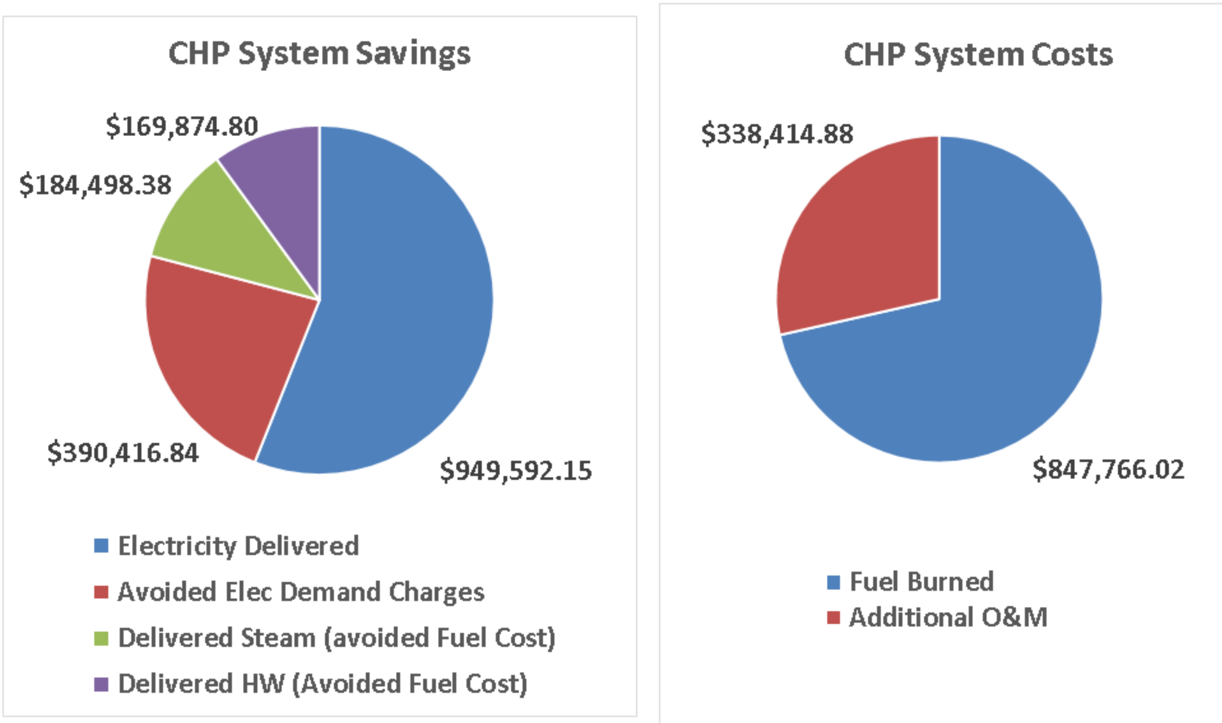


Figure 4. Potential CHP Costs and Savings

Recommendations:

In summary, a natural-gas fired CHP plant appears to be a feasible option for BGSU. There are a number of issues that require further investigation prior to BGSU installing such a system. First and foremost is consideration of the effect that implementation of multiple energy conservation measures (contained elsewhere in this report or in addition) could have on the campus energy consumption. Because the CHP analysis performed is based on historical data, reduction in future annual demand and consumption levels could have a significant effect on the predicted CHP system savings. Also, the capacity of the natural gas distribution system needs to be verified with the local utility. Costs related to upgrading the existing infrastructure to provide the required natural gas supply and pressure were not included in this analysis. Finally, the local utility needs to be consulted on the electrical rate structure and potential standby charges. Because no CHP system is capable of 100% availability, it is imperative that an electrical grid connection of sufficient capacity is maintained at the CHP plant. Typically, utilities charge monthly standby fees which represent costs associated with maintaining the capacity required to deliver 100% of the customer's electrical demand should the CHP system be offline during a peak event. In our experience, these charges vary widely from case to case, and should be discussed/negotiated with the local utility as part of the CHP design process.

V. Renewable Energy Overview

c. Geothermal Heating and Cooling

Geothermal (Geo-exchange) Heating and Cooling is a Green Energy Conservation Measure, per the request of the university it is included in the Renewable Section of the report.

The US Department of Energy estimates that total heating, ventilation and air conditioning (HVAC) represents 35% of building energy consumption for Climate Zone 2(Figure 1), of which heating is 19%. Upon review of the natural gas utility bills, the campus heating at BGSU accounts for 57% of the energy usage for the campus (Figure 2) this also assumes domestic water accounts for 8 EUI consumption. There are several reasons the heating energy consumption is higher than the US Department of Energy including envelope construction, equipment occupancy schedules, and central steam plant distribution inefficiencies. Due to this large difference, the HVAC system must be targeted for energy reduction.

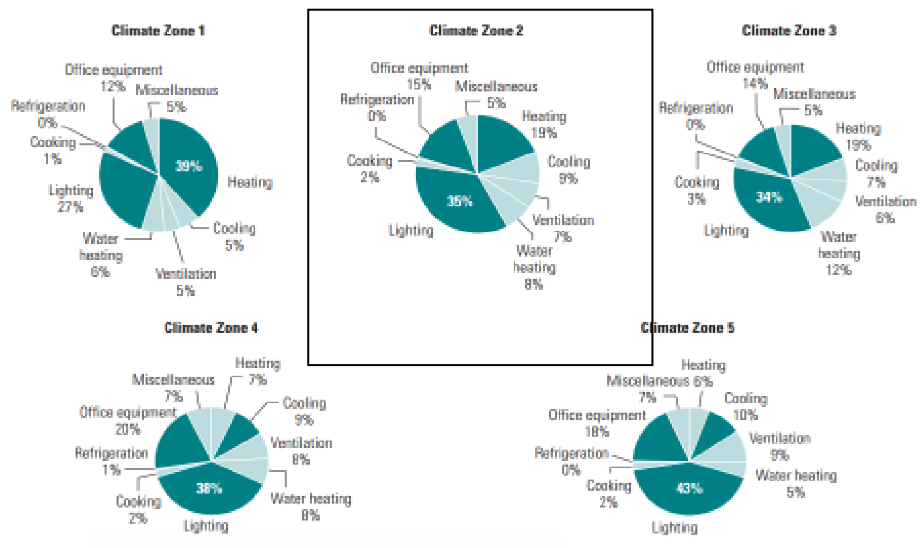


Figure 3. Typical Energy Consumption Across the US with BGSU in Zone 2

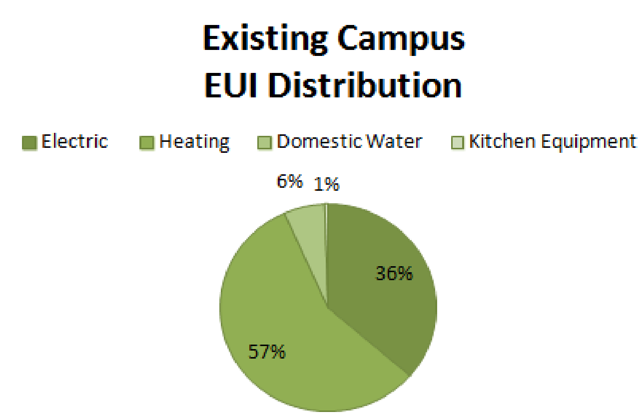


Figure 2. BGSU Breakdown

HVAC upgrades are a costlier strategy for reducing energy. It is recommended to implement HVAC upgrades as part of an Energy Service Contract (ESCo) where the shorter payback Energy Conservation Measures (ECM's) can finance these types of renovations. The other option is to utilize capital financing to perform HVAC renovations within buildings. The construction costs associated with installation of a new geothermal heat pump system with dedicated outside air units is in the range of $25-$30/sqft in construction costs for the HVAC system. The premium for geothermal HVAC systems within a facility is ~$6/ sqft. The simple payback for this system ~10-15 years.

Geothermal HVAC systems have the highest efficiency and lowest Energy Usage Intensity (EUI). Therefore, since the University has a goal for campus net zero and carbon neutrality, geothermal is recommended as part of the Sustainability Plan. The path to net zero utilizes Solar Photovoltaic and strategies to minimize EUI. Geothermal would require 20-25% of the Solar PV to obtain a net zero campus or carbon neutrality over natural gas heating options.

The purpose of this section is to review at how geothermal HVAC building systems on Campus would affect the Campus gas consumption profile, electric consumption, electric demand, utility provider demand and Campus Energy Use Intensity (EUI). Installation of geothermal HVAC systems would have a significant impact the energy and carbon reduction goals. At this time targeted building for geothermal renovations have a 100 EUI or greater for DX Rooftops and Air Cooled Chiller existing installations and 75 EUI or greater for heat pump installations. It will conclude with recommendations for moving forward as part of an ESCo project and investing in geothermal for future renovations.

Geothermal is a win-win with the University and the Utility Provider. This benefits the Utility provider by providing a more consistent demand throughout the year. It is recommended to negotiate elimination of demand charges in the winter. This is a reasonable request based on the benefit of the increased consumption realized through a HVAC geothermal renovation.

<u>Existing Heating and Cooling:</u>

First it is important to understand the existing Campus heating and cooling systems. Table 1 indicates the heating and cooling system sources utilized at each building. For evaluation, the different HVAC system types are grouped for calculating energy, EUI and cost savings.

Bldg #	Building	Cooling Method	Heating Method
44	BUSINESS ADMINISTRATION	DX Rooftop Equipment	Steam
38	CARILLON PLACE	DX Rooftop Equipment	Steam
36	CENTENNIAL HALL	WSHP	Steam
30	CONKLIN	Air Cooled Chillers	Steam
34	EAST HALL	DX Rooftop Equipment	Steam
42	EDUCATION BUILDING	Water Cooled Chillers	Steam
39	EDUC MEMORABILIA CTR	Split Unit	Steam
46,47,48	EPPLER CENTER	Air Cooled Chillers	Steam
116	FALCON HEIGHTS	WSHP – cooling Tower	
61	FAMILY & CONSUMER SCI	Window units	Steam

Bldg #	Building	Cooling Method	Heating Method
31	FINE ARTS	CCP-1 Water Cooled Chillers	Steam
106	FIELD HOUSE	Water-Cooled screw compressor chillers- (2) 120 Ton	Natural Gas Boilers-(2) boilers rated output at 5,230,000 MBH each
62	FOUNDERS QUAD	CCP-2 Water Cooled Chillers	Steam
52	HANNA HALL	Splits/ Window Units	Steam
49	HAYES HALL	Air Cooled Chillers	Steam
103	HEALTH CENTER	CCP-1 Water Cooled Chillers	Electric
3	ICE ARENA	Water-Cooled chiller(s) with 600 Tons &Additional 190 Tons of packaged roof top units for space conditioning	Natural Gas Boilers-(2) rated output at 4,000 MBH each
32	JEROME LIBRARY	Water Cooled Chillers	Steam
40	KOHL HALL	CCP-2 Ground Floor Only	Steam
7	KREISCHER QUAD	Water Cooled Chillers	Steam
88	LIFE SCIENCE BLDG	Water Cooled Chillers	Steam
89	MATH SCIENCE BLDG	Water Cooled Chillers	Steam
84	MCDONALD QUAD	Water Cooled Chillers	Steam
60	MCFALL CENTER	CCP-2 Water Cooled Chillers	Steam
43	MEMORIAL HALL	Splits/ Window Units	Steam
4	MILETI ALUMNI CENTER	DX Rooftop Equipment	Electric
104	MOORE MUSICAL ARTS	CCP-1 Water Cooled Chillers	Steam
50	MOSELEY HALL	Window Units/ No AC in Gym	Steam
113	THE OAKS DINING HALL	DX Rooftop Equipment	Steam
86,87	OFFENHAUER	Water Cooled Chillers	Steam
45	OLSCAMP HALL	Water Cooled Chillers (2) 240 ton	Steam
90	OVERMAN	Water Cooled Chillers	Steam
91	PHYSICAL SCIENCE LAB	Water Cooled Chillers	Steam
67	PROUT CHAPEL	No A/C- Operable Windows	Steam
2A	SEBO CENTER	WSHP	Natural Gas Condensing Boilers- (2) rated output @ 1,000 MBH each
66	SHATZEL HALL	CCP-2 Water Cooled Chillers	Steam
2	STADIUM	CCP-2 Water Cooled Chillers	Natural Gas Boilers
53	SOUTH HALL	VRF Cassettes	Steam
111	STROH CENTER	Air-Cooled chillers(2) 190 Ton	Natural Gas Boilers-(2) rated output at 3,000,000 MBH each
105	STUDENT REC CENTER	Water-Cooled chillers(2) 375 Ton	Steam

Bldg #	Building	Cooling Method	Heating Method
69	STUDENT UNION	Air Cooled Chillers	Natural Gas Boilers
102	TECHNOLOGY ANNEX		Steam
96	TECHNOLOGY BLDG	Water Cooled Chillers	Steam
51	UNIVERSITY HALL	N/A Demo	Steam- NA Demo
1	VISITORS INFORMATION CENTER	DX Rooftop Equipment	Electric
63	WILLIAMS HALL	CCP-2 Water Cooled Chillers	Steam
33	WOLFE CENTER	CCP-1 Water Cooled Chillers	Steam

Table 1. Existing HVAC Types per Building

Central Plant Heating and Cooling:

There are currently 3 central chilled water facilities. It is not recommended to install geothermal central plant for cooling at these locations. See thermal storage strategy.

Central Plant (CCP-1): This chiller plant has three chillers with a total capacity of 2,100 ton, operating at 1,400 serving FINE ARTS CENTER, MOORE MUSICAL ARTS, WOLFE CENTER and STUDENT HEALTH CENTER.

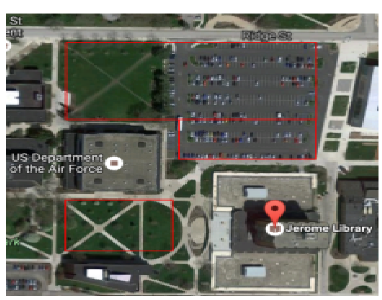
Centrex Building: This chiller plant has two chillers with a total capacity of 1,500 ton, operating at 900 serving FOUNDERS HALL, MCFALL CENTER, SHATZEL HALL AND WILLIAMS HALL.

Olskamp Hall Chiller Plant: This chiller plant has two chillers with a total capacity of 1,500 ton

Water Cooled Chillers Cooling:

The following buildings are not recommended for geothermal at this time: EDUCATION BUILDING, FIELD HOUSE, ICE ARENA, KREISCHER QUAD, LIFE SCIENCE BLDG, MATH SCIENCE BLDG, MCDONALD QUAD and OFFENHAUER due to the long payback. These building can be considered if future renovations are implemented and adjacent site is available for a well-field.

It is recommended to implement geothermal as part of a capitol project for Jerome Library Renovation. The Library is a central place for the students for the purpose of education and learning. Geothermal contributes to a reduction in the building EUI and is financially viable if coupled with a building renovation that includes HVAC replacement. Envelope improvements would target for 550 sqft/ton capacity and the well field located in the adjacent green space or parking lot. Geothermal as a stand-alone project would not be recommended due to the long payback.



DX Cooling Conversion to Geothermal Heating and Cooling

It is recommended to implement HVAC system upgrades to buildings with DX cooling as part of an ESCO project or with capital funding as building renovations are completed. The key benefit is the EUI reduction associated with the improved efficiencies in these buildings. Refer to Table 2 for building EUI reductions.

Building	Existing EUI	Geothermal EUI	Building Reduction
CARILLON PLACE	248	117	131
EAST HALL	153	57	96
MILETI ALUMNI CENTER	110	55	55
OAKS DINING HALL	345	154	191
VISITORS INFORMATION CENTER	202	90	112

Table 2. Building EUI Reduction (DX Rooftops)

The energy saving for conversion from DX roof top units to geothermal HVAC would be as follows:

- Cooling Electric Demand reduction is ~127KW *12 Months @ $16.00/KW= ~$24,500
- Cooling Electric consumption reduction by ~300,500 KWH @ $0.067 = ~$20,000.
- Heating Electric consumption would be increased by ~500,000 KWH @ $0.067 = (~$33,500).
- Heating natural gas reduction is ~14,400 MMBtu @ $3.74= ~$54,000.
- Total annual savings would be ~$65,000

Cooling

By improving the campus cooling efficiencies the campus demand would be reduced by ~127 KW and consumption reduction of ~300,500 KWH. This assumes there are no savings from control sequences or dedicated outside air systems which would ultimately be realized.

Building	Tons	Building EUI (less Kitchen NG)	Cooling EUI 9% total EUI assuming a .85 Kw/ton	KW/ton	KW	EUI adustment based on efficiency	KWH
CARILLON PLACE	54	248	22	1.20	65	31.5	176,069
EAST HALL	130	153	14	1.20	156	19.4	259,194
MILETI ALUMNI CENTER	46	110	10	1.20	55	14.0	65,356
OAKS DINING HALL	92	345	31	1.20	111	43.8	414,243
VISITORS INFORMATION CENTER	4	202	18	1.20	4	25.7	9,295
TOTALS	**326**				**391**		**924,158**

Table 3. Existing Cooling Energy Consumption (DX Rooftops)

Building	Tons	KW/ton	KW	EUI adjustment based on efficiency	KWH
CARILLON PLACE	54	0.81	44	21.3	118,847
EAST HALL	130	0.81	105	13.1	174,956
MILETI ALUMNI CENTER	46	0.81	37	9.4	44,115
OAKS DINING HALL	92	0.81	75	29.6	279,614
VISITORS INFORMATION CENTER	4	0.81	3	17.3	6,274
TOTALS	**326**		**264**		**623,807**

Table 4. Geothermal Cooling Energy Consumption (DX Rooftops)

Heating

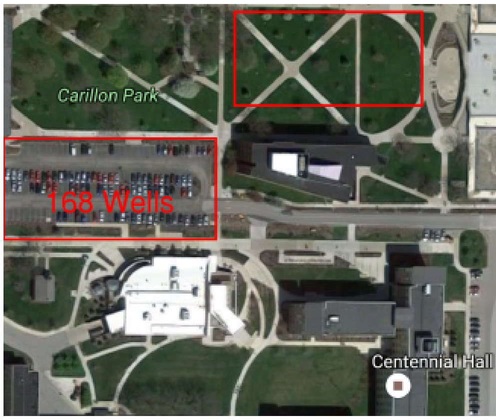
By improving the campus heating efficiencies the campus gas demand would be reduced by ~144,033 CCF and consumption increase of ~500,000 KWH. The calculations are based on the ability to negotiate with the Utility Provider to eliminate any heating demand charges. The demand will increase in the winter but would be less than the cooling demand and therefore if negotiated successfully will not impact the demand costs for the campus.

Building	Steam EUI	Electric Heating 59% EUI	Existing CCF	Existing KWH	Renovated Geothermal Heating EUI	Renovated Geothermal Heating KWH
CARILLON PLACE	140	-	26,055		19	104,159
EAST HALL	104	-	46,189		14	184,648
MILETI ALUMNI CENTER	-	65	-	303,482	14	67,441
OAKS DINING HALL	228		71,789		51	478,311
VISITORS INFORMATION CENTER	-	119	-	43,163	16	5,755
TOTALS			**144,033**	**346,645**		**840,314**

Table 5. Existing and Geothermal Heating Energy Consumption (DX Rooftops)

Geothermal is a ~$6/sqft premium over conventional HVAC systems. The total additional construction costs during a budgeted renovation would be ~$680,000 with ~15 year payback. If this was a project not part of an ESCo or without additional capital funding the payback would be much longer.

Implementation: This project would consist of a complete HVAC renovation coupled with a LED lighting retrofit and ceiling replacement. This would require coordination of mechanical heat pump closets to be coordinated with the architecture and zoning. Potential well-field locations are available at all the sites utilizing green space or parking lot. The budgeting does not include repaving parking lots this would need to be taken into consideration if existing capital is not available.



Carillon Place Dining Hall &
East Hall
Combined Wellfield

The Oaks Dining Hall

Mileti Alumni
Center

Visitors Center

<u>Air Cooled Chiller Conversion to Geothermal Heating and Cooling</u>

It is recommended to implement HVAC system upgrades to buildings with EUI over 100KBtu/sqft, air cooled chillers and steam heating as part of an ESCO project or with capital funding as building renovations are completed. Building with air cooled chillers with EUI less than 100 are Conklin North (69 EUI), Eppler Center (82 EUI), Stroh Center (33 EUI), and Student Union (51 EUI). The key benefit is the EUI reduction associated with the improved efficiencies in these buildings. Refer to Table 6 for building EUI reductions. Note that the EUI data for Stroh Center and Student Union appear to be low.

Building	Existing EUI	Geothermal EUI	Building Reduction
HAYES HALL	174	117	57

Table 6. Building EUI Reduction (Air Cooled Chiller)

The energy saving for conversion from DX roof top units to geothermal HVAC would be as follows:

- Cooling Electric Demand <u>reduction</u> is ~90KW *12 Months @ $16.00/KW= ~$17,300
- Cooling Electric consumption <u>reduction</u> by ~169,500 KWH @ $0.067 = ~$11,400.
- Heating Electric consumption would be <u>increased</u> by ~182,300 KWH @ $0.067 = (~$12,200).
- Heating natural gas <u>reduction</u> is ~4,560 MMBtu @ $3.74= ~$17,000.
- Total annual savings would be ~$33,500

Cooling

By improving the campus cooling efficiencies the campus demand would be reduced by ~90 KW and consumption reduction of ~169,500 KWH. This assumes there are no savings from control sequences or dedicated outside air systems which would ultimately be realized.

Building	Tons	Total Building EUI	Cooling EUI 9% total EUI assuming a .85 Kw/ton	KW/ton	KW	EUI adustment based on efficiency	KWH
HAYES HALL	230	176	16	1.20	276	22.1	521,132
TOTALS	230				276		521,132

Table 7. Existing Cooling Energy Consumption (Air Cooled Chiller)

Building	Tons	KW/ton	KW	EUI adustment based on efficiency	KWH
HAYES HALL	230	0.81	186	14.9	351,764
TOTALS	**230**		**186**		**351,764**

Table 8. Geothermal Cooling Energy Consumption (Air Cooled Chiller)

Heating

By improving the campus heating efficiencies the campus gas demand would be reduced by ~45,600 CCF and consumption increase of ~182,300 KWH. The calculations are based on the ability to negotiate with the Utility Provider to eliminate any heating demand charges. The demand will increase in the winter but would be less than the cooling demand and therefore if negotiated successfully will not impact the demand costs for the campus.

Building	Steam EUI	Existing CCF	Renovated Geothermal Heating EUI	Renovated Geothermal Heating KWH
HAYES HALL	58	45,608	8	182,325
TOTALS		**45,608**		**182,325**

Table 9. Existing and Geothermal Heating Energy Consumption (Steam)

Geothermal is a ~$6/sqft premium over conventional HVAC systems. The total additional construction costs during a budgeted renovation would be ~$480,000 with ~15 year payback. If this was a project not part of a ESCo or without additional capital funding the payback would be much longer.

Implementation: This project would consist of a complete HVAC renovation coupled with a LED lighting retrofit and ceiling replacement. This would require coordination of mechanical heat pump closets to be coordinated with the architecture and zoning. Potential well-field locations are available at all the sites utilizing green space or parking lot. The budgeting does not include landscaping repairs this would need to be taken into consideration if existing capital is not available.

Hayes Hall

Water Source Heat Pump Conversion to Geothermal Heating and Cooling

It is recommended to implement HVAC system upgrades to buildings with EUI over 75KBtu/sqft, with existing heat pumps and stem heating as part of an ESCO project or with capital funding as building renovations are completed. These can easily be replaced with new 2-stage geothermal heat pumps and install a wellfield adjacent to the building. Building with water source heat pumps with EUI less than 75 are Falcon Heights (26 EUI) and Sebo Center (73 EUI).The key benefit is the EUI reduction associated with the improved efficiencies in these buildings. Refer to Table 10 for building EUI reductions.

Building	Existing EUI	Geothermal EUI	Building Reduction
CENTENNIAL HALL	97	41	56

Table 10. Building EUI Reduction (Water Source Heat Pumps)

The energy saving for conversion from DX roof top units to geothermal HVAC would be as follows:

- Cooling Electric Demand reduction is ~77KW *12 Months @ $16.00/KW= ~$14,800
- Cooling Electric consumption reduction by ~82,000 KWH @ $0.067 = ~$5,500.
- Heating Electric consumption would be increased by ~347,000 KWH @ $0.067 = (~$23,200).
- Heating natural gas reduction is ~8,700 MMBtu @ $3.74= ~$32,500.
- Total annual savings would be ~$29,600

Cooling

By improving the campus cooling efficiencies the campus demand would be reduced by ~77 KW and consumption reduction of ~82,000 KWH. This assumes there are no savings from control sequences or dedicated outside air systems which would ultimately be realized.

Building	Tons	Total Building EUI	Cooling EUI 9% total EUI assuming a .85 Kw/ton	KW/ton	KW	EUI adustment based on efficiency	KWH
CENTENNIAL HALL	408	97	9	1.00	408	10.3	431,209
TOTALS	408				408		431,209

Table 11. Existing Cooling Energy Consumption (Water Source Heat Pumps)

Building	Tons	KW/ton	KW	EUI adustment based on efficiency	KWH
CENTENNIAL HALL	408	0.81	330	8.3	349,280
TOTALS	408		330		349,280

Table 12. Geothermal Cooling Energy Consumption (Water Source Heat Pumps)

Heating

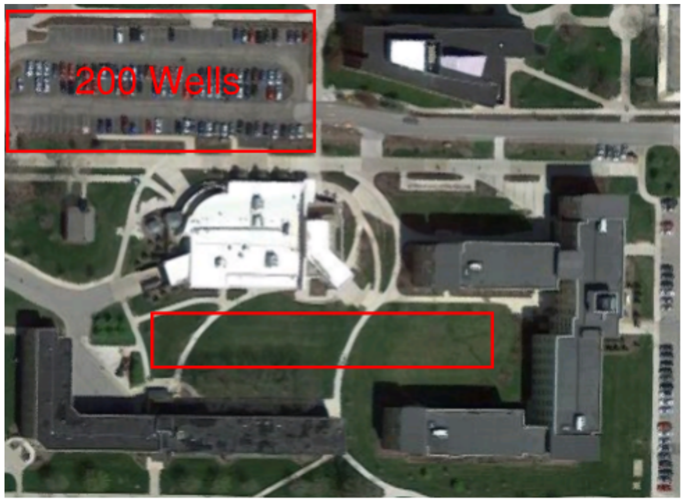
By improving the campus heating efficiencies the campus gas demand would be reduced by ~86,800 CCF and consumption increase of ~347,000 KWH. The calculations are based on the ability to negotiate with the Utility Provider to eliminate any heating demand charges. The demand will increase in the winter but would be less than the cooling demand and therefore if negotiated successfully will not impact the demand costs for the campus.

Building	Steam EUI	Existing CCF	Renovated Geothermal Heating EUI	Renovated Geothermal Heating KWH
CENTENNIAL HALL	62	86,803	8	347,008
TOTALS		86,803		347,008

Table 9. Existing and Geothermal Heating Energy Consumption (Steam)

Geothermal is a ~$8/sqft premium over conventional HVAC systems. The total additional construction costs during a budgeted renovation would be ~$1.1 Million with ~35 year payback. If this was a project not part of an ESCo or without additional capital funding the payback would be much longer.

Implementation: This project would consist of a complete HVAC renovation coupled with a LED lighting retrofit and ceiling replacement. This would utilize existing heat pump piping, ductwork and zoning. Potential well-field locations are available at all the sites utilizing green space or parking lot. The budgeting does not include landscaping repairs this would need to be taken into consideration if existing capital is not available.



Centennial Hall

Technologies:

A geothermal well-field will be coordinated with BGSU. There are potential well-field locations identified within this report. A test well would be required to evaluate the formation and the conductivity in the Schematic Design stage of the project. The bores would be 6" in diameter and would include a factory made DR-9, 1-1/4" U-tube, fully grouted well. The circuits would be piped with horizontal piping covered in sand or 57s rock. The final depth of the well-fields would need to be determined in the design process. A well-field manifold would be installed in a mechanical room located within the buildings.

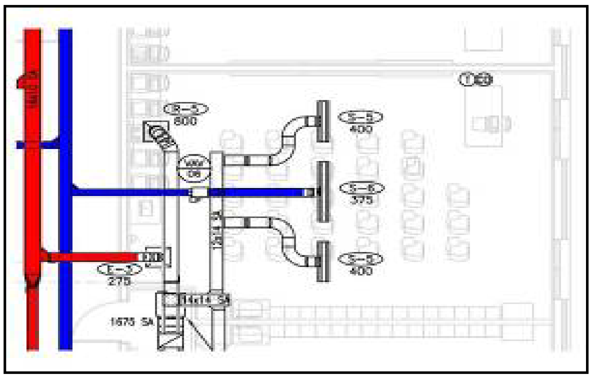
All geothermal piping interior of the building would be HDPE piping with fusion welded joints and fittings for 3" and larger piping and copper type L with soldered joints and fitting for 2-1/2" piping and smaller. Another option is all Polypropylene Piping throughout. All geothermal piping interior of the building would be insulated with 1" thick fiberglass insulation.

The geothermal system would have decentralized pumping. The dedicated pump would be located adjacent to each geothermal heat pump. The dedicated pump will provide flow to the heat pump only when the compressor is running,

Each heat pump would include local disconnect. Flexible stainless steel braided hoses shall be used at the connection of each unit. The hose kits would include shut-off valves on each the supply and return and a strainer on the supply hose. Each heat pump would have an exterior mounted filter racks and standard 24X24 filters.

Dedicated Outside Air System:

The geothermal system would be coupled with a dedicated outside air system that would have additional ventilation savings. This would include Variable Air Volume (VAV) type double wall modular air-handling units would provide all the required ventilation to the facility. The air-handling unit will include a heating/ cooling coil and energy recovery wheel. The heating/ cooling will be served through a heat pump chiller, storage tank and circulating pump. Due to the code required amount of fresh air required for these spaces, the energy recovery wheel is provided to conserve energy, reduce the well-field size and control humidity. All zones would have double wall VAV terminal unit to provide fresh air directly to the space decoupled from the heating and cooling requirements. Both occupancy sensors and carbon dioxide sensors would control the demand for ventilation to the space. The air handling unit will be schedule during the occupied hours. When the building is unoccupied the air handling unit will be off.



Feasibility:

The purpose of this study is to help guide Bowling Green State University with decisions that will affect their energy consumption and carbon reduction strategies over the next three decades. The purpose is not to design each ECM or Renewable Energy strategy. Limited Geothermal installations are recommended are would be feasible with the utilization of additional capital or as a long pay pack ECM included with an Energy Service Contract (ESCo).

This ECM without the savings from Dedicated Outside air systems and getting control of the building through Building Automation System (BAS) Upgrades would reduce the overall campus EUI from 129 KBtu/Sqft to 123 KBtu/Sqft for a 6 EUI campus reduction. Refer to Figure 3 for changes to the Campus heating percentage distribution reduction.

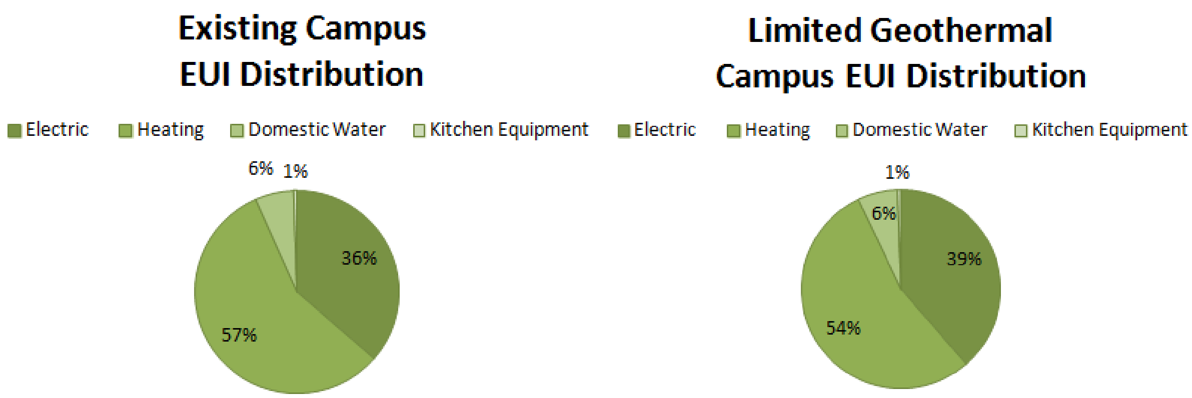


Figure 3. BGSU Campus EUI Breakdown Reduction (Geothermal)

Recommendations:

Our recommendation would be to do geothermal HVAC renovations Carillon Place, East Hall, Hayes Hall, Mileti Alumni Center, The Oaks Dining Hall and the Visitors Information Center. This can either be implemented with future renovations or as a long payback ECM included with an Energy Service Contract (ESCo). We recommend Centennial Hall be only considered if additional capital or it can be rolled into the ESCo Project. The energy savings or EUI reductions are too great at these locations to not consider as part of a Campus Energy Conservation Measure. The best way to achieve this would be to do a performance contract project with a guaranteed energy savings. The implementation would also include a negotiation with the Utility Provider to prevent any demand charges in the heating mode. This is a win-win for the utility provider to allow more consistent demand in the winter months.

If the University would prefer and area by area HVAC replacement, then our recommendation is to include this ECM with Capital planning for future renovations. The standards would be centered around 2-stage high efficiency geothermal heat pumps with distributed pumping. As part of the renovations, new HVAC building controls and sequences would be implemented to further increase the savings associated with this ECM. Refer to the Controls Section of the Report for additional information.

V. Renewable Energy` Overview

d. Wind

This renewable energy source was evaluated for the BGSU campus but with other investments opportunities for renewable energy and the long payback, this is not a preferred ECM to be pursued by the campus. The study of this renewable energy source is provided for reference purposes.

Most would think that Ohio is not a great state for wind energy production. However, there are a few areas in Ohio were wind energy production makes a lot of sense. The map shown in Figure 1 indicates the areas in Ohio that are the best for production. Those areas are shown in red along Lake Erie and a few to the south of Bowling Green along the Bellefontaine Ridge that are indicated in orange. Beyond the NREL map, we also reviewed the same Wind Monitoring study (from Green Energy Ohio) that Bowling Green Municipal Utilities used in the design of their turbines several years ago. That study was conducted from 1999 to 2000 and indicated that that our site would be a Class 2 site making it a viable area for Wind energy production.

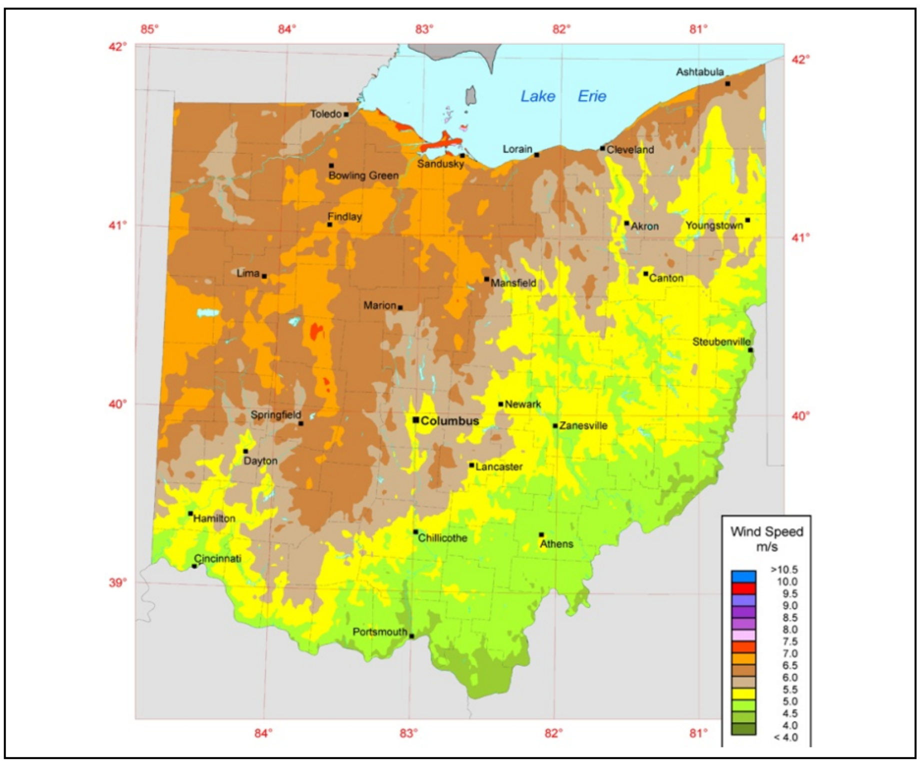


figure 1. NREL Wind Speed Map of Ohio.

Technologies:

There are two types of Wind Turbines that are typically used in wind energy production. They are Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT). Both have their advantages and both have their disadvantages. Let's start with looking at HAWT's.

A HAWT's power generation efficiency is typically between 50% and 60% which is not great, but on the positive side, their generating capability can be extremely high if used at the right height and with the right turbine. They can get as tall as 500' and have 1MW turbine. The downside to HAWT's is that they are very large and have gear boxes that can have higher failure rates than vertical turbines. They also require cut in speeds that are typically over 3 m/s. A Horizontal Axis Wind Turbine would be one like that shown in Figure 2

Figure 2. Horizontal Axis Wind Turbine (HAWT)

The other type of type of wind turbine is a Vertical Axis Wind Turbine (VAWT) and they also have many pros and cons. For instance, the efficiency of a VAWT is over 70%, is much easier to maintain since there is typically no gear box, does not require large towers and is not effected by ground level wind turbulence as much as horizontal turbines. The biggest pro is their low cut in speed which is typically between 1.5 and 3m/s. Therefore, in areas with low average wind speeds, vertical units are a much better approach. VAWT technology has changed dramatically over the past several years and many more styles have come into the market. Several of those are shown in Figure 3.

Figure 3. Vertical Axis Wind Turbines (VAWT)

Feasibility for On Site Applications:

The feasibility for our site all depends on the wind speed, velocity, direction and the average duration of time that speed or velocity is maintained. Figure 4 shows how the average speed changes during the course of the year. In the winter months the average speed is over 7 m/s while during the peak of the summer months it is barely over 5m/s. The figure also shows two lines. One for the average wind speed and the other is the cubic wind speed. The reason they are not the same is that higher wind speeds are more heavily weighed which also accounts for the turbines non-linear power curve. If the wind blew at constant velocity at all times, the two averages would be the same. At sites like ours with variable wind speeds, the designer has to use the cubic average. It will yield a much more accurate approximation of the energy that can be generated over the given period time being modeled.

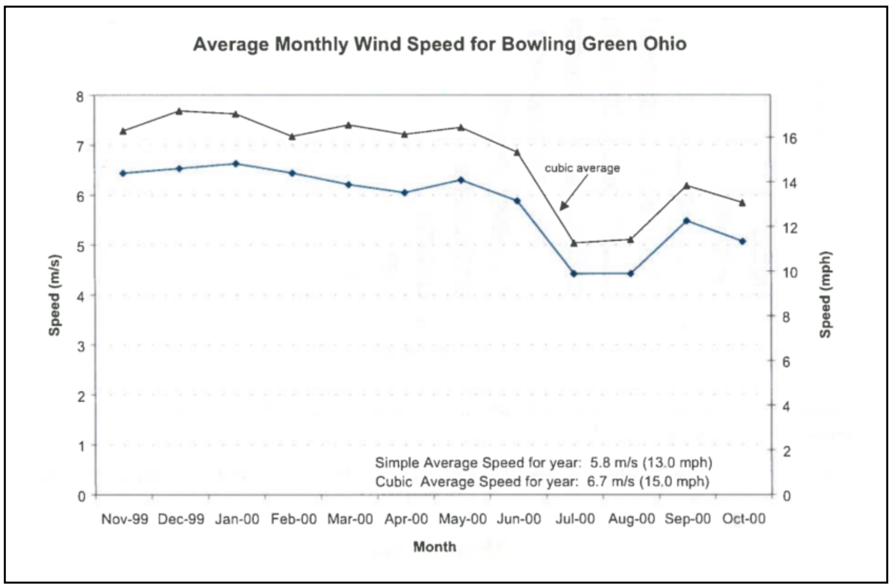


Figure 4. Average Monthly Wind Speed for Bowling Green Ohio

The next important thing to consider is how often the wind is blowing at a certain speed. This is important from a modeling standpoint. For example, if a wind turbine with a cut in speed of 7 m/s is specified for a project and only 10% of the time the speeds are at or above 7 m/s means that 90% of the time the turbine will be doing nothing. For our site, the Green Energy Ohio wind study shows the histogram of wind speeds. That graph is shown in Figure 5. This graph shows the percentage of time that the wind is blowing at a certain speed. For instance, 3% of the time the wind is at 1 m/s; 6% of the time the wind is at 2 m/s; 10% of the time the wind is at 3 m/s; and so on. Therefore, if a wind turbine was specified with a 3 m/s cut in speed we could reliably predict that the turbine would operate 80% to 85% of the time. On the flip side, if that same turbine was specified with an 8 m/s cut in speed it would only operate 50% of the time. Keep in mind that operating and producing are two different things. The speed of the wind is directly proportional to the amount of energy produced. Also, note that getting the right turbine specified for our specific site conditions is crucial.

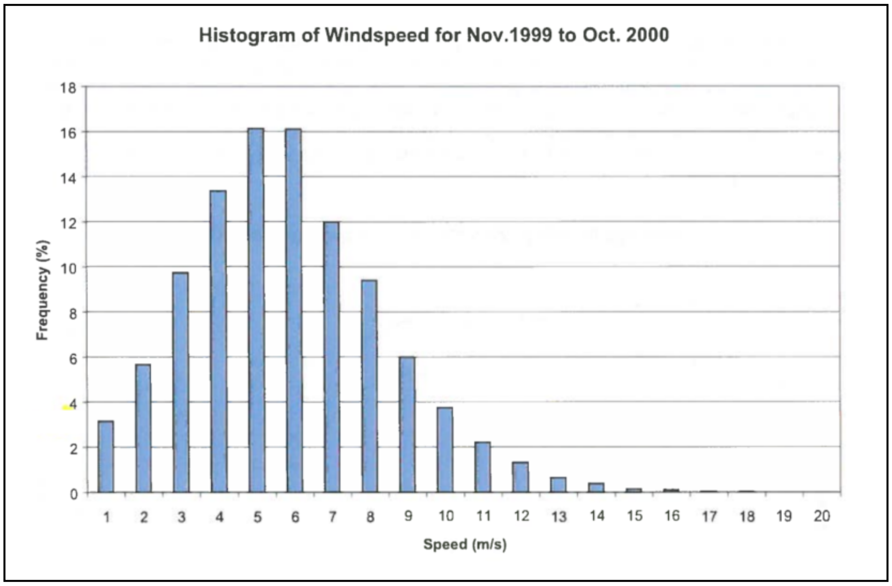


Figure 5. Histogram of Wind Speed (Nov 1999 to Oct 2000)

The final piece of the puzzle is the wind direction. We have looked at wind speeds and the duration of those speeds, now we need to consider the frequency of wind at each direction. These results are indicated in Figure 6. Without taking into consideration of blockage such as trees, buildings or other turbines, the graph indicates that the strongest wind direction for our area would be South to Southwest and Northeast. Therefore, if turbines are implemented on campus, they should be situated in areas without a great deal of natural or manmade blockages that could create turbulence that would affect the energy production of the turbine.

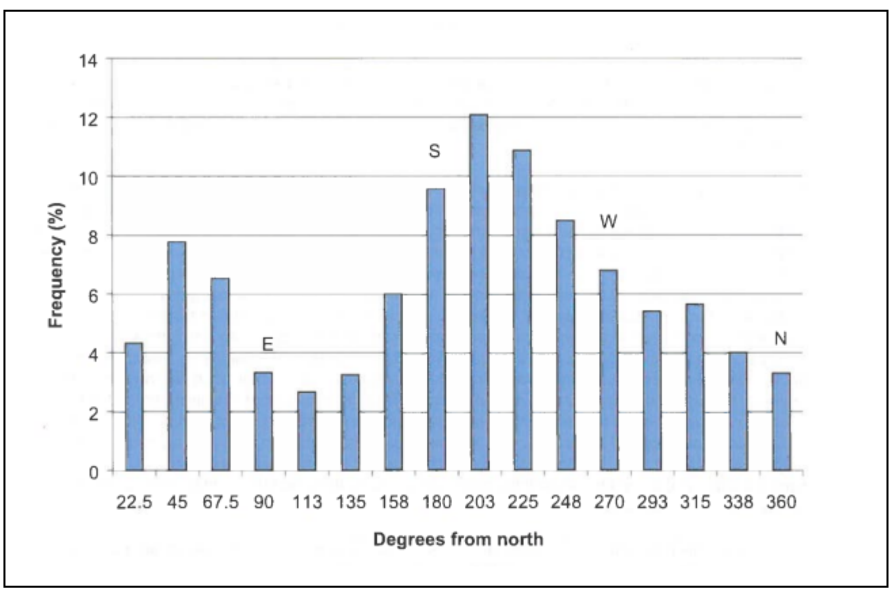


Figure 6. Wind Direction Frequency

Cost

The cost for installation and operation of a wind turbines can range anywhere from $3 per watt up to $9 or $10 per watt. For this study a good assumption would be around $6.25 per watt since our site will work best with vertical turbines under 50kW. Looking at the existing campus and our prerequisite of having winds out of the northwest and south or southwest the areas in orange in Figure 7 may be best. Recall from the presentation delivered from CMTA to BGSU on June 2nd, 2016 noted that if the University added 213 Windspire 2kW vertical turbines at a cost of $3,200,000 they would only generate 0.8% of the campuses current energy needs. The return on investment is well over 50 years.

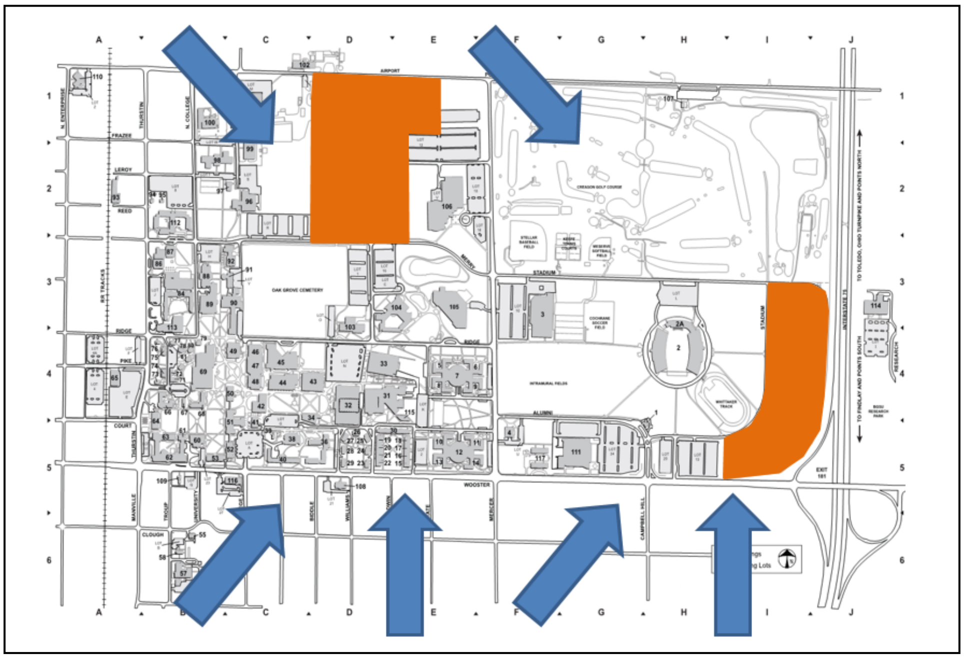


Figure 7. Possible Areas for Wind Turbines

Recommendation:

With this site having good access to wind, our recommendation would be to add Wind Turbines to the campus but no more than 5 to 10 locations. Since we cannot use taller towers (due to the proximity of the airport) and larger turbines to access good wind energy, we have to stay less than 100' tall. This limits us to vertical turbines at 5kW or below. However, there is a good story to tell by adding wind turbines to the University. They are highly visible and in BGSU's case would be spinning over 85% of the time. This would provide the "highly visible" project that BGSU stake holders mentioned early in the process. The best place for turbines would be along the edge of campus along I75 running north to south and possibly continuing along the exit ramp towards the main entrance to campus. Another possible location would be running east to west along Poe between Park and Willard.

V. Renewable Energy Overview

e. Biomass Systems

This energy conservation measure was evaluated for the BGSU campus but with logistics of maintaining and the long payback, this is not a preferred ECM to be pursued by the campus. The study of this ECM is provided for reference purposes.

Biomass is biological material from living or recently living organisms, most often referring to plant or plant derived materials. It is all biologically produced matter based in carbon, hydrogen and oxygen. As a renewable energy source, biomass can either be used directly, or indirectly, once or converted into another type of energy such as biofuel. Biomass can be converted into energy in three ways: thermal conversion, chemical conversion and biochemical conversion. Although biomass generators emit massive amounts of carbon, they are commonly considered low carbon or even carbon neutral as they simply release previously captured carbon back into the atmosphere.

The term biomass is referred to in two different ways. The first is biomass as plant matter used to generate electricity or to produce heat. The second is biomass that includes plant or animal matter that can be converted into fibers or other industrial chemicals, including biofuel. We will be considering biomass as a form of plant matter that would be used to produce electricity or heat.

Energy generation from biomass sources typically require a large and steady fuel source. For example, a 2MW biomass generator can consume tens of thousands of pounds of fuel per hour.

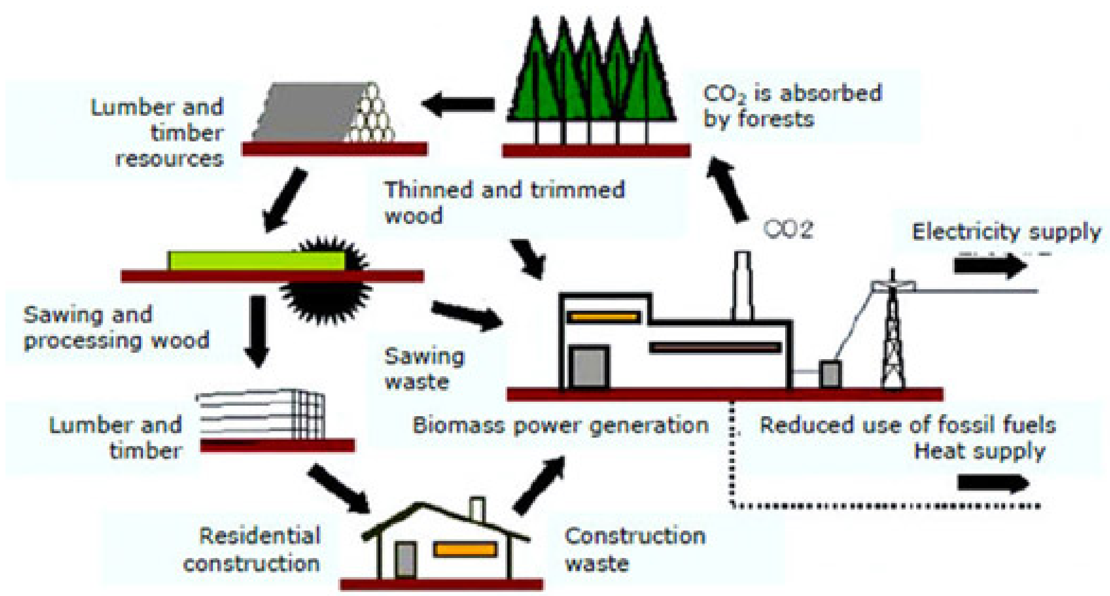


Diagram of Biomass Energy Life Cycle.

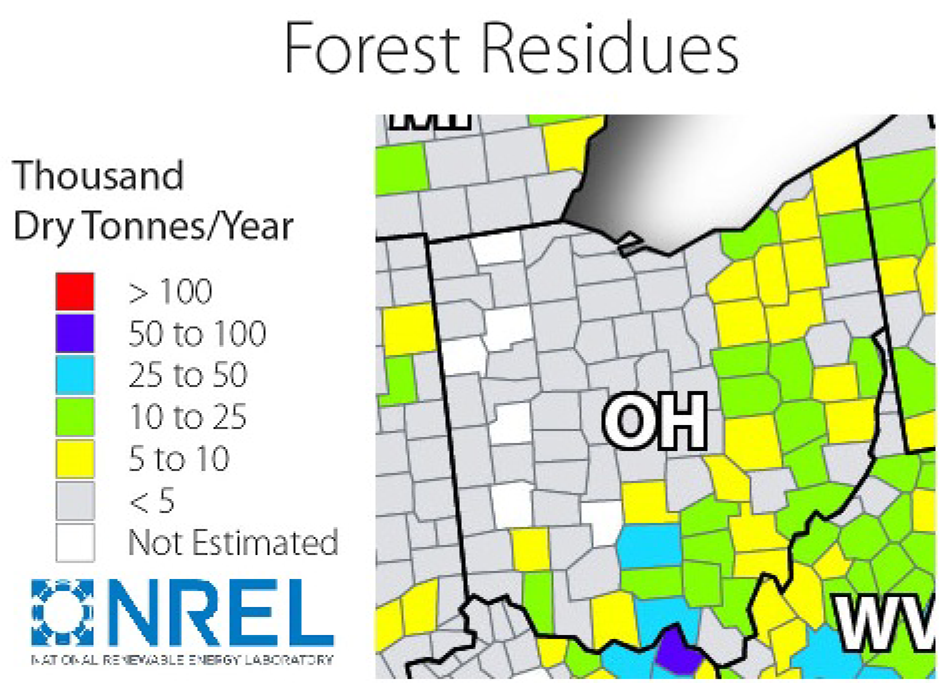
Technologies:

Biomass energy is derived from six distinct energy sources: garbage, wood, plants, waste, landfill gases and alcohol fuels. Wood energy, which is what we are mainly interested in, is derived by using harvested wood directly as fuel, or collecting from wood waste liquor or "black liquor." This is the waste product from processes of the pulp, paper and paperboard industry.

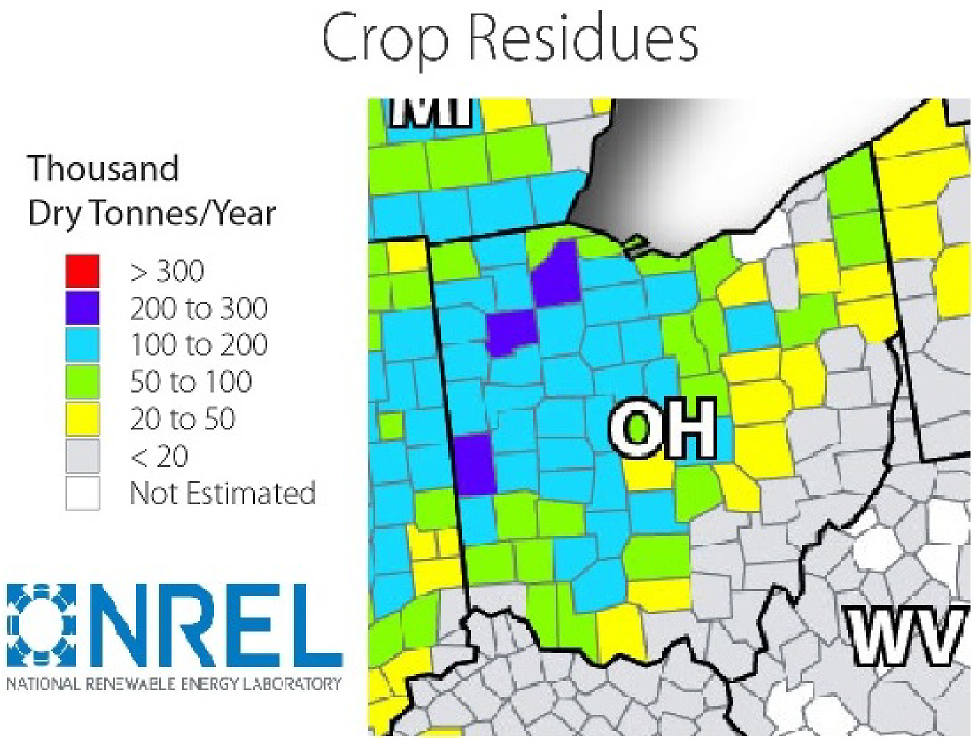
There are a number of technologies available to make use of a wide variety of biomass types as a renewable energy source. For the woody biomass, it is most often transformed to usable energy by direct combustion, either alone or co-fired with coal. Biomass can also be used in CHP applications.

In this area of the country, woody biomass would mainly be derived from logging slash, urban tree and shrub pruning and waste from forest and wood related industries. At this time, there do not appear to be any companies nearby that focus on the production of woody waste or mill residue specifically for bio-energy.

A reasonably large amount of crop residue is available in Wood County; however, this type of biomass waste is most often used for industrial bio-fuel production instead of to produce electricity and/or heat. These crop residues are also valuable in a number of other applications such as soil amendment, fertilizers production, as animal fodder and in goods manufacturing. There are a number of studies which question the practice of using crop residue for energy production at the expense of soil fertility and overall crop health.



NREL Chart indicating forest residues for Wood County at less than 5 thousand dry tonnes/year.



NREL Chart indicating crop residues for Wood County between 200 and 300 thousand dry tonnes/year.

<u>Feasibility for On Site Applications (pros/cons):</u>

There are obviously many hurdles in the way of using biomass as a fuel source for either producing energy or producing heat. The availability of the wood to accomplish either is probably the largest drawback, however, there are also significant logistical challenges that would remain if a woody waste source were available. There is presently a company called Recast that is converting boilers at a Louisville chemical plant to wood fired. They have established an agreement with the city to use the waste wood products from trimmings, storms and such. They estimate that they will need as much as 75,000 tons of wood products annually for the feedstock. The city estimates they can provide between 600 and 1000 tons per year. Obtaining the rest of the feedstock will be difficult at best but may be able to be met. Uses of wood biomass for this site would need more research to determine capacities and feedstock needs.

- Cost is dramatically more for this type of system
- Reduces long term greenhouse gas emissions, increases short term emissions
- Reduces dependence on fossil fuels

- Reduces landfill space
- On site logistical challenges

Biomass facilities can require lots of space for handling enormous amounts of woody waste.

Cost

The cost for installation and operation of a biomass CHP system is typically 2.5 times the cost of that of a natural gas system. Biomass economics are generally poor below a scale of 10MW. A 2MW CHP system would cover the base heat load for summer time reheat operations. A 2MW CHP system is estimated to cost between $15M and $20M with a return on investment of between 25-33 years.

Recommendation:

Biomass energy generation is not recommended at this time due to the relatively small system size required and the lack of available fuel source.

Energy Conservation Measures

VI. Energy Conservation Measures

a. LED Lighting

The US Department of Energy estimates that lighting represents between 30% and 40% of building energy consumption. Lighting upgrades are by far one of the easiest and most cost-effective strategies for reducing energy. When you look at the composition of the energy consumption of typical commercial and educational building as noted in Figure 1, you can see HVAC and ventilation systems make up about 35% to 40%, water heating about 10%, miscellaneous loads around 5%, office equipment around 15% with the remainder being lighting. The purpose of this section is to look at how lighting throughout the campus is affecting the campus consumption profile and what lighting upgrades have already been made that will reinforce energy and carbon reductions. It will conclude with recommendations for moving forward.

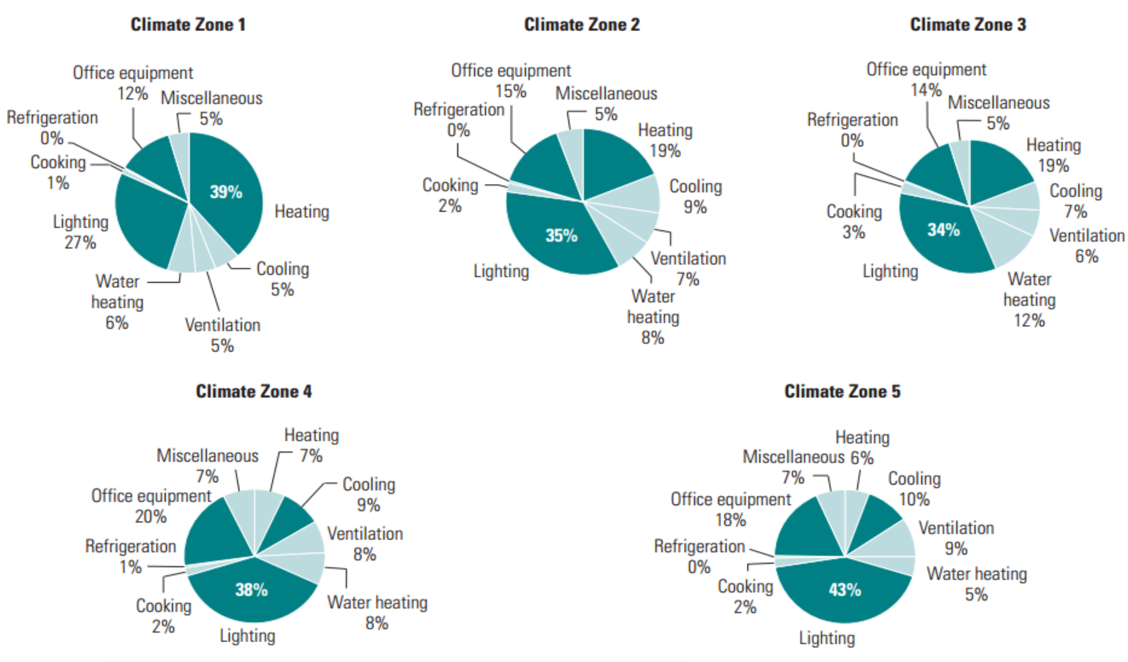


Figure 4. Typical Energy Consumption Across the US with BGSU in Zone 2

Existing Lighting:

Let us start by looking at the existing lighting being used throughout campus. On August 1st, 2016, CMTA visited BGSU's main campus for the 4th time with the intent to walk every floor of every building. Most of these were accessible but some were not. Table 1 indicates the typical lighting used in buildings east of S. College and Table 2 includes the typical lighting used in buildings west of S. College. It is important to note when looking at these tables that not all buildings could be accessed due to summer time closures. They also do not indicate counts, applications, controls, etc. They do however paint a vivid picture of type types of lighting being used in each of these existing buildings.

EAST CAMPUS (EAST OF S. COLLEGE)

Lamp Type	# of Lamps	Fixture Type	Stroh Center	Student Recreation Center	Moore Musical Arts Center	Health and Human Sciences	Eppler Center	Olscamp Hall	Education Building	Business Administration	Carillon Place Dining (Closed)	Centennial Hall	East Hall	Memorial Hall (Gym Closed)	Jerome Library	Fine Arts Center	Wolfe Center for the Arts
Compact Fluorescent	4 to 8	24" High Bay Acrylic	x	x													
Compact Fluorescent	1	8" Downlights			x	x				x		x	x		x		
Compact Fluorescent	1	12" Wall Sconces						x									
Compact Fluorescent	1	8" Exterior Downlights									x						
Compact Fluorescent	1	Decorative Pendant									x						
Compact Fluorescent	1	Exterior Wall Packs										x					
Compact Fluorescent	1	Retrofit Downlights												x			
Compact Fluorescent	1	Surface Mounted Cylinders													x		
T8 Fluorescent	2	6"x4' Recessed Cover Lighting											x				
T8 Fluorescent	2	12"x4' Surface Mounted Wall Fixture											x				
T8 Fluorescent	2	6"x4' White Lens Acrylic															x
T8 Fluorescent	2	1'x4' Suspended Industrials		x												x	x
T8 Fluorescent	2	1'x4 Recessed Acrylic Lens			x												
T8 Fluorescent	2	6"x4" Strip Lights			x												
T8 Fluorescent	2	1'x4' Suspended Acrylic Lens			x												
T8 Fluorescent	2	1'x4' Surface Mounted Acrylic Wraparounds			x							x		x		x	
T8 Fluorescent	3	1'x4' Surface Mounted Acrylic Wraparounds			x											x	
T8 Fluorescent	2	1'x4' Surface Mounted Acrylic Lens			x												
T8 Fluorescent	3	2'x4' Drop Lens Acrylic					x										
T8 Fluorescent	4	2'x4' Paracube					x										
T8 Fluorescent	2	2'x2' Prismatic Acrylic Lens Recessed										x					
T8 Fluorescent	3	2'x4' Prismatic Acrylic Lens Recessed					x				x					x	x
T8 Fluorescent	4	2'x4' Prismatic Acrylic Lens Recessed															
T8 Fluorescent	2	2'x4' Prismatic Acrylic Lens Recessed										x					
T8 Fluorescent	2	2'x2' Parabolic Louver Recessed											x				
T8 Fluorescent	4	2'x4' Parabolic Louver Recessed					x										
T8 Fluorescent	2	2'x4' Parabolic Louver Recessed							x	x							
T8 Fluorescent	3	2'x4' Parabolic Louver Recessed				x			x	x			x			x	
T8 Fluorescent	2	2'x4' Recessed Basket Fixtures	X							x							x
T8 Fluorescent	4	12"x4' Decorative Wall Bracket														x	
T8 Fluorescent	2	2'x2' Prismatic Acrylic Lens Surface															x
T8 Fluorescent	2	2'x2' Recessed Basket Fixture	x														x
T8 Fluorescent	2	12"x4' Cove Lighting/Wall Wash	x														x
T5 Fluorescents	8	2'x4' High Bay Linear Industrials		x													
T5 Fluorescents	2	2'x2' Recessed Volumetric		x													
T12	2	1'x4' Prismatic Acrylic Lens Recessed													x		
HID	1	2'x2' Recessed Acrylic Lensed		x													
HID	1	24" High Bay					x										
HID	1	Recessed Lens Exterior Canopy							x	x							
HID	1	18" Decorative Pendants									x						
HID	1	18" Wall Sconces											x				
HID	1	12" Exterior Pendant Lighting														x	
HID	1	12" Pendant Cylinders	x														
Incandescent	1	8" downlight					x										
Incandescent		Track Lighting									x						
LED Retrofit lamps	1	24" glass pendants			x												
LED		6"x4' Recessed Linears		x		x		x									
LED		6"X4' Pendant linears		x													
LED		8" Downlights						x									
LED		2'x4' Recessed Volumetric							x								
LED		24" Uplight Wall Brackets	x	x													
LED		2'x2' Recessed Volumetric		x													
LED		Decorative Pendants						x									

NOTE: COULD NOT ACCESS THE FOLLOWING BUILDINGS: SEBO ATHLETIC CENTER, DOTY PERRY STADIUM, FALCON LANDING, MILEIT ALUMNI CENTER, ICE ARENA, KOHL HALL, KREISCHER AND HARSHMAN HALL

Table 5. Existing Lighting Types per Building East of S. College

WEST CAMPUS (WEST OF S. COLLEGE)

Lamp Type	# of Lamps	Fixture Type	Founders Hall and Family/Consumer	West Hall	McFall Center	Kuhlin Center	Hanna Hall	Adminstrative Building	Shatzel Hall	Williams Hall	Bowen-Thompson Student Union	Hayes Hall	The Oaks Dining (Closed)	Overman Hall	Math Science	Offenhauer (Only Public Areas)	Life Sciences Center	Physical Sciences	Psychology
Compact Fluorescent	4 to 8	24" High Bay Acrylic													x				
Compact Fluorescent	1	8" Downlghts						x		x	x						x		x
Compact Fluorescent	1	Retrofit Downlights													x				
Compact Fluorescent	1	Surface Mounted Cylinders											x						
Compact Fluorescent	1	12" Decorative Lensed Recessed									x								
Compact Fluorescent	1	10" Decorative Wall Sconce	x																
Compact Fluorescent	6	30" Decorative Bowl Penants			x														
T8 Fluorescent	2	1'x4' Suspended Industrials											x						
T8 Fluorescent	2	1'x4 Recessed Acrylic Lens	x						x						x				
T8 Fluorescent	2	1'x4' Surface Mounted Acrylic Wraparounds	x													x	x		
T8 Fluorescent	3	1'x4' Surface Mounted Acrlic Wraparounds																	
T8 Fluorescent	2	1'x4' Surace Mounted Acrylic Lens	x		x														x
T8 Fluorescent	4	2'x4' Paracube															x		
T8 Fluorescent	2	2'x2' Prismatic Acrylic Lens Recessed	x								x								
T8 Fluorescent	3	2'x4' Prismatic Acrylic Lens Recessed	x	x	x			x						x	x	x	x	x	x
T8 Fluorescent	4	2'x4' Primatic Acyrlic Lens Recessed													x				
T8 Fluorescent	2	2'x4' Prismatic Acrylic Lens Recessed		x						x				x					
T8 Fluorescent	2	2'x2' Parabolic Louver Recessed									x					x			
T8 Fluorescent	2	2'x4' Parabolic Louver Recessed			x				x			x							
T8 Fluorescent	3	2'x4' Parabolic Louver Recessed		x	x					x		x				x			x
T8 Fluorescent	2	12"x4' Decorative Wall Bracket							x										
T8 Fluorescent	2	2'x2' Prismatic Acrylic Lens Surface					x	x											
T8 Fluorescent	2	2'x2' Parabolic Louver Surface						x											
T8 Fluorescent	2	18"x4' Old School House Linear Pendants	x				x												
T8 Fluorescent	2	2'x2' Recessed Basket Fixture									x								
T8 Fluorescent	2	12"x4' Cove Lighting/Wall Wash									x								
T8 Fluorescent	3	18"x8' Direct/Indirect Linear Pendants																x	
T8 Fluorescent		Custom Linear Uplights										x							
T5 Fluorescents	1	Wall Wash Fixture						x											
T12	2	1'x8' Surface Mounted Strip Lights					x												
Incandescent	1	8" downlight											x						
Incandescent		Track Lighting											x						
LED		6"x4' Recessed Linears				x					x								
LED		8" Downlights			x	x					x								
LED		2'x4' Recessed Volumetric				x													
LED		6"x4' Pendant				x					x								
LED		Track Lighting									x								
LED		48" Wall Wash			x														
LED		Retrofit of Existing Historical Fixtures			x														

NOTE: COULD NOT ACCESS THE FOLLOWING BUILDINGS: MCDONALD HALL, UNIVERSITY/MOSELY HALL, FALCON HEIGHTS AND BUREAU OF CRIMINAL INVESTIGATION.

Table 2. Existing Lighting Types per Building West of S. College

When you start looking through the data you will quickly see that most of the existing lighting on campus is comprised of T8 fluorescent. It is the predominate lighting source with compact fluorescent sources coming in second. There are of course pockets of LED lighting as well. This profile is not unexpected and the good news is that there is very limited incandescent and T12 fluorescent lighting on campus. Another positive is most spaces have occupancy control, helping save even more energy.

On east campus everything is T8, T5, Compact Fluorescent or LED except for the following:

- HID
  - Lensed recessed fixtures in the racquet ball courts in the Student Recreation Building
  - Surface Cylinders in the Stroh Center
  - Pendant high bays in the Eppler Center
  - Recessed lensed fixtures in exterior canopy of the Education and Business Administration Building (note, these could be incandescent)
  - Decorative pendants in Carillon Place Dining
  - Wall mounted up lighting in East Hall and Fine Arts Center
- Incandescent
  - Down lights in Eppler Center
  - Track lighting Carillon Place Dining
- T12
  - The recessed lighting in the library appeared to be T12, but there was also T8. Could not confirm the entire building.

Sticking with the east side of campus, there have been improvements in some areas by replacing older fluorescent lighting to LED lighting. Some of this as part of the Student Green Initiative Fund (SGIF) and others as part of general renovations. These areas include:

- LED
  - Wall wash fixtures in the Stroh Center
  - Recessed and pendant acrylic lens, wall wash fixtures and volumetric fixtures in the Student Recreation Center (SGIF)
  - Retrofit lamp replacements in glass globes in Moore Musical Arts Center
  - Recessed acrylic lens fixtures in Health and Human Sciences building
  - Recessed acrylic lens, decorative pendants and downlights in Olskamp Hall
  - Recessed volumetric fixtures in Education Building

Switching to the west side of campus in a similar discussion, everything is either T8, T5, compact fluorescent of LED except for the following:

- T12
  - Surface mounted strip lighting in Hall
- Incandescent
  - Track lighting in the Oaks Dining
  - Recessed down lighting

As with the east portion of campus, there have been a number of upgrades lighting systems on the west side of campus. Some of these as part of the Student Green Initiative Fund (SGIF) and others as part of general renovations. These areas include:

- LED
    - Retrofit of existing historical fixtures in the McFall Center
    - Recessed downlights and wall wash fixtures in the McFall Center
    - Recessed linear lensed, downlights, volumetric and volumetric pendants in the Kumlin Center.
    - Recessed linear lensed, downlights, decorative pendants and track lighting in the Bowen-Thompson Student Union.

In addition to the information listed above, we know from the Student Green Initiative Fund Annual reports in buildings that could not be accessed during our site visits that the lighting in the Perry Field House, the Ice Arena commons areas and the two pools in the Student Recreation Center have all been replaced with LED lighting in the past several years. The estimated savings on these three projects alone is over 385,000 kWh per year with an estimated savings of $32,000 per year.

<u>Technologies:</u>

Analyzing the savings above associated with the LED upgrades in the Perry Field House, the Ice Arena and the Student Recreation Center, it is hard not to push for as much energy reduction through lighting replacement and retrofit as possible. Recall that most of the lighting sources on campus now are T8 fluorescent. These T8 lamps are used in all different areas including corridors, classrooms and offices and are typically parabolic louver/prismatic lens or surface wraparound. Occasionally there is a linear pendant as well, but in the larger picture, the three types above represent the majority of what is on campus.

How does performance from an energy and efficiency standpoint change between these different types of fixtures? Let’s start with looking at the two lamp recessed parabolic fixture indicated in Figure 2 below. This fixture consumes between 55 and 60 watts when provided with two, 32W T8 lamps.

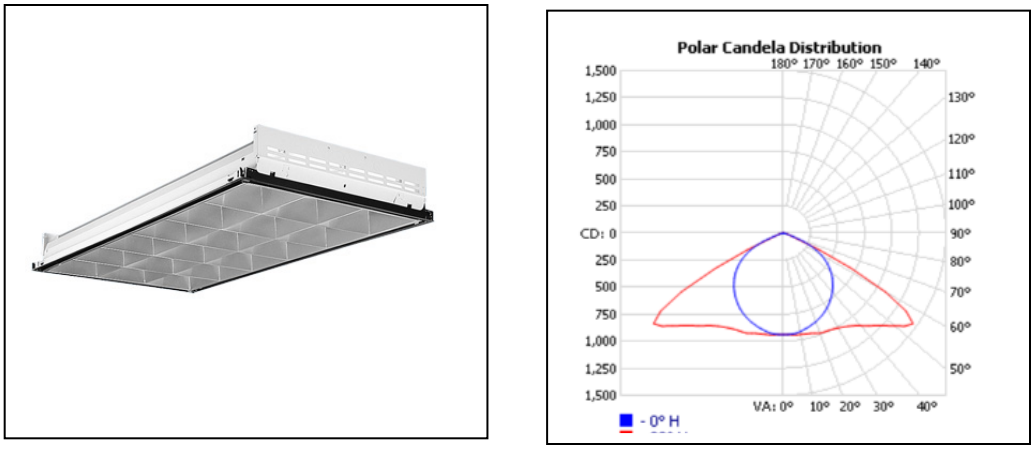


Figure 2. Recessed Parabolic Lighting and Distribution Curve

In addition to the input wattage, this fixture is only 58% efficient meaning that over 40% of the output is lost in some fashion. This efficiency creates a design challenge since more fixtures would be needed to provide a certain illumination level than other higher efficiency fixtures. Therefore, since there are many of these parabolic light fixtures installed through campus, most of the output is lost through poor efficiency. Any lighting replacement of parabolic light fixtures with LED would not only provide a higher efficiency with lower wattages, it would also require less fixtures to light the same about of space. Existing classrooms with twelve fixtures may only need nine. Or offices with two or three fixtures may only need one. The net result is a huge savings in energy.

The second fixture to review is the most widely used on campus. The specification grade two lamp, acrylic prismatic lensed troffer that is indicated in Figure 3. This fixture also consumes between 55 and 60 watts when provide with two, 32W T8 lamps.

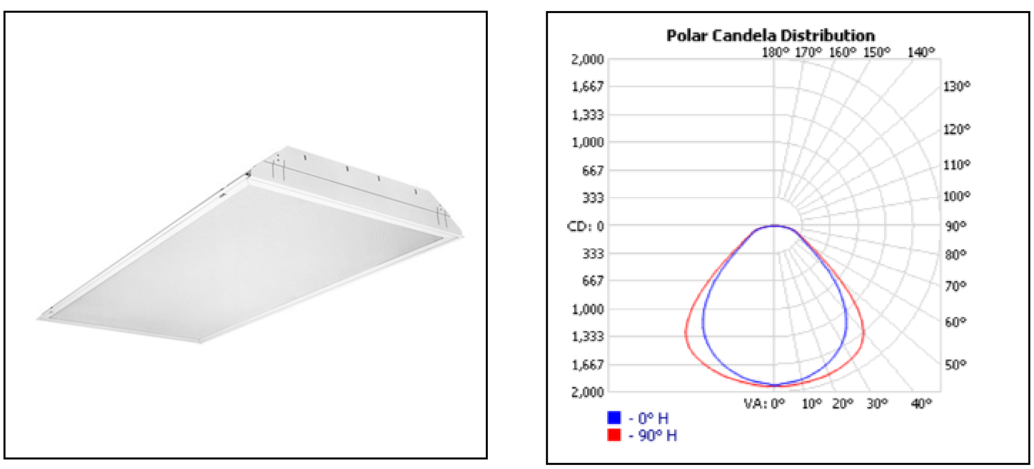
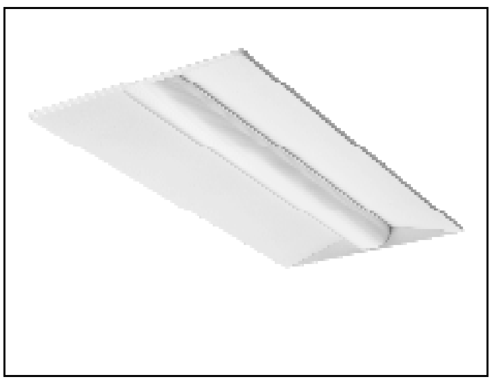


Figure 3. Recessed Prismatic Lighting and Distribution Curve

The recessed prismatic troffer is a better performer than the recessed parabolic at 85% efficient. You can tell from the polar candela distribution curve that much more of the light (almost 1000 Candela more) is pushed down toward the floor while the distribution curve for the parabolic is much more outward. Even though this efficiency is much better it still provides less lumen per watt and uses more energy than typical recessed LED troffers.

So how do LED recessed fixtures compete against the two options listed above. First let's start with the overall wattage of an LED option. The fixture used in this example is Lithonia Lighting 2OBLT4 series and is shown in Figure 4. This fixture has a 4000 lumen package, curved prismatic lens and delivers almost 3800 lumens maintained. It also operates with an input wattage of 34W, which is around 40% less than both options listed above. What is noteworthy about this LED fixture is that It can be ordered with a high efficiency package that is greater than 130 lumens per watt. For reference the lumens per watt associated with the prismatic fixture referenced in Figure 3 was under 90 lumens per watt. This higher lumen per watt allows the designers to use fewer fixtures while still maintaining input wattages much lower than the fluorescent counterparts.



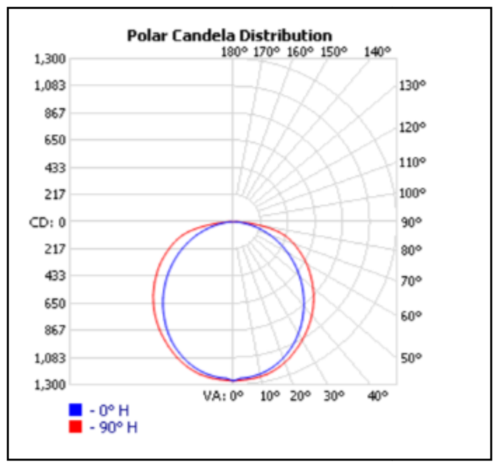


Figure 4. Recessed LED Lighting and Distribution Curve

Feasibility:

The purpose of this study is to help guide Bowling Green State University with decisions that will affect their energy consumption and carbon reduction strategies over the next three decades. The purpose is not to design each ECM or Renewable Energy strategy. However, it may be best to demonstrate how big of an effect a lighting replacement could have on just one building. Then look holistically at how this same approach could be applied to the rest of campus.

The example used here is the Math Science Building. This building was almost completely lit with recessed 2'x4' prismatic lens troffers. There were two, three and four lamp units. There were also a few areas like the Office of Resident life that had two lamp recessed 1'x4' prismatic lens troffers were over lit. A few things that we know about this building: the building itself is around 113,000 square foot. Electrically it is consuming 1,680,836 kWh per year and has an EUI of 164.

When this example is modeled as indicated in Figure 5, you can see that over the course of 20 years that the total cumulative cash saved is over $1.4 million dollars and around 418,000kWh in saved energy per year. This represents a 28% savings in electrical consumption costs for this building alone. So why were the savings not closer to the 35% average the Department of Energy suggests? Some of this is related to some other energy savings strategies that have been implemented such as occupancy control in the corridors and in the classrooms. In addition to the lighting controls, the building has other energy related problems with an EUI that high more than likely due to HVAC and controls that could be studied more in the future.

This example demonstrates the dramatic energy reductions that LED lighting replacements can have on a single buildings energy performance. So, what would be the best way to roll this out across campus? That question has a very complex response. There are many things you have to consider when making that decision. Some that come to mind are the age of the existing equipment, the existing EUI of the building, and future renovation considerations. Some possible ideas will be provided in the recommendations section of the report.

Math Science Building LED Lighting Energy Savings

Connected Lighting Reduction below ASHRAE/Typical (0.45 W/sf Vs. 1.3 W/sf @ 113,200SF) (kW)	96.5
Year 1 Energy Savings @ Average 10 hrs/day (kWh)	352,466
BGSU Blended Commercial Utility Rate ($/kWh)	0.099
Annual Energy Escalation Rate (Historical Average)	5.0%
Avoided HVAC First Cost (20 Tons @ $1,600/ton w/ 20% Diversity N+1 Redundancy)	$32,000
Total LED Cost Premium (1000 Estimated Total Fixtures @ Average $60 Premium)	**$60,000**
Annual Avoided HVAC Energy @ COP = 4 (kWh)	65,653
Annual Avoided Cost Due to No Relamping (1/2 Lamp per Fixture per Year @ $8/Lamp labor+materials and 2% inflation)	$4,000

Year	KWH Saved	($/kWh)	$ Saved	Avoided Relamp Cost	Annual Cash Flow	Total Cash Flow
1	418,119	$ 0.099	$41,498	$ 4,000	**$ 45,498**	**$ 45,498**
2	418,119	$ 0.104	$43,573	$ 4,080	**$ 47,653**	**$ 93,152**
3	418,119	$ 0.109	$45,752	$ 4,162	**$ 49,914**	**$ 143,065**
4	418,119	$ 0.115	$48,040	$ 4,245	**$ 52,284**	**$ 195,349**
5	418,119	$ 0.121	$50,441	$ 4,330	**$ 54,771**	**$ 250,121**
6	418,119	$ 0.127	$52,964	$ 4,416	**$ 57,380**	**$ 307,501**
7	418,119	$ 0.133	$55,612	$ 4,505	**$ 60,116**	**$ 367,617**
8	418,119	$ 0.140	$58,392	$ 4,595	**$ 62,987**	**$ 430,604**
9	418,119	$ 0.147	$61,312	$ 4,687	**$ 65,999**	**$ 496,603**
10	418,119	$ 0.154	$64,378	$ 4,780	**$ 69,158**	**$ 565,760**
11	418,119	$ 0.162	$67,596	$ 4,876	**$ 72,472**	**$ 638,233**
12	418,119	$ 0.170	$70,976	$ 4,973	**$ 75,950**	**$ 714,183**
13	418,119	$ 0.178	$74,525	$ 5,073	**$ 79,598**	**$ 793,781**
14	418,119	$ 0.187	$78,251	$ 5,174	**$ 83,426**	**$ 877,206**
15	418,119	$ 0.197	$82,164	$ 5,278	**$ 87,442**	**$ 964,648**
16	418,119	$ 0.206	$86,272	$ 5,383	**$ 91,656**	**$ 1,056,304**
17	418,119	$ 0.217	$90,586	$ 5,491	**$ 96,077**	**$ 1,152,380**
18	418,119	$ 0.227	$95,115	$ 5,601	**$ 100,716**	**$ 1,253,096**
19	418,119	$ 0.239	$99,871	$ 5,713	**$ 105,584**	**$ 1,358,680**
20	418,119	$ 0.251	$104,864	$ 5,827	**$ 110,691**	**$ 1,469,372**
Total	**8,362,385**		**$ 1,372,182**	**$ 97,189**	**$ 1,469,372**	

Figure 5. Math Science ROI Example

Cost:

The cost of LED lighting fixtures has come down dramatically over the past year. In many cases there is little or no cost difference depending on the LED fixture that you are considering for use in the replacement. The other good news is that over half of the buildings have ceilings that are in good shape and would not need any ceiling work associated with a full lighting replacement. For instance, the Bowen-Thompson Student Union has a large number of 2'x2' recessed parabolic fixtures that would be good candidates for replacement and the ceilings are in great shape. In that case, we could just do a one for one swap. On the flip side, the Jerome Library has a ceiling system (concealed spline) and a lighting layout that does not work with the existing circulation and stack layouts. In this case the entire ceiling and lighting systems should be replaced.

The other cost consideration would be ensuring that occupancy sensors are added into all of the existing spaces. During our site investigation, it appears that almost all corridors and classrooms had been upgraded with occupancy control. However, there were several instances that areas were not covered by occupancy sensors. One such area was the corridors in West Hall. None of those corridors had occupancy control. This may not be an issue if the demolition of West Hall is still planned to happen in the near future. Regardless, any complete building LED retrofits would need to be evaluated for occupancy control.

From a cost standpoint, the typical lighting replacements where existing circuiting and controls can be used the University would see between $4 and $5 per square foot. If controls need to be added, then we would recommend adding an additional $0.50 per square foot. In some areas, we may suggest just replacing the existing lamps with LED tubes. We would only recommend this in areas where the fixture is fairly new and in good shape, in short, has some life left. In areas like the Jerome Library where you need to also add in ceiling rework, additional costs need to be added in for the ceiling work itself. In this case, you would need to add an additional $4.00 to $5.00 per square foot. So, from a rough number standpoint to go all in and replace a majority of lighting on campus you would be in the $20M to $25M range. This number is obviously a rough estimate assuming that the square footages that we would be touching would be 20% or so below the total square foot of the campus.

Recommendations:

Our recommendation would be to do as much of this lighting replacement as possible versus doing a project here and there. The savings and paybacks are too great not to focus a great deal of attention to this Energy Conservation Measure. The best way to achieve this would be to do an Energy Service Contract (ESCo) project with a guaranteed energy savings. This method will be discussed more in the recommendations section of the overall report.

If the University would prefer and area by area replacement, then our suggestion would be to start with buildings that have older technology that needs to be replaced anyway and do lighting and controls replacement design projects for each building. These buildings would include the Jerome Library (original fixtures), Hanna Hall (T12 and Linear Classroom Pendants), Eppler (4 lamp paracube, 2’x4’ drop opaque lens and HID). The second areas that we would focus in on would be areas that are the front door to campus. This would include the Bowen-Thompson Student Union (replacement of 2’x2’ parabolic and the cove lighting in the ballrooms. The final suggestion would be to look at the buildings with the highest EUI’s. These would include The Oaks Dining Hall (403), Carillon Place (319), Physical Science Lab (255), Psychology Building (scheduled for demo, 225), Visitor Information Center (201), etc. The last recommendation would be to create lighting standards on performance as mentioned in section IV of this study. Standards that are held to a higher level than ASHRAE compared to what is currently in BGSU’s campus design standards.

Final Thoughts:

This portion of the report focused entirely on the interior building lighting loads. We do not want to forget about the exterior lighting. There have been some LED replacements on campus including the main road lighting along Mercer, the plaza and parking around the Student Recreation Center, the parking areas between Kreischer and Harshman Halls, the parking area between the green houses and the BCI building and the new parking area to the west of the Bowen-Thompson Student Union. However, the rest of the lighting on campus is HID arm mounted or post top. We would recommend replacement of all of these as well. In addition to that, we would recommend doing LED replacements that would allow for high low occupancy control. LED lighting provides much better vertical and horizontal distribution. It also has much better color rendering. There are many examples of this strategy being used on campus across the country knowing that security is always going to be the most important consideration. We would also recommend reusing poles and bases that are still in good condition and only replacing the lighting heads.

VI. Energy Conservation Measures

b. Building Automation System Upgrades

The campus energy goals are impacted by the ability to control the HVAC and Lighting systems within each building. Through the implementation of standard control sequences and occupancy schedules significant energy and cost savings would be obtained.

Building Automation System (BAS) upgrades are a less costly strategy for reducing energy. It is recommended to implement BAS Upgrades as part of an Energy Service Contract (ESCo) where it can provide funding for longer payback Energy Conservation Measures (ECM's). The other option is to utilize capital financing to perform BAS upgrades within buildings.

Feasibility:

The purpose of this study is to help guide Bowling Green State University with decisions that will affect their energy consumption and carbon reduction strategies over the next three decades. The purpose is not to design each ECM or Renewable Energy strategy. This ECM would consist of expansion of the existing system and implementation of new sequences of operation. In addition, the staffing for detailed scheduling of classrooms based on course schedule to maximize savings.

The BGSU is recommended to leverage the BAS to maximize energy savings. This includes a high level of scheduling the spaces and controlling the ventilation to the buildings.

It is highly recommended to consolidate the summer courses with the Campus most efficient buildings where possible. This recommendation largest hurdle is faculty and staff buy-in. The BGSU Energy Charrette indicated a lack of desire to teach in classrooms assigned based on optimizing the building efficiencies. As the University progresses in their sustainability efforts this will need to be addressed. The building management system in conjunction with policy changes for classroom efficiencies will reduce electric demand, electric consumption and building natural gas reheat.

Recommendations:

The majority of the campus is on the BAS System. Additional investment is recommended for implementation of schedules and sequences though-out the campus. The CMTA Energy services group typically can achieve 20% energy reduction through BAS upgrades. Addition of the following sequences would be recommended.

Building Automation System Upgrades

- Decouple Ventilation and Conditioning Schedules
- Hot Water Heating System : Reset schedules and variable volume
- Chilled Water System: Reset schedules and variable volume.

- VAV Air Handling Units: Reset Schedules
- Energy Recovery Wheels for Minimum Ventilation
- Dedicated Outside Air Systems
- Domestic Hot Water: Scheduling
- Demand Limiting

VI. Energy Conservations Measures

c. Power Factor Correction

Power factor correction is a savings strategy that BGSU is already making strides in. In August 2015, 450 kVAR of capacitors were installed on the 4160 V side of the Southeast feeder. This installation is shown in appendix as "Item A". This installation has led to average annual power factor of 94.2% which is an increase of 1.4% over previous years.

Year	Average Annual Power Factor
2013	93.3%
2014	92.9%
2015	94.2%

Table 6. BGSU Annual Average Power Factor

This increase is shown in more detail in the monthly power factor data shown in Figure 1. The largest increases as well as the largest room for improvement are in the cooling season. This dip in power factor is typical of cooling loads, since many components of the chilled water system are heavy in inductive loads (centrifugal chillers, pumps, and large fans).

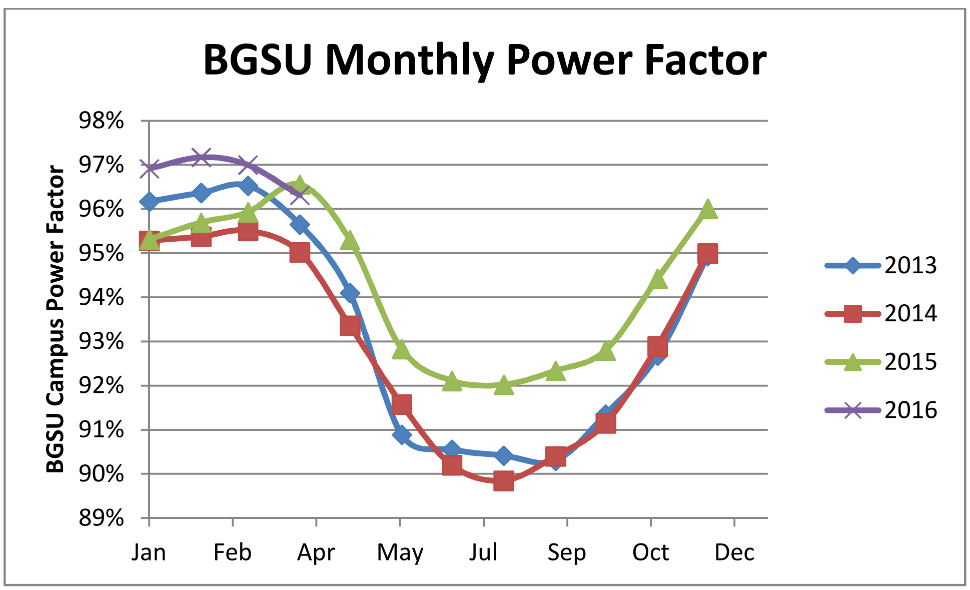


Figure 8. BGSU Monthly Power Factor for 2013-2016

Figure 2 shows the power factor associated with each of the four feeders throughout the BGSU campus. The two feeds that have the best opportunity for improvement are the Southeast and Southwest feeders. The Southeast feeder was addressed by the 450 kVAR capacitor bank installed in August.

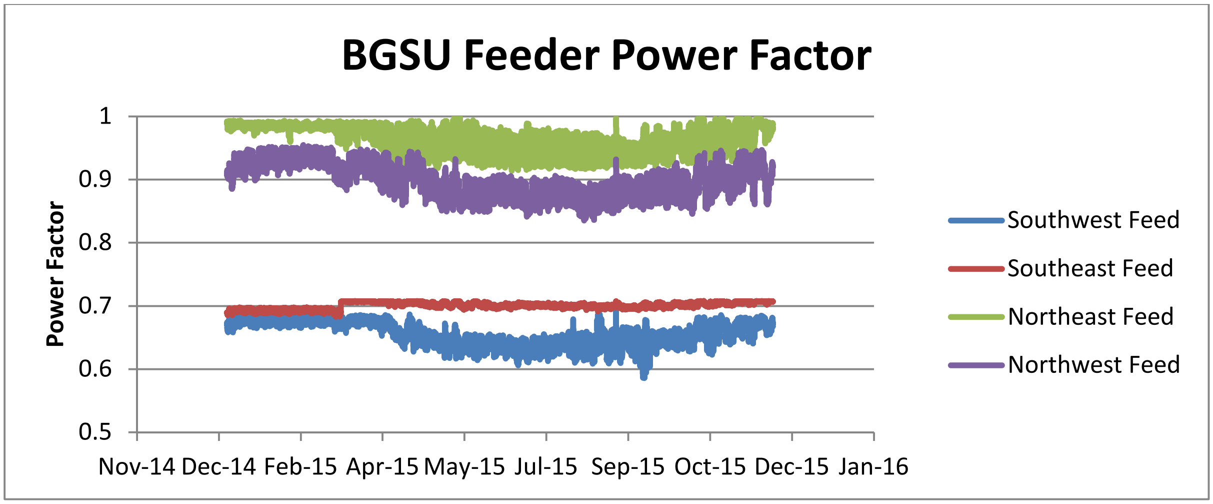


Figure 2. BGSU Feeder Power Factor for 2015

Technologies:

Power factor correction is done by adding capacitor banks or inductors to the electrical system. In BGSU's situation, the lower power factor is a result of inductive loads and therefore capacitor correction is needed. There are multiple strategies for power factor correction. The first choice to be made in correcting power factor is where to correct it. There are two options; at the end device that causes the low power factor, or at the service entrance of the electric utility.

Point source power factor correction is done with fixed or static capacitors. These capacitors are sized specifically for the load that they are connected to and only correct the power factor of the load they are installed on. Common loads that cause low power factor are magnetic ballasts, under loaded transformers, and electric motors. The high quantity of lights and variability of transformer loads make it cost prohibitive to address these loads on a device by device level. Large constant volume motors attached to pumps and fans are good candidates for installing point source capacitors. Fixed capacitors are fine with large motors (25 HP and above) because they are installed between motor contactor and the overloads. Therefore, the capacitance is only on the system when the motor is running. The issue is checking on them. They fail over time and if no one knows about it, the savings associated with them will not be realized. An additional strategy for improving power factor on motors is installing variable frequency drives (VFD). This strategy doesn't raise the power factor as much as a capacitor bank, but the additional control and power savings associated with the VFD makes this strategy a quicker payback.

Service entrance capacitor banks are much more sophisticated because that have to be able to alter and adjust the capacity as the load fluctuates. These types of units are called auto capacitor banks. In addition to correcting power factor, these units can provide harmonic distortion resolution. These units are typically more expensive to install, but the ease of maintaining one system in a central location can outweigh these costs. Building level auto capacitor banks can be utilized to address individual buildings that are known issues. Multiple building level systems would be the most robust system.

Cost:

The costs vary widely for power factor correction depending on which strategy is employed. Many strategies need additional equipment installed in coordination that drives the price up for installation. These additional systems include meter current transducers (CTs), voltage transducers (VTs), and isolation breaker banks. Fixed capacitor systems are typically $75/kVAR while auto capacitor banks are typically $150/kVAR. Systems made for distribution voltage (greater than 480 V) are additional costs due to the fact that they need to be custom designed for each application.

Recommendation:

By making continual improvements, BGSU can make strides to get to an annual average power factor of 98%. By strategically installing an additional capacitor banks and reducing inductive loads, the annual savings available due to power factor correction are approximately $93,000. BGSU has three options to get to this point:

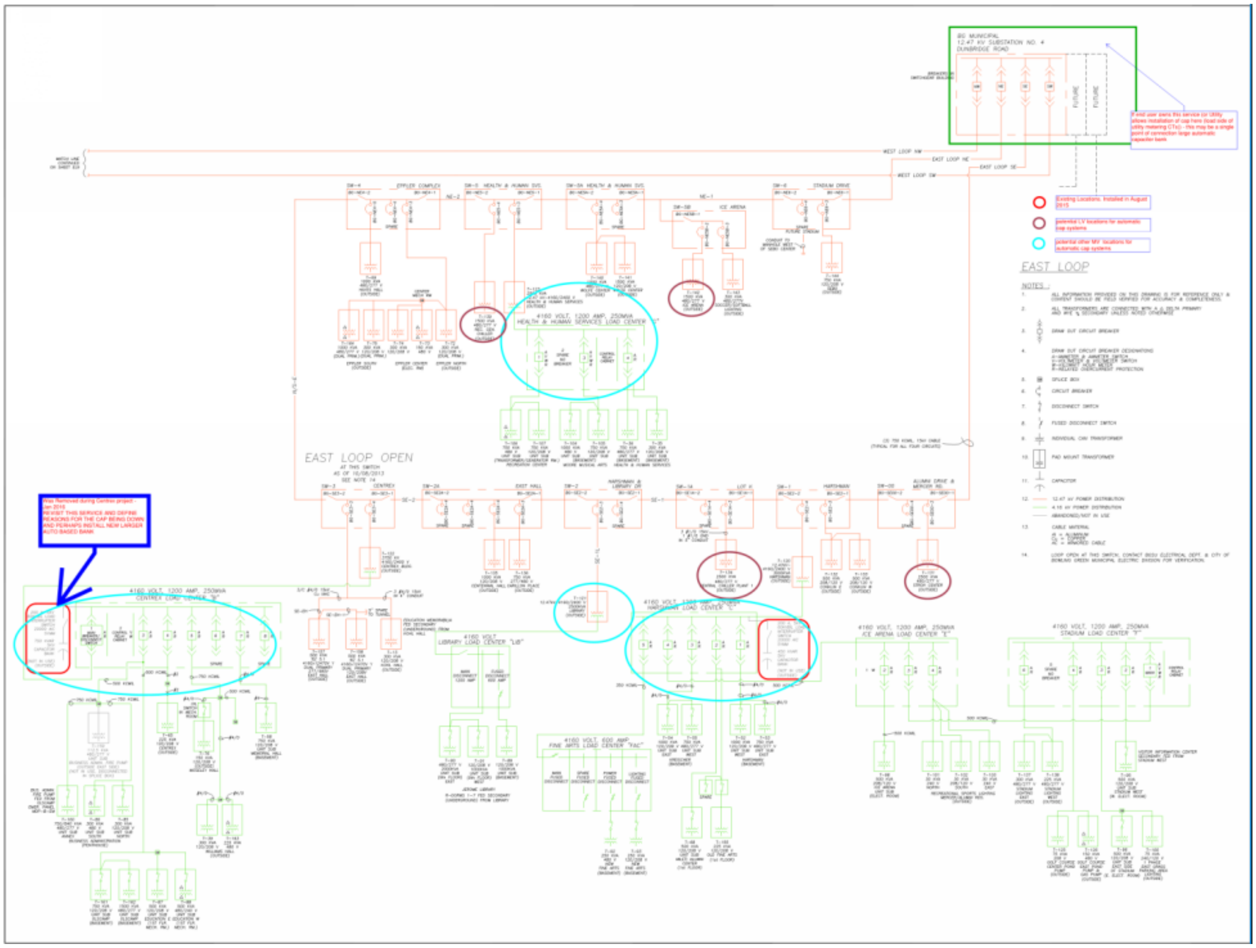
- Install all VAR as one centralized 12.47 kV auto capacitor system. For this, BGSU needs to own the 12.47 kV substation and all utility revenue metering CTs must be on the line side of the capacitor connection. In addition, a new feeder breaker cell would be needed to be fitted with breaker.
- Install all at low voltage (480V) locations. This may be challenging due to the pure number of various services and variety of VAR needs.
- Install a mix of medium voltage (4.16 kV and 12.47 kV) and low voltage. Target some large low voltage services requiring large amount of VAR (see attached drawing in Item A for possible locations) and apply the remaining need a few 4.16 kV locations.

CMTA recommends utilizing option 3 after a systematic approach is taken to reviewing loads (specifically cooling). This option is likely the most feasible option from an equipment and redundancy point of view. This will likely be a 6-year payback opportunity.

	Existing Conditions			Proposed Conditions			
	kVA	Power Factor	Demand Bill	kVA	Power Factor	Demand Bill	Savings
Jan-15	9,027	95.3%	$ 144,433	8,780	98.0%	$ 140,473	$ 3,960.02
Feb-15	8,841	95.7%	$ 141,452	8,633	98.0%	$ 138,122	$ 3,329.97
Mar-15	9,157	95.9%	$ 146,513	8,963	98.0%	$ 143,412	$ 3,100.36
Apr-15	9,135	96.6%	$ 146,153	9,000	98.0%	$ 144,000	$ 2,152.55
May-15	11,899	95.3%	$ 190,387	11,571	98.0%	$ 185,143	$ 5,243.67
Jun-15	12,410	92.8%	$ 198,561	11,755	98.0%	$ 188,082	$10,479.76
Jul-15	13,054	92.1%	$ 208,868	12,269	98.0%	$ 196,310	$12,558.01
Aug-15	13,654	92.0%	$ 218,461	12,820	98.0%	$ 205,127	$13,334.11
Sep-15	15,354	92.3%	$ 245,659	14,466	98.0%	$ 231,458	$14,200.84
Oct-15	15,863	92.8%	$ 253,811	15,021	98.0%	$ 240,333	$13,477.75
Nov-15	12,467	94.4%	$ 199,478	12,012	98.0%	$ 192,196	$ 7,282.20
Dec-15	12,351	96.0%	$ 197,623	12,100	98.0%	$ 193,607	$ 4,016.34
Total			$2,291,398			$2,198,263	$ 93,136

Table 7. Savings Calculations for increasing to 98% Power Factor

Appendix Notes:



Item A. Campus Primary Electric Single line

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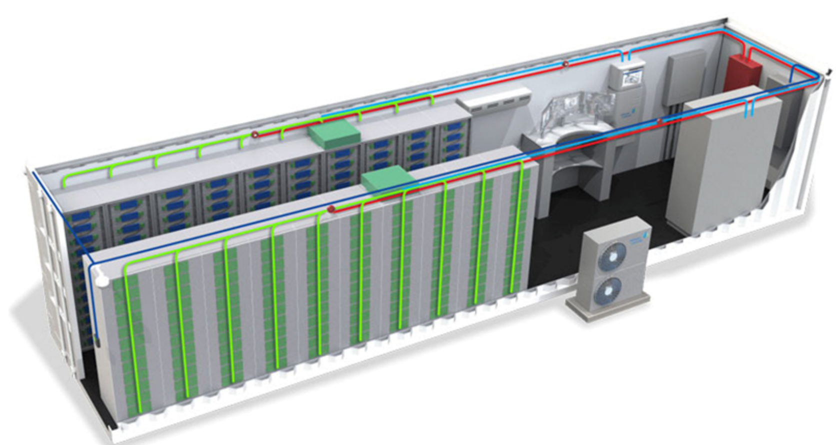
VI. Energy Conservation Measures

d. Li-Ion Energy Storage Systems

Energy storage can be accomplished in a number of ways including compressed air, gravitational potential energy, flywheels and thermal and chemical energy systems just to name a few. However, battery storage systems, in particular Li-Ion battery storage systems, are becoming more common for a variety of applications mostly due to decreasing costs.

There are several battery chemistries that have been used historically, each with a slightly different set of strengths and weaknesses depending upon the application. Cost ($/kWh), specific energy density (kWh/kg), specific power density (kW/kg) and cycle life (# charge/discharge cycles before EOL) are typically the most import factors to consider. Hardly a week goes by without a scientific article touting a promising new battery chemistry that will solve the world's energy problems if only it didn't have a critical flaw in one of these four categories. Meanwhile, Li-Ion battery technology has steadily improved year after year resulting in major improvements in all areas, especially cost.

Li-Ion energy storage systems are extremely modular. They can be provided in capacities as low as two kWh to tens of MWh in order to meet specific needs. The kWh (storage capacity) and kW (power output) ratings are both important to the functionality of the system but the kWh almost always drives the overall cost. Therefore, applications which require a relatively low kWh per kW will see faster paybacks.



Two examples of Li-Ion energy storage systems: JCI L1000 – 65kWh, JCI L2000 – 2MWh.

Applications:

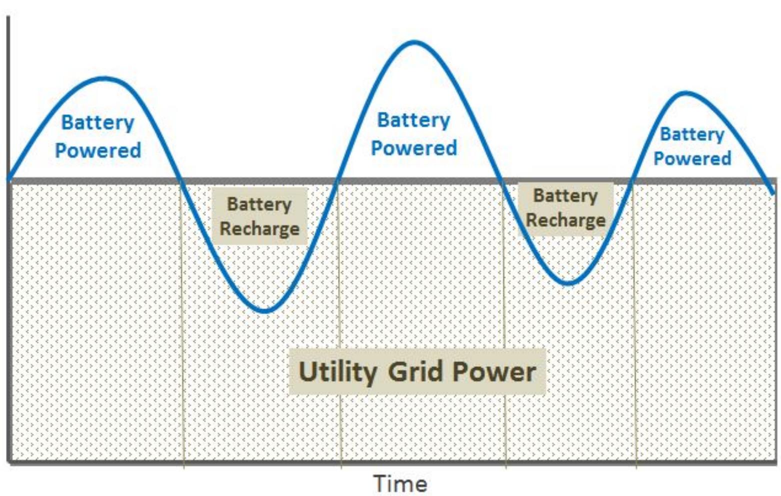
The days of flywheels and enormous rooms full of lead-acid batteries are quickly coming to an end. While traditional energy storage applications such as data center UPS's are switching to Li-Ion, this technology is finding new applications as cost continues to decrease.

Li-Ion energy storage systems have many uses including:

- Backup Power
- Power Conditioning
- Frequency Regulation
- Renewable Energy Firming
- Peak Shaving
- PF Correction
- Decoupling generation from loads
- Microgrid Support

The systems that are able to stack multiple applications generally see the shortest payback periods. Some of these applications such as peak shaving and frequency regulation cannot occur simultaneously but others such as PF correction and power conditioning always take place. Peak shaving is often the top priority for non-utility entities; however, the system may only need to actively peak shave less than 5% of the time. Therefore, it is possible for the system to participate in a frequency regulation program during the other 95% of time in order to earn additional revenue.

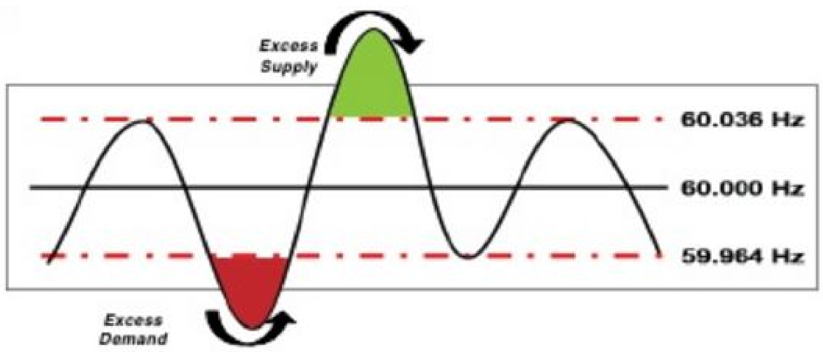
Peak shaving reduces the billed demand from the utility by discharging the battery during demand spikes and recharging in between these spikes. In some situations, peak shaving alone can yield payback of less than three years. Detailed demand interval data is required to generate a load profile in order to confirm potential savings for this application.



Basic peak shaving example.

There is a direct relationship between the grid's signal frequency (nominal 60Hz) and the balance of supply and demand. When there is not enough generation to meet loads, grid frequency decreases and conversely will increase when there is not sufficient load. Many utility generation sources are very large and respond slowly, therefore programs are available in many regions which compensate participants who have more agile generation sources for helping to maintain grid frequency. A Li-Ion energy storage system can be programmed to charge during times of low grid demand and discharge during times of high grid demand but only when not actively engaged in peak shaving. This generally only requires very small charge/discharge activity so that the effect on other stacked applications is minimal.

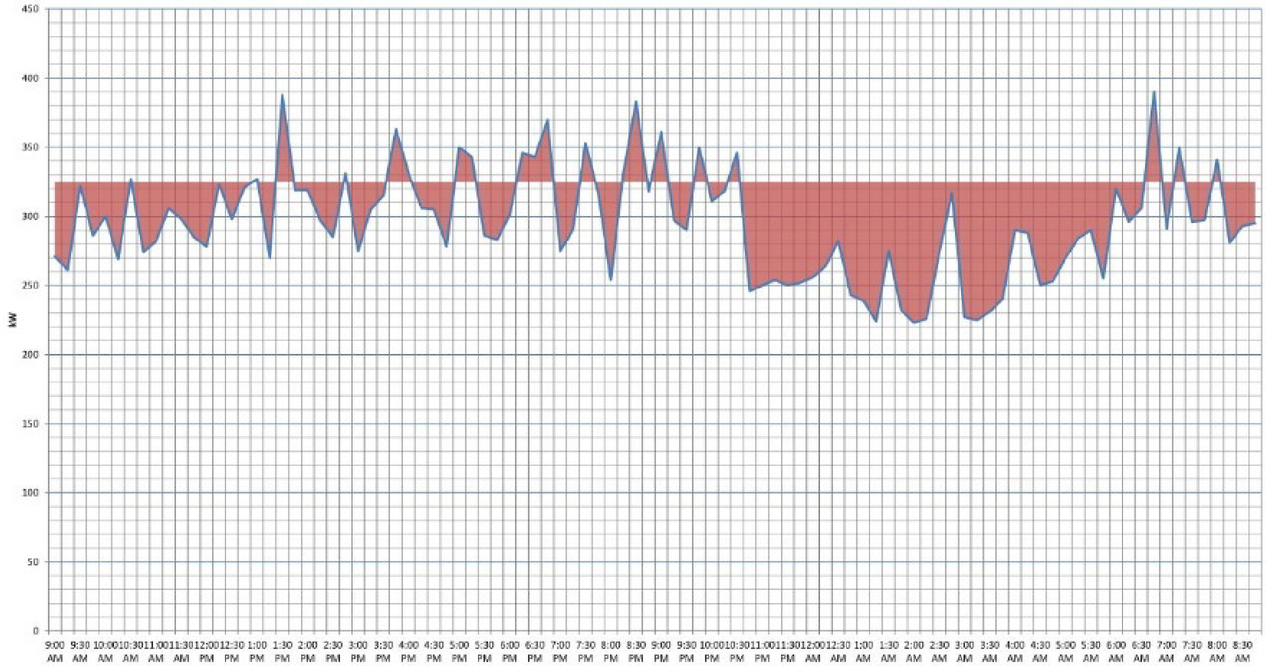
The PJM Regional Transmission Organization (RTO) is considered to be one of the strongest markets for frequency regulation and typically offers between 4-5¢/kWh of frequency support. This involves charging *and* discharging based on a utility signal so that there is no energy cost to the customer for participation in the program. BGSU is located in the PJM market and should be eligible.



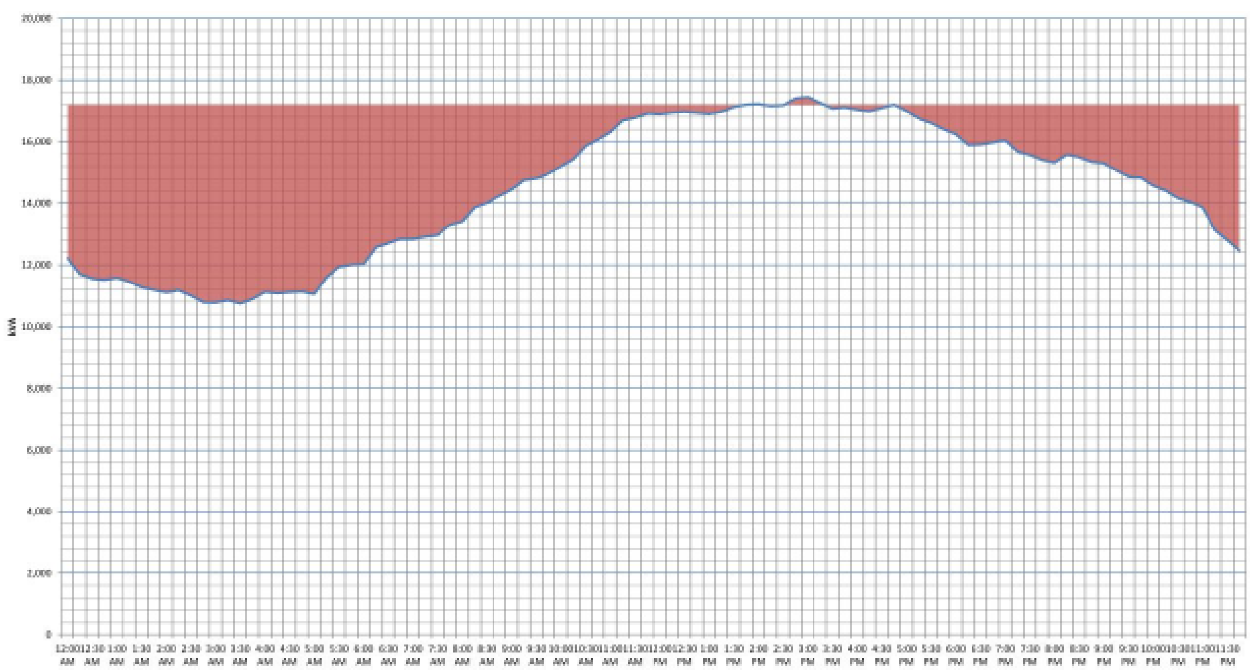
Basic frequency regulation example.

Feasibility:

The hourly load profile of any large primary metered customer will likely be flatter and more directly tied to day/night cycles than secondary metered customers whose load profiles generally contain more intermittent peaks to shave. Peak shaving is not as cost effective on relatively flat load profiles.



Ideal load profile with large short duration peaks.



BGSU load profile for 2015 peak day: Sept. 8th @17,444 KVA.

Demand Reduction Revenue						
Annual kW Reduction						4,440
Demand Rate ($/kW)						16.000
Annual Energy Escalation Rate						4.0%
System Cost						598,757
Battery Degradation						2%
Year	**KW Reduction**	**Revenue ($/kW)**		**KW Rev.**	**Cumulative Rev.**	
1	4,440	$	16.000	$61,061	**$**	**61,061**
2	4,351	$	16.640	$62,425	**$**	**123,485**
3	4,264	$	17.306	$63,815	**$**	**187,300**
4	4,179	$	17.998	$65,232	**$**	**252,532**
5	4,095	$	18.718	$66,676	**$**	**319,208**
6	4,013	$	19.466	$68,148	**$**	**387,355**
7	3,933	$	20.245	$69,648	**$**	**457,003**
8	3,854	$	21.055	$71,176	**$**	**528,179**
9	3,777	$	21.897	$72,735	**$**	**600,914**
10	3,702	$	22.773	$74,323	**$**	**675,236**
11	3,628	$	23.684	$75,941	**$**	**751,178**
12	3,555	$	24.631	$77,591	**$**	**828,769**
13	3,484	$	25.617	$79,272	**$**	**908,041**
14	3,414	$	26.641	$80,986	**$**	**989,027**
15	3,346	$	27.707	$82,732	**$**	**1,071,759**
Total	**17,428**			**$ 396,523**		

Estimated ROI for 1 MWh battery system with peak saving only.

A 1 MWh Li-Ion energy storage system on the BGSU primary grid would have an estimated ROI of ten years based on peak shaving alone. This would only be sufficient to reduce campus peak demand by 370 KVA or roughly 2%. Additional demand reduction requires battery capacity to grow exponentially causing the payback period to increase. In other words, a larger battery means a longer ROI for this type of load profile when only being used for peak shaving.

However, similar battery systems in the PJM market have historically shown ROI's of 5-6 years based on frequency regulation alone. Therefore, a 1 MWh system on the BGSU campus stacking multiple applications (peak shaving, frequency regulation and power factor correction) could provide a ROI of 3-5 years. This system would have a comparable footprint to that of a shipping container and ideally would be tied into the primary distribution grid near the utility meter.

Battery systems are often installed in parallel with renewables in order to help firm up generation. A future large solar array could significantly alter the BGSU load profile carving the intermittent peaks needed to make peak shaving with batteries cost effective. Because the BGSU load profile tracks the day/night cycle closely, PV generation should be high when campus loads are also high. This potential demand offset will not achieve significant cost savings without a battery system to help fill in the gaps of renewable generation.

An alternate approach to a large central system would be to provide smaller building scale systems (<100kWh) distributed at various locations throughout campus. Peak shaving and frequency regulation can still be employed (at lower efficiency) and costs would be somewhat higher due to a lack of economy of scale. However, funds could be cost shifted from planned back-up generators to battery systems for those buildings that require only several hours of back-up time. This would stack yet another value application and help offset the initial cost of each system installed.

Cost

The cost of Li-Ion energy storage systems is anticipated to continue to fall for the next several years, mostly as a result of increased efficiencies in cell production. A 1 MWh system today will likely cost around $600,000 (~$600/kWh) installed. A 100 kWh system would be approximately $80,000 (~$800/kWh). Battery costs have fallen more rapidly in the past few years than even the most aggressive predictions. It is likely that system costs will have fallen another 30-40% five years from now.

Battery system manufacturers offer ongoing maintenance agreements generally around $10 per kWh per year. This has been factored in to the above ROI estimates. The latest generation of LI-Ion storage systems are estimated to last 15-20 years depending upon usage. Previous technology issues concerning depth-of-discharge, where a Li-Ion battery could not be fully discharged without seriously compromising cycle life, have largely been resolved. It is also important to note the Li-Ion batteries, unlike many other chemistries, do not suddenly die but instead gradually degrade just like an LED light bulb or PV panel. Therefore, even after a system has reached end of life, it should continue to earn revenue at a reduced rate.

Recommendation:

Li-Ion energy storage systems by themselves will have almost zero impact on the carbon footprint of BGSU. However, by stacking applications such as peak shaving, frequency regulation and power factor correction, a roughly 1 MWh system tied to the primary distribution grid should have an attractive ROI. Once significant quantities of renewable energy generation have been connected to the campus grid by which time battery costs will have further decreased, it is likely that a much larger storage system can be economically justified due to its ability to firm renewable generation output. Therefore, Li-Ion energy storage systems could help contribute to GHG reduction by increasing the effective demand offset of renewable energy systems.

VI. Energy Conservation Measures

e. Thermal Energy Storage / Ice Storage Strategy

This energy conservation measure was evaluated for the BGSU campus but without a carbon footprint/energy reduction and the project implementation simple payback, this is not a preferred ECM to be pursued by the campus. The study of this ECM is provided for reference purposes.

As stated previously in the report, demand charges are a significant portion of BGSU's utility bills. The analysis of the 2014 electricity bills showed that 36% of the cost is associated with demand charge. This is a large increase from prior years due to significant rate increases. Since the 2013, BGSU has been making strides by reduced their billed electric demand by 10%. It should be restated that a 1% reduction of consumption at peak periods will translate into 6% utility bill savings.

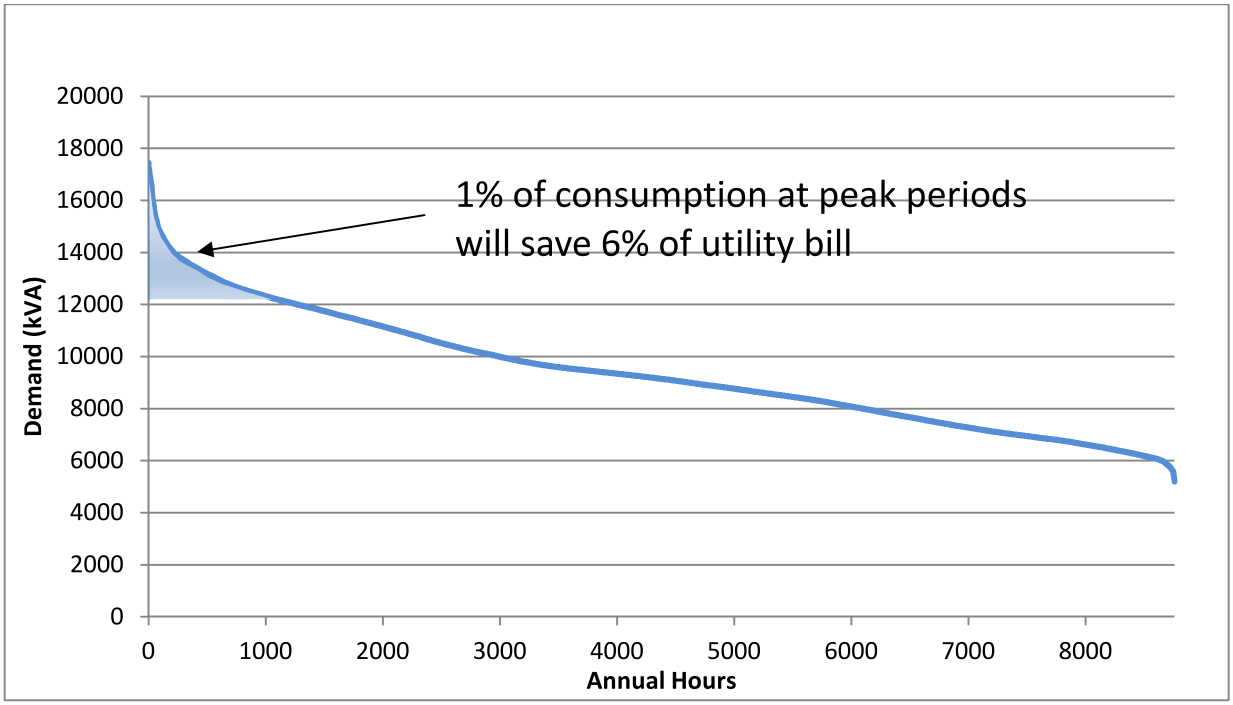


Figure 1. BGSU Load Duration Curve

The highlighted area in Figure 1 shows this steep climb in demand for a small percentage of annual hours. This is a savings that would also help BGMU reduce their supply costs. BGSU's peak demand is completely cooling dependent. The overall goal is to realize a 2 MW power demand reduction, therefore a Thermal Energy Storage strategy utilizing Ice Storage Technology will be considered as a part of that overall reduction.

Ice Storage Concept for BGSU:

The basic concept of ice storage systems is to use a chiller(s) to make ice during off-peak demand hours (nighttime) to then be used during the daytime for peak-time cooling needs of buildings served by the plant. The optimum time for the ice plant to operate based on BGMU's rate structure is 10pm to 10am to take the most advantage of the time-of-day rates.

The ice storage system considered for this purposes of this study will be comprised of air-cooled chillers, ice storage tanks and a pumping/heat exchanger skid. Additionally, the equipment will be located outdoors and enclosed with screen walls. This equipment would be located adjacent to the existing chiller plant CCP-1. Ice storage can be designed for full ice storage or partial ice storage. Due to first cost, a partial ice storage system is to be considered as a supplement to the existing chiller plant CCP-1 (Bldg 115). This system type is scalable and could be considered for other chilled water plants on Campus. Refer to Figure 2 and 3.

Figure 2. BGSU Chiller Plant CCP-1

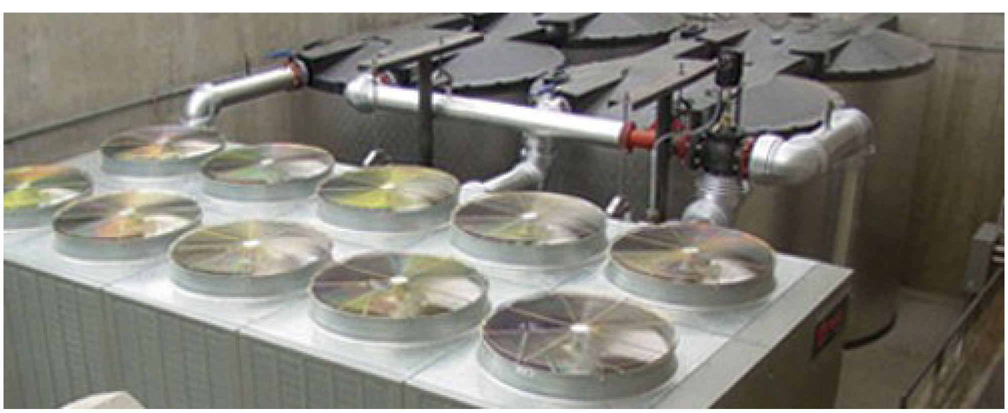


Figure 3. Typical air-cooled chiller with ice storage tanks

CCP-1 provides chilled water to ~405,000 sf of buildings including Fine Arts, Wolfe Center, Moore Musical Arts and Student Health Center with 3 water cooled chillers. The installed capacity is 2,100 tons, with 1,400 tons used to serve the load of these buildings with one chiller provided for redundancy.

A preliminary analysis indicates that two 250 ton air-cooled chillers (derated to 175 tons each due to application) coupled with 25 ice storage tanks with ~17,000 pounds of ice storage each could be utilized in conjunction with CCP-1. This translates to 3,700 ton-hours of ice capacity with ~ 40 / 60 split of storage to generation.

Energy Savings and First Costs:

Further analysis is required to determine the appropriate sizing of the equipment, but the goal is to only operate one of the 700 ton chillers and leave the other 700 ton chiller off. We can assume the chiller plant operates with an average efficiency of 0.7 kW / ton, therefore the power demand would be reduced by ~500 kW.

Based on the current demand rate charge of $16.00 / kVA, the University can expect an annual savings of ~$55,000 annually in demand charges as well as consumption charges.

The preliminary cost breakdown for the ice storage system is as follows:

Air Cooled Chillers:	$300,000
Ice Storage Tanks:	$300,000
Pump / HX Skid:	$125,000
Controls:	$50,000
Mechanical Install:	$450,000
Electrical Install:	$150,000
Screen Wall:	$50,000
Sub-Total:	$1,425,000
Design Contin.	$140,000
Total:	$1,565,000

Recommendations:

In summary, ice storage is a viable option to reduce overall Campus demand charges. CCP-1 is shown as one example of how ice storage could be implemented. Ice storage on its own does not have a fast payback, but when combined with other ECMs on Campus it would be recommended.

VI. Energy Conservation Measures

f. Decentralized Condensing Boilers

This energy conservation measure was evaluated for the BGSU campus but with past investments in the steam plant, this is not a preferred ECM to be pursued by the campus. The study of this ECM is provided for reference purposes.

The US Department of Energy estimates that total heating, ventilation and air conditioning (HVAC) represents 35% of building energy consumption for Climate Zone 2(Figure 1), of which heating is 19%. Upon review of the natural gas utility bills, the campus heating at BGSU accounts for 57% of the energy usage for the campus (Figure 2). This also assumes domestic water accounts for 8 EUI consumption. There are several reasons the heating energy consumption is higher than the US Department of Energy including envelope construction, equipment occupancy schedules, and central steam plant distribution inefficiencies. Due to this large difference, the HVAC heating system must be targeted for energy reduction.

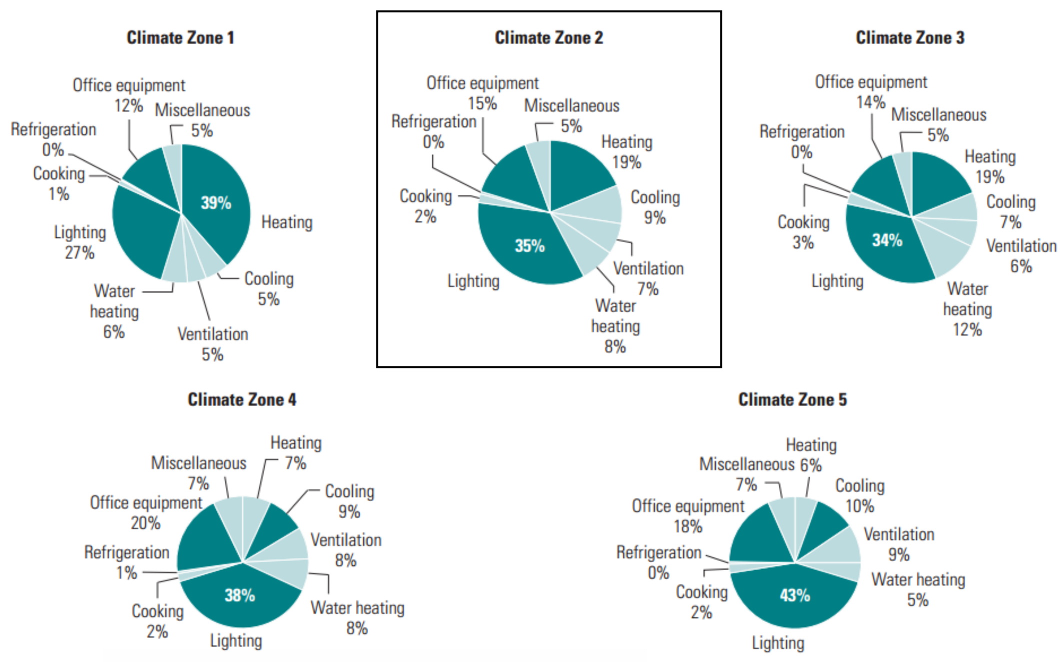


Figure 8. Typical Energy Consumption Across the US with BGSU in Zone 2

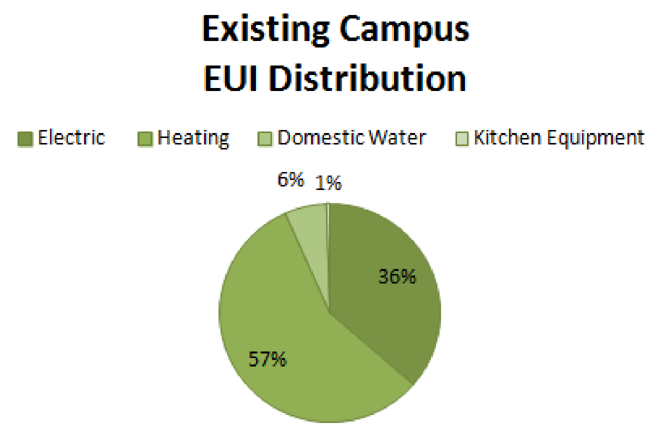


Figure 2. BGSU Breakdown

HVAC upgrades are a more costly strategy for reducing energy. It is recommended to implement HVAC upgrades as part of an Energy Service Contract (ESCo) where the shorter payback Energy Conservation Measures (ECM's) can finance these types of renovations. The other option is to utilize capital financing to perform HVAC upgrades within buildings. The construction costs would consist of site natural gas to the buildings and installing condensing boilers in the mechanical room.

Condensing boilers increase the efficiency of the HVAC heating systems up to 92%. This strategy would have the lowest cost HVAC ECM with the highest efficiency and lowest Energy Usage Intensity (EUI). Therefore, since the University has a goal for campus net zero and carbon neutrality, condensing boilers is recommended as part of the Sustainability Plan. The Central Plant is documented at 84% efficient. But the overall system is performing at 60%-65% efficiency when taking into account the steam trap losses and make-up water needs. According to Federal Energy Management Program, friction losses in piping, condensate losses, blow down losses, system leaks, receivers to vent to the atmosphere have a significant impact on total system efficiencies. During the summer months the efficiency is further reduced 10%-15% according to the October 10, 2013 Energy Assessment of Central Heating Plant study by URS.

The purpose of this section is to review at how distributed condensing boilers on Campus would affect the Campus gas consumption profile and Campus Energy Use Intensity (EUI). Installation of distributed condensing boilers would have a significant impact the energy and carbon reduction goals. At this time targeted building for condensing boilers are not included for HVAC geothermal renovations and have steam heating. It will conclude with recommendations for moving forward as part of an ESCo project and investing in HVAC upgrades for future capital projects.

<u>Existing Heating:</u>

First it is important to understand the existing Campus heating systems. Table 1 indicates the buildings recommended for distributed condensing boilers. For evaluation, building recommended for upgrades from central steam to distributed condensing boilers exclude buildings recommended for HVAC geothermal upgrades.

Bldg #	Building
44	BUSINESS ADMINISTRATION
30	CONKLIN
42	EDUCATION BUILDING
46,47,48	EPPLER CENTER
116	FALCON HEIGHTS
61	FAMILY & CONSUMER SCI
31	FINE ARTS
62	FOUNDERS QUAD
32	JEROME LIBRARY
40	KOHL HALL
7	KREISCHER QUAD
88	LIFE SCIENCE BLDG
89	MATH SCIENCE BLDG
Bldg #	**Building**
84	MCDONALD QUAD
60	MCFALL CENTER
43	MEMORIAL HALL
104	MOORE MUSICAL ARTS
86,87	OFFENHAUER
45	OLSCAMP HALL
90	OVERMAN
91	PHYSICAL SCIENCE LAB
66	SHATZEL HALL
111	STROH CENTER
105	STUDENT REC CENTER
69	STUDENT UNION
96	TECHNOLOGY BLDG
63	WILLIAMS HALL
33	WOLFE CENTER

Table 1. Existing Buildings with Central Steam Heating

Central Steam to Decentralized Condensing Boilers

It is recommended to implement decentralized boiler installations as part of an ESCO project or with capital funding for HVAC upgrades. The key benefit is the EUI reduction associated with the improved efficiencies in these buildings. Refer to Table 2 for building EUI reductions.

The energy savings associated with reduction from ~60% efficient central steam plant to an average of 92% condensing boilers is a reduction from ~2,525,000 CCF to ~1,645,000 CCF with 880,000 CCF gas savings. Refer to Tables 3 and Table 4 for individual building consumptions and savings.

The energy saving for conversion from central steam to condensing boilers would be as follows:

- Heating natural gas reduction is ~87,500 MMBtu @ $3.74= ~$325,000.

Building	Existing Steam CCF	Building Heating output CCF with 60% efficient system	Condensing Boilers CCF @92% efficient	CCF Reduction
BUSINESS ADMINISTRATION	95,629	57,378	62,367	33,262
CONKLIN	16,648	9,989	10,857	5,790
EDUCATION BUILDING	43,127	25,876	28,126	15,001
EPPLER CENTER	55,141	33,085	35,962	19,180
FAMILY & CONSUMER SCI	31,332	18,799	20,434	10,898
FINE ARTS	125,312	75,187	81,725	43,587
FOUNDERS QUAD	128,014	76,808	83,487	44,526
JEROME LIBRARY	101,032	60,619	65,890	35,142
KOHL HALL	66,936	40,161	43,654	23,282
KREISCHER QUAD	221,743	133,046	144,615	77,128
LIFE SCIENCE BLDG	99,257	59,554	64,733	34,524
MATH SCIENCE BLDG	125,988	75,593	82,166	43,822
MCDONALD QUAD	279,805	167,883	182,481	97,323
MCFALL CENTER	40,771	24,463	26,590	14,181
MEMORIAL HALL	69,276	41,566	45,180	24,096
MOORE MUSICAL ARTS	135,992	81,595	88,690	47,302
OFFENHAUER	228,731	137,239	149,173	79,559
OLSCAMP HALL	70,045	42,027	45,682	24,364
OVERMAN	113,612	68,167	74,095	39,517
PHYSICAL SCIENCE LAB	86,410	51,846	56,355	30,056
SHATZEL HALL	25,521	15,313	16,644	8,877
STUDENT REC CENTER	238,268	142,961	155,392	82,876
TECHNOLOGY BLDG	13,836	8,302	9,024	4,813
WILLIAMS HALL	14,873	8,924	9,700	5,173
WOLFE CENTER	50,697	30,418	33,063	17,634
TOTALS	2,477,996	1,486,797	1,616,084	861,912

Table 3 Building CCF Consumption Reduction (Condensing Boilers)

Building	EUI	Condensing Boiler EUI	EUI Reduction
BUSINESS ADMINISTRATION	106	63	42
CONKLIN	39	24	16
EDUCATION BUILDING	61	37	25
EPPLER CENTER	47	28	19
FAMILY & CONSUMER SCI	208	125	83
FINE ARTS	135	81	54
FOUNDERS QUAD	79	48	32
HAYES HALL	67	40	27
JEROME LIBRARY	61	37	25
KOHL HALL	111	67	44
KREISCHER QUAD	95	57	38
LIFE SCIENCE BLDG	92	55	37
MATH SCIENCE BLDG	131	79	52
MCDONALD QUAD	133	80	53
MCFALL CENTER	112	67	45
MEMORIAL HALL	109	65	44
MOORE MUSICAL ARTS	131	79	52
OFFENHAUER	113	68	45
OLSCAMP HALL	87	52	35
OVERMAN	142	85	57
PHYSICAL SCIENCE LAB	183	110	73
SHATZEL HALL	74	44	29
STUDENT REC CENTER	154	92	62
TECHNOLOGY BLDG	21	13	9
WILLIAMS HALL	49	29	19
WOLFE CENTER	50	30	20

Table 2. Building EUI Reduction (Condensing Boilers)

Building	Existing Costs	Condensing Boiler Costs	Savings
BUSINESS ADMINISTRATION	$ 35,765	$ 23,325	$ 12,440
CONKLIN	$ 6,226	$ 4,061	$ 2,166
EDUCATION BUILDING	$ 16,129	$ 10,519	$ 5,610
EPPLER CENTER	$ 20,623	$ 13,450	$ 7,173
FAMILY & CONSUMER SCI	$ 11,718	$ 7,642	$ 4,076
FINE ARTS	$ 46,867	$ 30,565	$ 16,301
FOUNDERS QUAD	$ 47,877	$ 31,224	$ 16,653
JEROME LIBRARY	$ 37,786	$ 24,643	$ 13,143
KOHL HALL	$ 25,034	$ 16,327	$ 8,707
KREISCHER QUAD	$ 82,932	$ 54,086	$ 28,846
LIFE SCIENCE BLDG	$ 37,122	$ 24,210	$ 12,912
MATH SCIENCE BLDG	$ 47,119	$ 30,730	$ 16,389
MCDONALD QUAD	$ 104,647	$ 68,248	$ 36,399
MCFALL CENTER	$ 15,248	$ 9,945	$ 5,304
MEMORIAL HALL	$ 25,909	$ 16,897	$ 9,012
MOORE MUSICAL ARTS	$ 50,861	$ 33,170	$ 17,691
OFFENHAUER	$ 85,546	$ 55,791	$ 29,755
OLSCAMP HALL	$ 26,197	$ 17,085	$ 9,112
OVERMAN	$ 42,491	$ 27,711	$ 14,779
PHYSICAL SCIENCE LAB	$ 32,317	$ 21,077	$ 11,241
SHATZEL HALL	$ 9,545	$ 6,225	$ 3,320
STUDENT REC CENTER	$ 89,112	$ 58,117	$ 30,996
TECHNOLOGY BLDG	$ 5,175	$ 3,375	$ 1,800
WILLIAMS HALL	$ 5,562	$ 3,628	$ 1,935
WOLFE CENTER	$ 18,961	$ 12,366	$ 6,595
TOTALS	$ 926,770	$ 604,415	$ 322,355

Table 4 Building Cost Reduction (Condensing Boilers)

<u>Implementation:</u> This project would consist of targeting the largest building heating energy EUI reduction and installing through an Energy Service Contract (ESCo) or budgeting for installation as capital or maintenance budgets become available.

The total costs will require coordinate with the gas utility provider for installing gas service at each building. Conversion to high efficiency domestic water heaters at the same time is recommended for additional savings.

During the design process any buildings that can be grouped into a central hot water plant would be recommended to reduce the first costs and the costs associated with redundancy.

<u>Technologies:</u>

There will be (2) high efficiency condensing boilers for redundancy and peak load conditions. The boiler would be packaged, sealed combustion cast aluminum condensing hot water boiler, constructed per the ASME boiler code for 125 PSIG, capable of full condensing operation and 200°F maximum supply water temperatures. Each rate for 75% of the building peak load requirements. It would be equipped with a fully modulating Natural Gas burner with 7:1 turndown, and integrated boiler / burner management system. Boiler is fully assembled, factory fire tested, complies with ANSI Z21.13, ASME CSD-1 Safety Code. The boilers would replace the steam to hot water heat exchangers.

It is recommended to primary variable flow with condensing boilers for the building heating system. Utilizing condensing boilers allows the elimination of the additional pumps because they operate with variable flow. The condensing boilers efficiency increases as the supply water temperatures are reduced.

Feasibility:

The purpose of this study is to help guide Bowling Green State University with decisions that will affect their energy consumption and carbon reduction strategies over the next three decades. The purpose is not to design each ECM or Renewable Energy strategy. Limited condensing boiler replacements are recommended are would be feasible with the utilization of additional capital or as a long pay pack ECM included with an Energy Service Contract (ESCo).

This ECM without the savings from Dedicated Outside air systems and getting control of the building through Building Automation System (BAS) Upgrades would reduce the overall campus EUI from 129 KBtu/Sqft to 123 KBtu/Sqft for a 6 EUI campus reduction. Refer to Figure 3 for changes to the Campus heating percentage distribution reduction

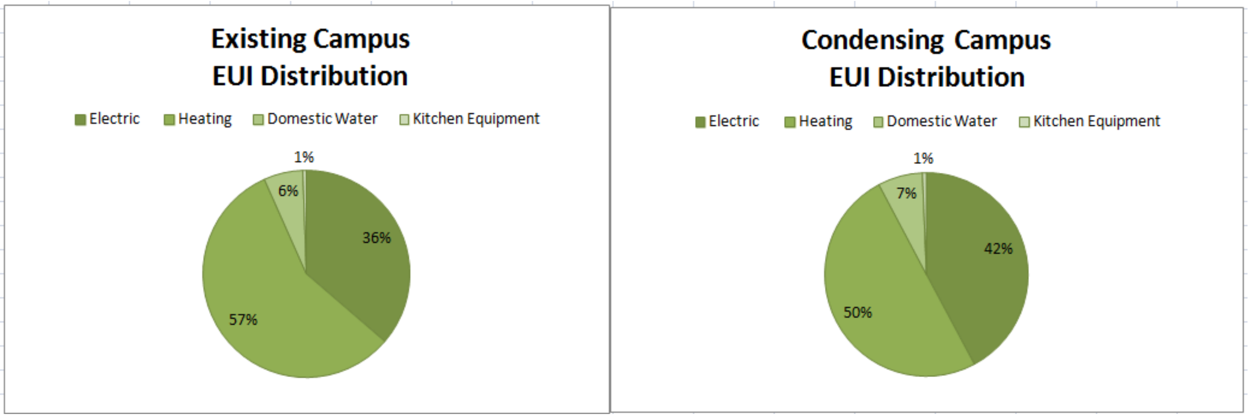


Figure 3. BGSU Campus EUI Breakdown Reduction (Condensing Boilers)

Recommendations:

Our recommendation would be to replace the central steam heat exchanges with decentralized condensing boilers. This can either be implemented with future renovations or as a long payback ECM included with an Energy Service Contract (ESCo). Our recommendation should only be considered if additional capital can be applied or it can be incorporated into an ESCo Project. The EUI reductions are too great at these locations to not consider as part of a Campus Energy Conservation Measure. Refer to Figure 4 for heating costs and EUI reductions for natural gas. The best way to achieve this would be through a performance contract project with a guaranteed energy savings.

If the University would prefer and area by area HVAC replacement, then our recommendation is to include this ECM with Capital planning for future renovations. The standards would be centered around high efficiency condensing boilers with primary pumping.

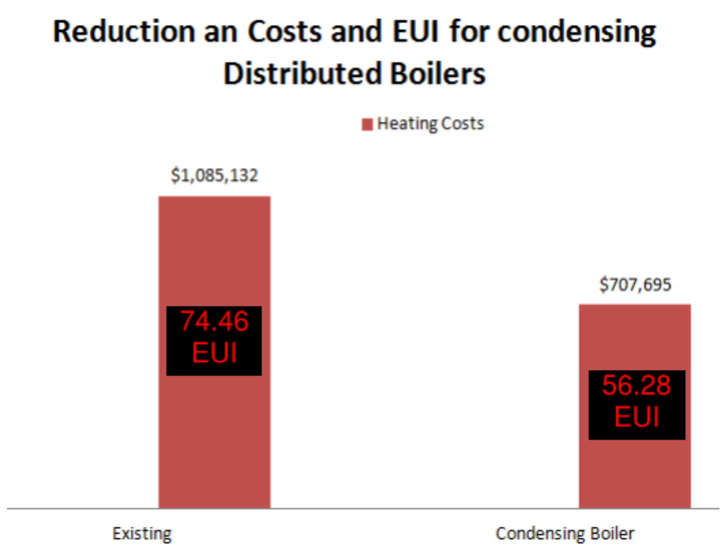


Figure 4. BGSU Campus Heating EUI Natural Gas and Costs Reduction (Condensing Boilers)

VII. Financial Options

a. Performance Contracting or Third Party Financing

Performance contracting can be described as a design- build project with the added protection of guaranteeing the outcome as energy and maintenance savings by an Energy Services Company (ESCO). A capital or a design-build project requires initial capital investment while a performance contract by law has to pay for itself from energy and maintenance savings within 15 years in State of Ohio.

There are multiple financial mechanisms available to be used in a performance contract. The most popular mechanism for higher education facilities is a tax-exempt lease purchase. A financial institution through a competitive process will be selected to enter into a lease to purchase contract with the owner. An escrow account with construction funds will be set up to pay the ESCO during the construction. The selected financial institution will receive the lease payments from the guaranteed savings. Upon successful completion of the performance contract the ownership of equipment will be transferred to the owner.

Like with any project, attention to details, dedicated contractor, capable project managers, detailed engineering work assure the success of the project and performance contacts are no different. Performance contracting has been used by the Ohio State University, Cincinnati Technical Community College, North Central State College as a few examples with very successful results.

Following are key benefits of performance contacting;

- When adequate funds are not available to address facility needs, such as aging equipment and systems, but a significant amount of money is being spent on utilities, Performance Contracting can be used as an additional funding source.
- Energy savings are guaranteed.
- Long term Measurement & Verification of the new systems ensures performance is sustained over time.
- Turnkey fixed price project – no finger pointing and no change orders.
- Contractors and suppliers are selected that add best value vs. low cost, but still competitively bid.
- Reduce environmental impact through the use of innovative energy efficient equipment and controls technologies.
- Our recommendation would be to employ a firm that uses open book pricing that provides a completely transparent project. We would be happy to provide assistance in identifying firms that could perform these services.

VII. Financial Options

b. Power Purchase Agreements (PPA)

Since BGSU cannot take advantage of solar related tax incentives, a third party PPA agreement could be a very attractive option. This type of agreement could be implemented with the array being located on campus or even offsite. A large ground mounted array (>5MW) at the E Merry Ave site could provide rates of 7¢/kWh with 1% annual escalation for a contract period of 20-25 years. This would be a much lower cost than the almost $0.10/kWh rate that BGSU will pay this year and years to come.

PPA agreements often include an option for the customer to purchase the system once the contract period expires. The PPA provider would sell the more valuable SREC's generated but sell REC's back to BGSU in order to offset GHG's.